THE BOTANY, HISTORY,

COMPOSITION, ECONOMICS AND USES OF
COLORADO FIELDS CROPS

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A manuscript submitted to the
Department of Agronomy
of the
College of Agriculture
of the
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by
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of the subject of
Field Crops
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PREFACE

This manuscript contains the main lecture and text material for a Field Crops Laboratory Course which consists of a general study, except of cultural methods, of the important field crops of the State of Colorado.

The appendix contains the laboratory exercises which constitute the main part of the course, the text material being considered supplementary to the laboratory work. The illustrations included in the text give a general idea of the nature of the laboratory work.

This course of study was prepared to fit into the plan of college work used by the Department of Agronomy of the Colorado Agricultural College. Under this plan all the Sophomore Agricultural Students are required to take a general course in Crops Production. This course consists of a study of factors and activities which are concerned with the actual growing of the crops and include such subjects as soil preparation, planting, cultivation, irrigation and harvesting. Some time is also given to a study of the water and soil requirements of the crops and to their general relationship and adaptation to different soil and climatic conditions under both irrigation and upland farming.

For the Agronomy students and others who wish additional Field Crops work there is offered in the Junior year a course
in Field Crops Laboratory which largely includes the material given in this manuscript.

As far as time will permit, additional work is given in judging the different crops studied.

This course consists principally of laboratory work, two hours per day for three days in the week and continues thru one college semester. The student receives three hours credit for the semester's work.

The colored plates and figures 40 and 41 are from negatives owned by Mr. Lou D. Sweet of Denver, Colorado.

The drawing for figures 3, 5 to 11, 16, 19, 21 to 25, 27 34 to 39 and 42 to 44 were made in regular botany and field crops laboratory classes by Messrs. W. A. Ferris, N. Lee Foster and W. J. Roth, students of the Colorado Agricultural College.

The photographs excepting the colored plates and figures 40 and 41 were made under the writer's direction by Mr. H. H. Kidder a student in the Colorado Agricultural College.

Figures 12, 29, 31 and 33 are from negatives loaned by Mr. W. W. Robbins, Assistant Professor of Botany in the Colorado Agricultural College, to whom the writer is indebted for helpful suggestions and assistance in preparing the manuscript.

Figure 14 is from a negative loaned by the Colorado Experiment Station.
Figures 1, 2, 4, 13, 15, 17, 18, 26, 28, 30 and 32 are of specimens prepared and mounted by the writer. Figure 20 is from a drawing made by the writer.

The writer reserves all right to the keys, illustrations and laboratory exercises contained in this manuscript.

D. W. Frear.

Colorado Agricultural College
Fort Collins, Colo., May, 1914.
CONTENTS

CEREALS
Grass Tribes Containing the Cereals....................... 1
Key to Groups (Genera) of Important Cereals............. 2
Geographical Distribution....................................... 3

WHEAT
Definition of Terms.............................................. 4
Description.......................................................... 4
  Habit................................................................. 4
  Roots................................................................. 4
  Leaves............................................................... 5
  Infloroscence...................................................... 5
  Spikelet........................................................... 7
  Flower............................................................... 7
Opening of flower and pollination............................ 9
Fertilization and ripening of grain.......................... 9
The mature grain of wheat...................................... 11
  Embryo............................................................. 12
  Endosperm.......................................................... 14
Aleurone layer..................................................... 15
Nucellus or perisperm............................................ 16
Testa or Episperm................................................... 13
Pericarp............................................................. 13
Bran layer.......................................................... 19
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition of bran</td>
<td>20</td>
</tr>
<tr>
<td>Protein of wheat</td>
<td>21</td>
</tr>
<tr>
<td>Globulins</td>
<td>22</td>
</tr>
<tr>
<td>Albumins</td>
<td>22</td>
</tr>
<tr>
<td>Proteose</td>
<td>22</td>
</tr>
<tr>
<td>Gliadin</td>
<td>22</td>
</tr>
<tr>
<td>Glutenin</td>
<td>23</td>
</tr>
<tr>
<td>Glutin</td>
<td>24</td>
</tr>
<tr>
<td>Germination of seed</td>
<td>23</td>
</tr>
<tr>
<td>Phylogeny of wheat</td>
<td>29</td>
</tr>
<tr>
<td>History of wheat</td>
<td>30</td>
</tr>
<tr>
<td>Geographical distribution</td>
<td>31</td>
</tr>
<tr>
<td>Key to Economic Types of wheat (Triticum)</td>
<td>32</td>
</tr>
<tr>
<td>The species of wheat</td>
<td>33</td>
</tr>
<tr>
<td><strong>T. monococcum (Einkorn)</strong></td>
<td>33</td>
</tr>
<tr>
<td>description</td>
<td>34</td>
</tr>
<tr>
<td>Uses and adaptability</td>
<td>34</td>
</tr>
<tr>
<td>Desirable quantities of Einkorn</td>
<td>35</td>
</tr>
<tr>
<td>Undesirable qualities of Einkorn</td>
<td>35</td>
</tr>
<tr>
<td><strong>T. polonicum</strong></td>
<td>35</td>
</tr>
<tr>
<td>Description</td>
<td>35</td>
</tr>
<tr>
<td>Uses and adaptability</td>
<td>36</td>
</tr>
<tr>
<td>Special qualities of Polish wheat</td>
<td>37</td>
</tr>
<tr>
<td><strong>T. spelta (Spelt)</strong></td>
<td>37</td>
</tr>
<tr>
<td>Description</td>
<td>37</td>
</tr>
<tr>
<td>Adaptability and uses</td>
<td>37</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Desirable qualities of Spelt</td>
<td>39</td>
</tr>
<tr>
<td>Undesirable qualities of Spelt</td>
<td>39</td>
</tr>
<tr>
<td>T. dicoccum (Emmer)</td>
<td>39</td>
</tr>
<tr>
<td>Description</td>
<td>39</td>
</tr>
<tr>
<td>Uses and adaptability</td>
<td>40</td>
</tr>
<tr>
<td>Desirable qualities of Emmer</td>
<td>41</td>
</tr>
<tr>
<td>Undesirable qualities of Emmer</td>
<td>41</td>
</tr>
<tr>
<td>T. turgidum</td>
<td>41</td>
</tr>
<tr>
<td>Description</td>
<td>42</td>
</tr>
<tr>
<td>Uses and adaptability</td>
<td>42</td>
</tr>
<tr>
<td>Special qualities of Poulard wheat</td>
<td>43</td>
</tr>
<tr>
<td>T. durum (Durum)</td>
<td>43</td>
</tr>
<tr>
<td>Description</td>
<td>43</td>
</tr>
<tr>
<td>Uses and adaptation</td>
<td>44</td>
</tr>
<tr>
<td>Special qualities of Durum wheat</td>
<td>46</td>
</tr>
<tr>
<td>T. Compactum</td>
<td>47</td>
</tr>
<tr>
<td>Description</td>
<td>47</td>
</tr>
<tr>
<td>Uses and adaptibility</td>
<td>48</td>
</tr>
<tr>
<td>Special qualities of Club wheats</td>
<td>48</td>
</tr>
<tr>
<td>T. vulgare (Common)</td>
<td>48</td>
</tr>
<tr>
<td>Description</td>
<td>49</td>
</tr>
<tr>
<td>Groups of common bread wheat</td>
<td>49</td>
</tr>
<tr>
<td>Description and approximate distribution of</td>
<td></td>
</tr>
<tr>
<td>common wheat</td>
<td>49</td>
</tr>
<tr>
<td>Uses and adaptability</td>
<td>51</td>
</tr>
<tr>
<td>Special qualities of bread wheats</td>
<td>51</td>
</tr>
<tr>
<td>Chemical composition of wheat</td>
<td>52</td>
</tr>
</tbody>
</table>
Physical properties of wheat grains.......................... 52
  Specific gravity........................................... 52
Relation between length of growing season, moisture
  supply and protein content............................ 54
Sweating of wheat.......................................... 56
  Effect of stack-sweating on appearance and test
    weight.................................................. 60
Milling value of water soaked wheats...................... 60
Milling of wheat............................................ 62
  Course of wheat and flour through the mill.......... 63
Cleaning..................................................... 63
Tempering................................................... 64
Milling proper............................................. 64
  The dust collector....................................... 66
Types and grades of flour.................................. 67
  Definition................................................. 67
Patent....................................................... 67
Clear........................................................ 68
  Straight and straight patent.......................... 68
  Red Dog.................................................... 68
Flour yield of wheat....................................... 72
Relation between the official state grade of wheat and
  the flour yield and other qualities................... 73
Spring vs. Winter wheat.................................... 79
Composition and food value of flours...................... 80
Adulteration of flour..................................... 83
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleaching of flour</td>
<td>84</td>
</tr>
<tr>
<td>The uses of flour</td>
<td>35</td>
</tr>
<tr>
<td>Durum wheat flour</td>
<td>85</td>
</tr>
<tr>
<td>Entire wheat flour</td>
<td>86</td>
</tr>
<tr>
<td>Graham flour</td>
<td>86</td>
</tr>
<tr>
<td>Cracker and biscuit flour</td>
<td>87</td>
</tr>
<tr>
<td>Bread yield of flour</td>
<td>38</td>
</tr>
<tr>
<td>Baking quality of flour</td>
<td>39</td>
</tr>
<tr>
<td>Absorption</td>
<td>90</td>
</tr>
<tr>
<td>Color</td>
<td>90</td>
</tr>
<tr>
<td>Strength of flour</td>
<td>90</td>
</tr>
<tr>
<td>Relative Acidity</td>
<td>91</td>
</tr>
<tr>
<td>Value and digestibility of breads</td>
<td>92</td>
</tr>
<tr>
<td>Digestibility of bread</td>
<td>92</td>
</tr>
<tr>
<td>Per capita consumption of wheat</td>
<td>95</td>
</tr>
<tr>
<td>Location of Milling industry</td>
<td>97</td>
</tr>
</tbody>
</table>

**BARLEY**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>93</td>
</tr>
<tr>
<td>Habit</td>
<td>93</td>
</tr>
<tr>
<td>Root, stem and leaves</td>
<td>93</td>
</tr>
<tr>
<td>Inflorescence</td>
<td>93</td>
</tr>
<tr>
<td>Spikelet</td>
<td>100</td>
</tr>
<tr>
<td>Flower</td>
<td>101</td>
</tr>
<tr>
<td>Pollination</td>
<td>101</td>
</tr>
<tr>
<td>Fertilization and ripening of the grain</td>
<td>101</td>
</tr>
</tbody>
</table>
Two-rowed barley (H. distichon)........................................ 110
Description................................................................. 110
Habit, root, stem and leaves............................................. 110
Spike, spikelet, flower and fruit....................................... 111
Types and varieties of H. distichon.................................... 112
Fan two-rowed barley (H. dist. zeocriton).............................. 112
Description................................................................. 112
Distribution and economic importance................................. 112
Nodding two-rowed barley (H. dist. nutans)............................ 112
Description................................................................. 112
Varieties and distribution and importance............................ 113
Erect two-rowed barley (H. dist. erectum).............................. 113
Varieties, distribution and importance................................. 114
Types of barley based on characters of Rachilla and
lateral nerves of the lemma.............................................. 114
Composition of barley..................................................... 116
Relation between Texture (mealiness) of kernel and
protein content.................................................................. 117
Uses of barley for brewing.................................................. 120
European brewing barley standards.................................... 122
American brewing barley standards.................................... 124
Malting and brewing......................................................... 127
Brewing........................................................................... 127
Malting............................................................................ 127
Malt............................................................................... 127
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewing materials</td>
<td>127</td>
</tr>
<tr>
<td>Dark malts</td>
<td>129</td>
</tr>
<tr>
<td>Malting</td>
<td>129</td>
</tr>
<tr>
<td>Cleaning the grain</td>
<td>129</td>
</tr>
<tr>
<td>Steeping</td>
<td>129</td>
</tr>
<tr>
<td>Germination</td>
<td>130</td>
</tr>
<tr>
<td>Kilning</td>
<td>130</td>
</tr>
<tr>
<td>Process of germination</td>
<td>131</td>
</tr>
<tr>
<td>The Scutellum or malting organ</td>
<td>132</td>
</tr>
<tr>
<td>OATS.</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>134</td>
</tr>
<tr>
<td>Habit</td>
<td>134</td>
</tr>
<tr>
<td>Roots</td>
<td>134</td>
</tr>
<tr>
<td>Stems</td>
<td>134</td>
</tr>
<tr>
<td>Leaves</td>
<td>134</td>
</tr>
<tr>
<td>Inflorescence</td>
<td>136</td>
</tr>
<tr>
<td>Spikelet</td>
<td>137</td>
</tr>
<tr>
<td>Flower</td>
<td>137</td>
</tr>
<tr>
<td>Opening of flowers and pollination</td>
<td>139</td>
</tr>
<tr>
<td>Fertilization and development of fruit</td>
<td>140</td>
</tr>
<tr>
<td>Fruit and seed</td>
<td>141</td>
</tr>
<tr>
<td>Germination of seed</td>
<td>145</td>
</tr>
<tr>
<td>Geographical distribution</td>
<td>146</td>
</tr>
<tr>
<td>History of oats</td>
<td>147</td>
</tr>
<tr>
<td>Phylogeny of oats</td>
<td>148</td>
</tr>
</tbody>
</table>
Closely related Genera ................................................. 148
Key to Economic Species of oats .................................... 148
Description of species ................................................. 149
  Avena sativa .......................................................... 149
  Avena orientalis ...................................................... 150
  Avena nuda ........................................................... 150
Phylogeny of species ................................................. 151
Closely related species not of economic importance ... 151
  Wild oats .............................................................. 151
  False wild oats ....................................................... 153
Geographical distribution .......................................... 155
Number of kernels in the spikelet and their size ........... 157
Percentage of hull and kernel ..................................... 160
Weight per bushel and per cent of hull .......................... 162
Kernel weight and yield ............................................. 165
Weight per bushel and yield ........................................ 166
Length of growing season and yield .............................. 167
Composition ............................................................ 168
Uses of oats ............................................................. 169
  Uses of oats for human food ...................................... 169
  Uses of oats for animal food ..................................... 170
  Oat by-products ..................................................... 173

RYE

Genus Secale ............................................................ 174
Cultivated Rye (Secale cereale) .................................... 174
Description ............................................................. 174
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roots</td>
<td>174</td>
</tr>
<tr>
<td>Stems</td>
<td>175</td>
</tr>
<tr>
<td>Leaves</td>
<td>175</td>
</tr>
<tr>
<td>Inflorescence</td>
<td>175</td>
</tr>
<tr>
<td>Spikelet</td>
<td>176</td>
</tr>
<tr>
<td>Pollination</td>
<td>176</td>
</tr>
<tr>
<td>Fruit and seed</td>
<td>176</td>
</tr>
<tr>
<td>History</td>
<td>178</td>
</tr>
<tr>
<td>Phylogeny</td>
<td>179</td>
</tr>
<tr>
<td>Geographical distribution</td>
<td>179</td>
</tr>
<tr>
<td>Types and varieties</td>
<td>180</td>
</tr>
<tr>
<td>Composition</td>
<td>181</td>
</tr>
<tr>
<td>Uses of rye</td>
<td>181</td>
</tr>
<tr>
<td>Human food</td>
<td>181</td>
</tr>
<tr>
<td>Animal food</td>
<td>182</td>
</tr>
<tr>
<td>Industrial uses</td>
<td>183</td>
</tr>
<tr>
<td><strong>CORN</strong></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>184</td>
</tr>
<tr>
<td>Habit</td>
<td>184</td>
</tr>
<tr>
<td>Roots</td>
<td>184</td>
</tr>
<tr>
<td>Stem</td>
<td>184</td>
</tr>
<tr>
<td>Leaves</td>
<td>186</td>
</tr>
<tr>
<td>Inflorescence</td>
<td>188</td>
</tr>
<tr>
<td>Staminate inflorescence</td>
<td>190</td>
</tr>
<tr>
<td>Pistillate inflorescence</td>
<td>191</td>
</tr>
<tr>
<td>Hermaphrodite flowers</td>
<td>194</td>
</tr>
</tbody>
</table>
Habit of plant............................... 216
Root........................................... 216
Stem........................................... 216
Leaves......................................... 216
Inflorescence............................... 217
Flowers........................................ 217
Stamens....................................... 217
Pistil.......................................... 217
Fruit and seed............................... 217
Geographical distribution............... 218
Phylogeny of family......................... 218
General economic importance............. 218
Genera of Linaceae........................... 218
Geographical distribution of genus linum 219
Phylogeny of genus linum................... 220
Common flax (L. usitatissimum)........... 222
Description.................................. 222
Habit......................................... 222
Root.......................................... 223
Stem.......................................... 223
Leaves........................................ 223
Inflorescence............................... 224
Flowers....................................... 224
Pollination................................... 224
Fruit......................................... 225
Seed.......................................... 225
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germination of seed.</td>
<td>226</td>
</tr>
<tr>
<td>Geographical distribution of common flax</td>
<td>226</td>
</tr>
<tr>
<td>Composition</td>
<td>227</td>
</tr>
<tr>
<td>Use of flax</td>
<td>227</td>
</tr>
<tr>
<td><strong>Solanaceae (Potato Family)</strong></td>
<td></td>
</tr>
<tr>
<td>The Solanaceae</td>
<td>230</td>
</tr>
<tr>
<td>Key to important genera</td>
<td>231</td>
</tr>
<tr>
<td>Solanum genus</td>
<td>231</td>
</tr>
<tr>
<td>Key to important species</td>
<td>232</td>
</tr>
<tr>
<td><strong>Potato</strong></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>236</td>
</tr>
<tr>
<td>Habit</td>
<td>236</td>
</tr>
<tr>
<td>Roots</td>
<td>236</td>
</tr>
<tr>
<td>Stem</td>
<td>236</td>
</tr>
<tr>
<td>Stem (aerial)</td>
<td>236</td>
</tr>
<tr>
<td>Leaves</td>
<td>237</td>
</tr>
<tr>
<td>Flower</td>
<td>241</td>
</tr>
<tr>
<td>Opening of flower and pollination</td>
<td>244</td>
</tr>
<tr>
<td>Artificial pollination (crossing)</td>
<td>246</td>
</tr>
<tr>
<td>Fruit</td>
<td>247</td>
</tr>
<tr>
<td>Seed</td>
<td>248</td>
</tr>
<tr>
<td>Germination of seed</td>
<td>248</td>
</tr>
<tr>
<td>Development of the seedling</td>
<td>249</td>
</tr>
<tr>
<td>Topic</td>
<td>Page</td>
</tr>
<tr>
<td>-----------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Tuber morphology</td>
<td>265</td>
</tr>
<tr>
<td>Periderm or skin</td>
<td>266</td>
</tr>
<tr>
<td>Vascular ring</td>
<td>269</td>
</tr>
<tr>
<td>Parenchyma</td>
<td>269</td>
</tr>
<tr>
<td>Cortex</td>
<td>269</td>
</tr>
<tr>
<td>Medulla</td>
<td>270</td>
</tr>
<tr>
<td>Outer Medulla</td>
<td>271</td>
</tr>
<tr>
<td>Inner Medulla</td>
<td>271</td>
</tr>
<tr>
<td>Shape</td>
<td>271</td>
</tr>
<tr>
<td>Shape and quality</td>
<td>272</td>
</tr>
<tr>
<td>Color</td>
<td>273</td>
</tr>
<tr>
<td>Eyes</td>
<td>275</td>
</tr>
<tr>
<td>Germinating or sprouting of tuber</td>
<td>277</td>
</tr>
<tr>
<td>Composition: Physical</td>
<td>278</td>
</tr>
<tr>
<td>Composition: Chemical</td>
<td>281</td>
</tr>
<tr>
<td>Starch and sugar</td>
<td>285</td>
</tr>
<tr>
<td>Mealiness</td>
<td>289</td>
</tr>
<tr>
<td>Quality of potatoes</td>
<td>291</td>
</tr>
</tbody>
</table>
Geographical distribution ........................................ 321
Phylogeny .......................................................... 324
Shape and structure of the beet ................................. 325
Composition .......................................................... 328
Purity ................................................................. 329
Uses of sugar beets ................................................ 330
  Human food ....................................................... 330
  Stock food ....................................................... 331
Industrial uses .................................................... 332
  Sugar yield of beets U. S. 1912 ............................. 333
  Beet sugar production in 1912 .............................. 334
APPENDIX
Laboratory directions ............................................. 335
Laboratory exercises ............................................. 337
  Wheat ............................................................ 337
  Barley ............................................................ 340
  Oats .............................................................. 343
  Rye ............................................................... 345
  Corn .............................................................. 345
  Flax .............................................................. 347
  Potato ........................................................... 347
  Sugar beet ....................................................... 348
# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Plate</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Barley Field (Colored)</td>
<td>Frontispiece</td>
</tr>
<tr>
<td>II. Potato Field in Bloom (Colored)</td>
<td>Between 223-229</td>
</tr>
<tr>
<td>Figure</td>
<td></td>
</tr>
<tr>
<td>1. Spikelets of Wheat</td>
<td>6</td>
</tr>
<tr>
<td>2. Heads of Wheat</td>
<td>6</td>
</tr>
<tr>
<td>3. Rachis of Knarkov Wheat</td>
<td>8</td>
</tr>
<tr>
<td>4. Dissected Spikelet of Wheat</td>
<td>8</td>
</tr>
<tr>
<td>5. Rachis of Common Beardless Wheat</td>
<td>8</td>
</tr>
<tr>
<td>6. Sections of Wheat Grains</td>
<td>13</td>
</tr>
<tr>
<td>7. Longitudinal Section of Wheat Grain</td>
<td>13</td>
</tr>
<tr>
<td>8. Sections of Wheat Grains</td>
<td>13</td>
</tr>
<tr>
<td>9. Portion of Wheat Culm</td>
<td>17</td>
</tr>
<tr>
<td>10. Palet and Flower of Wheat</td>
<td>17</td>
</tr>
<tr>
<td>11. Germinating Wheat Grain</td>
<td>17</td>
</tr>
<tr>
<td>12. Groups of Barley Spikelets</td>
<td>99</td>
</tr>
<tr>
<td>13. Spikelets and Grains of Barley</td>
<td>99</td>
</tr>
<tr>
<td>14. Heads of Beardless Barley</td>
<td>102</td>
</tr>
<tr>
<td>15. Barley Spikelets with Secondary Florets</td>
<td>102</td>
</tr>
<tr>
<td>16. Groups of Six-rowed Barley Spikelets</td>
<td>102</td>
</tr>
<tr>
<td>17. Oat Spikelets and Grains</td>
<td>135</td>
</tr>
<tr>
<td>18. Hulless Oats Spikelets</td>
<td>135</td>
</tr>
<tr>
<td>19. Oat Spikelet</td>
<td>138</td>
</tr>
<tr>
<td>20. Double, Normal and Pin Oat Grains</td>
<td>138</td>
</tr>
<tr>
<td>21. Oat Culms</td>
<td>142</td>
</tr>
<tr>
<td>22. Longitudinal Sections of Oat Grain</td>
<td>142</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>23.</td>
<td>Spikelet of Wild Oats</td>
</tr>
<tr>
<td>24.</td>
<td>Wild Oat Grains</td>
</tr>
<tr>
<td>25.</td>
<td>Panicle of Wild oats</td>
</tr>
<tr>
<td>26.</td>
<td>Rye Spikes</td>
</tr>
<tr>
<td>27.</td>
<td>Rye Spikelet</td>
</tr>
<tr>
<td>28.</td>
<td>Rye Spikelets</td>
</tr>
<tr>
<td>29.</td>
<td>Portion of Corn Culm</td>
</tr>
<tr>
<td>30.</td>
<td>Kernels of Corn and Teosinte</td>
</tr>
<tr>
<td>31.</td>
<td>Corn Tassel in Bloom</td>
</tr>
<tr>
<td>32.</td>
<td>Corn Tassel, Spikelets and Grains</td>
</tr>
<tr>
<td>33.</td>
<td>An Ear of Corn &quot;In the Silk&quot;</td>
</tr>
<tr>
<td>34.</td>
<td>Corn Spikelets</td>
</tr>
<tr>
<td>35.</td>
<td>Longitudinal Section of Kernel of Dent Corn</td>
</tr>
<tr>
<td>36.</td>
<td>Transverse Section of Kernel of Dent Corn</td>
</tr>
<tr>
<td>37.</td>
<td>Potato Flower</td>
</tr>
<tr>
<td>38.</td>
<td>Potato Anther</td>
</tr>
<tr>
<td>39.</td>
<td>Transverse Section of Potato</td>
</tr>
<tr>
<td>40.</td>
<td>&quot;Off Type&quot; Seed Potatoes</td>
</tr>
<tr>
<td>41.</td>
<td>&quot;True Tp Type&quot; Seed Potatoes</td>
</tr>
<tr>
<td>42.</td>
<td>Sugar Beet</td>
</tr>
<tr>
<td>43.</td>
<td>Cross Section of Sugar Beet</td>
</tr>
<tr>
<td>44.</td>
<td>Sugar Beet Seed Ball and Seed</td>
</tr>
<tr>
<td>45.</td>
<td>Longitudinal Section of Sugar Beet</td>
</tr>
</tbody>
</table>
CEREALS

Cereals are those grasses which are grown for their seeds or grains.

Buckwheat is sometimes considered a cereal because its seeds (achenes) are ground into flour, but it is not so considered here. This crop as well as flax and others which are defined here as, "those crops which are grown for their seeds for commercial or feeding purposes."

The grains other than the true cereals will be discussed wherever they happen to come in the botanical order of treatment which has been followed. The only grains which are considered in this paper are wheat, corn, oats, barley, rye and flax.

GRASS TRIBES CONTAINING THE CEREALS.

The grass family (Gramineae) is divided into a number of tribes which are in turn divided into genera.

The tribes containing the cereals are as follows: Aveneae, containing genus Avena (oats); Maydeae, containing genus Zea (maize or corn); and tribe Hordeae, containing genera Triticum (wheat), Hordeum (barley) and Secale (rye).

The tribe descriptions are not given, the genera being treated as one group.
KEY TO GROUPS (GENERA) OF IMPORTANT CEREALS.

A. Flowers staminate and pistillate; borne in separate inflorescence but on the same plant, i.e. flowers unisexual and monoecious........Zeae (Maize or Indian Corn)

AA. Flowers perfect or staminate; borne in same inflorescence.

B. Spikelets two kinds, the perfect sessile with one staminate flower pedicellate on either side or rudimentary or wanting; empty glumes 2...

Sorghum (Sorghum, milo, broom corn, etc.)

BB. Spikelets 1-2 flowered, flowers perfect; when 2-flowered, the upper larger, the lower staminate; empty glumes usually three, thin membraneous; lemma and palet hard, shiny, longer and broader than glumes; grain very small, enclosed in hardened lemma and palet.................Chactochloa,

Echinochloa, Panicum, Pennisetum (Millet)

BBB. Spikelets 1-many flowered; flowers perfect; empty glumes 2, persistent.

C. Inflorescence a panicle...........Avena (Oats)

CC. Inflorescence a spike.

D. One spikelet at each joint of rachis.

E. Empty glumes bristle-like........

...............Secale (Rye)

EE Empty glumes not bristle-like, broad

............Triticum (Wheat)

DD. Three spikelets at each joint of rachis

...........Hordeum (Barley)
GEOGRAPHICAL DISTRIBUTION

Cereals combined comprise the most important crop grown in the world. They are very widely distributed and extensively grown by civilized people and to a considerable extent by the semi-civilized and savage races. The following table gives the production by continents for the year 1911.

<table>
<thead>
<tr>
<th>Continent</th>
<th>Corn</th>
<th>Wheat</th>
<th>Barley</th>
<th>Oats</th>
<th>Rye</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>2,531,488,000</td>
<td>621,338,000</td>
<td>160,240,000</td>
<td>922,298,000</td>
<td>33,119,000</td>
</tr>
<tr>
<td>North America</td>
<td>2,740,261,000</td>
<td>849,256,000</td>
<td>207,371,000</td>
<td>1,270,901,000</td>
<td>35,858,000</td>
</tr>
<tr>
<td>South America</td>
<td>32,539,000</td>
<td>170,174,000</td>
<td></td>
<td>49,643,000</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>585,630,000</td>
<td>1,804,705,000</td>
<td>1,002,117,000</td>
<td>2,352,519,000</td>
<td>1,522,765,000</td>
</tr>
<tr>
<td>Africa</td>
<td>88,457,000</td>
<td>85,055,000</td>
<td>63,907,000</td>
<td>19,670,000</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>19,933,000</td>
<td>106,644,000</td>
<td>3,248,000</td>
<td>26,326,000</td>
<td>238,000</td>
</tr>
<tr>
<td>Asia</td>
<td></td>
<td>624,881,000</td>
<td>98,768,000</td>
<td>66,747,000</td>
<td>19,686,000</td>
</tr>
<tr>
<td>Total</td>
<td>3,460,820,000</td>
<td>3,540,717,000</td>
<td>1,375,411,000</td>
<td>3,785,806,000</td>
<td>1,578,547,000</td>
</tr>
</tbody>
</table>
WHEAT (Triticum)

DEFINITION OF TERMS.

The word wheat means white and likely refers to the color of the grain or the flour made from the grain. (Derived from M. E. white, which is from L. Hvete = D. weist = G. weissen = Icel. hveti = Sw. hvete = Dan. hvede, which means liberally that which is white).

The generic name, Triticum, means to rub, grind, or thresh.

Description

Habit. Wheat is an erect growing annual varying in height from 20 to 60 inches.

Roots. Wheat has a fibrous root system. In the germination of the grain the primary root takes the lead; very soon two secondary roots appear on either side of the primary thus forming a whorl of three. Later other roots may be added to these. This whorl constitutes the primary or temporary root system, usually dying before the plant is fully grown. Permanent roots appear in whorls at the nodes some distance above the three temporary roots. These whorls do not usually consist of more than four roots. The first whorl of permanent roots is generally about one inch below the soil surface no matter at what depth the grain was planted. In their growth, the whorls of permanent roots curve outward and downward, taking an almost vertical course. They branch very freely near the soil surface forming within the first foot to 18 inches a fine net-work thus constituting a large absorbing surface. Below about
the first 13 to 24 inches the roots have few or no branches; hence it is considered that absorption takes place largely in the first foot and a half of soil.

Many of the roots of wheat reach a depth of four feet, or even under more favorable soil conditions. The Minnesota Experiment Station found wheat roots to a depth of over 3 feet 3 inches; North Dakota, 6 feet; Kansas, 4 feet.

**Leaves.** The wheat leaf is of the ordinary grass type. The blade varies considerably; the sheath is split; ligule is thin and transparent; the auricles are conspicuous; these latter are small pointed outgrowths from the base of the blade at its juncture with the sheath.

**Inflorescence.** The wheat flowers are arranged in spikelets and the spikelets into a head or spike. The spike varies in size, compactness and form in the different types of wheat. The number of spikelets in a head has a wide range; fifteen to twenty fertile spikelets is a fair average while spikes have been produced with a number considerably higher.

The rachis or main axis of the spikelet is zigzag in shape. Each joint of the rachis is flattened and curved, the concave surface being on the side next to the spikelet. There is but one spikelet at each joint of the rachis. At the base of each spikelet are usually numerous short so-called

---

Fig. 1. Spikelets of the 8 economic species of wheat showing the side next to the rachis.

Fig. 2. Heads of the 8 economic species of wheat.

A. Spelt (Triticum spelta)
B. Einkorn (Triticum monococcum)
C. Emmer (Triticum dicoccum)
D. Polish (Triticum polonicum)
E. Common (Triticum vulgare)
F. Durum (Triticum durum)
G. Club (Triticum compactum)
H. Poulard (Triticum turgidum)
called "basal hairs". The lower spikelets of the head are often sterile; less frequently the terminal spikelet is sterile.

**Spikelet.** The number of flowers in a wheat spikelet varies from 2 to 5. Usually but 2 or 3 grains mature. In some varieties most of the spikelets usually mature 3 grains and less frequently 4.

The glumes are broad, varying much in shape, color, smoothness or hairiness, width and distinctness of keel and length and sharpness of tip. In working with 17 varieties of wheat Franz seemed to show that in general the second kernel of a spikelet is the heaviest; the first is next heaviest, then third, fourth, fifth, etc.

**Flower.** There are three stamens, with thread-like filaments and rather large anthers. The single ovary has two feathery stigmas. There are 2 lodicules.

**Opening of flower and pollination.** Mays has shown that in the case of spring wheat the flower opens early in the morning, the entire process of pollination taking place within about an hour. Hackel asserts that the swelling of the lodicules causes the separation of the lemma and pale and hence the opening of the flower. Flowers in which the lodicules are membranous or lacking remain closed while those in which there is only a slight swelling of these organs open but slightly. In the unopen flower the filaments are short and the stigmas erect and in con-

---

Fig. 3. Rachis of Kharkov bearded wheat with one spikelet attached. X 2½

Fig. 4. Dissected Spikelets of wheat.

A. Einkorn    B. Emmer
C. Common    D. Polish

4. Palet. 5. Sterile flower.

Fig. 5. Rachis of common beardless wheat with one spikelet attached. X 4.
tact. As the flower opens, the filaments elongate rapidly pushing the anthers up and outside the glumes; the stigma lobes separate and catch the pollen. The anthers are shedding pollen before the flower is fully open and continue to do so until it is reclosed. Wheat is largely self-fertilized. Two varieties may be grown side by side with little or no danger of crossing. The first flowers to open are those situated about 1/3 of the way from the tip of the spike. The others follow in succession above and below this point. Each flower remained open from a half to one hour. The head completes its flowering usually in several days.

**Fertilization and ripening of grain.** The time elapsing between pollination and fertilization in the case of wheat is known only in a general way. This is probably variable in different varieties and under different environmental conditions, particularly temperature. Fertilization must be effected in a few hours after pollen reaches the stigma for the ovary soon begins to enlarge.

Double fertilization has not been demonstrated in wheat, but from its relation to corn, in which this phenomenon has been amply proven, it is quite probable that the same is the rule in wheat and other grasses. After fertilization, the embryo begins to develop and the endosperm to grow and accumulate carbohydrates and proteins. Several stages are passed through in the ripening of the grain. At first the endosperm contains a milky juice,
consisting of water and starch. It then takes on a con-
sistency like that of wax, while the pericarp surrounding
it loses its green color. Finally the whole grain becomes
hard and brittle.

True¹ has described in detail the development of the
grain of wheat.

At the time of maturation of the ovule, the conical
ovary has its micropyle directed downward. At first, the
young ovule does not fill the ovary cavity, but soon comes
to do so by farther growth. The ovule is attached to the
ovary along its side. The groove indicates the position
and extent of this attachment. The ovule is curved (cam-
pylotropous). All the grasses are characterized by such
an ovule. The micropyle is at the lower end. The ovary
wall is usually thicker toward the top of the ovary than
at the micropylar end. Before fertilization, the ovary
wall consists of the following layers:

1. Outer epidermis, a single layer of cells.
2. Many layers of parenchyma cells.
3. Chlorophyll-bearing cells, a single layer of cells
   near the groove.
4. Inner epidermis of delicate cells.

There are two ovule integuments each consisting of
two layers of cells. Within the integuments is the nuce-
lus, made up of thin-walled parenchyma cells, all bounded
by a distinct nucellar-epidermis.

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¹ Botanical Gazette V. 18, pp. 212-226.
After fertilization marked changes take place not only within the nucellus but in the integuments and ovary wall as well. The outer integument soon disappears entirely. The parenchyma cells of the ovary wall that are in contact with the chlorophyll layer are absorbed, leaving from 2 to 4 layers next to the epidermis. The further development of the grain, the chlorophyll cells become longer, lose their chlorophyll and their walls become thickened. The epidermis and both layers of the inner integument persist with their cells much compressed. The parenchyma cells, consisting of two or three layers, become thickened. In the mature grain the inner epidermis of the ovary wall or pericarp is firmly attached to the outer layer of the inner integument of the ovule. This behavior seems to be well demonstrated in all grasses investigated. The firm attachment of the pericarp to the ovule distinguishes the grain or caryopsis from the akene.

The mature grain of wheat. The grain or kernel of wheat is longer than broad and somewhat flattened from side to side. At the small end of the grain is a tuft of hairs, the brush, and at opposite end the embryo. Along the side the grain facing the palest is a groove or furrow. The brush and the groove have much to do with the collection of dirt. The position of the embryo may easily be seen at the base of the grain. In a cross section of a mature grain of wheat cut at right angles to its length
so as not to include the embryo, the following layers may be recognized:

1. Pericarp or ovary walls made up three layers of cells.
2. Testa, two layers of inner integument.
3. Nucellus remains of nuccellar tissue.
4. Aleurone layer, outermost layer of the endosperm, a single row of cells.
5. Starchy endosperm, everything within aleurone layer.

The following table shows the proportion of the different parts of the wheat grain given by different writers and investigators:

<table>
<thead>
<tr>
<th>Part</th>
<th>Woods and Bessey</th>
<th>Kerrill</th>
<th>Snyder</th>
<th>Dondlinger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pericarp</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Testa and nucellus</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Aleurone layer</td>
<td>3-4</td>
<td>3-4</td>
<td>3-4</td>
<td>3</td>
</tr>
<tr>
<td>Bran layer (Pericarp, testa, nucellus)</td>
<td>8-9</td>
<td>5</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Floury endosperm</td>
<td>82-86</td>
<td>82-86</td>
<td>82-86</td>
<td></td>
</tr>
<tr>
<td>Embryo</td>
<td>6</td>
<td>6-7</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

**Embryo.** The embryo is rich in fat or oil, mineral matter and protein, and contains considerable quantities of soluble carbohydrates (sugar), but probably none or very little starch. About one-sixth of the embryo has been found to be fat and one-third protein the two consti-

1. Maine Bul. 105, pp. 61-80
3. Chemistry of Plant and Animal Life, Harry Snyder, p. 273
Fig. 6. Sections of wheat grains. Upper section highly magnified. Lower section enlarged about 10 times.

Fig. 7. Longitudinal sections of wheat grain.

Fig. 8. Sections of wheat grains. Section at left highly magnified; at right X 10.
tuting about one-half of its weight. The embryo has been found to contain about 3.5% of nucleic acid. The proteids of the embryo are said to differ from those of the endosperm in the case with which they undergo changes.

A median longitudinal section of a grain of wheat shows the embryo to be made up of the following three main parts: scutellum, 3 primary roots, and plumule.

Structurally, the scutellum is the one cotyledon of the embryo. It is a specialized structure of the embryo laying next to the endosperm and aiding in the transfer of digested food from endosperm to growing points. This point will be further discussed under "germination." Surrounding the embryo is a single row of palisade-like epidermal cells beneath which are the large parenchyma cells. The primary roots point toward the micropylar end. All three are completely surrounded by a root sheath, the coleorhiza. In wheat the two secondary lateral roots are smaller than the middle or primary. These three roots constitute the primary root system. Between the primary root and plumule is the hypocotyl, a very short, inconspicuous part of the embryo. The plumule consists of a bud formed by several sheath-like leaves on a very short stem.

**Endosperm.** The endosperm has been found to occupy about 13/14 of the entire space of the grain. It consists of two portions, the starchy or floury endosperm and the aleurone layer.

---

1. Cereals in America, Hunt p 34.
2. Cereals in America, Hunt p 35.
The starchy endosperm is made up of large, somewhat elongated thin-walled cells. The longer axes of the cells are usually at right angles to the grain surface. These cells are filled for the most part with starch grains varying in size and form, but when fully grown they are rounded or oval in shape and reach a diameter of 37 micromillimeters or $\frac{1}{675}$ of an inch. Chemical analysis of flour shows the presence of ash and proteins and smaller amounts of other substances in the endosperm. Most if not all of the wheat starch and all of the gluten occur in this part of the endosperm. The percentage of gluten increases from the center outward, those cells next to the aleurone layer containing the largest amount.

**Aleurone layer.** The aleurone layer is a single layer of large, nearly square cells immediately inside of the nucellus and completely surrounding the starchy endosperm and embryo. These cells are rather uniformly square or rectangular when viewed in transverse or longitudinal section of the grain but are irregular in shape when viewed perpendicular to the surface.

The aleurone cells are said to be similar in composition and physical properties to the material found in the embryo. They are stored largely with aleurone or aleurone grains. This is a granular, slightly yellowish substance which upon the application of iodine turns yellow or yellowish brown thus being easily distinguished.

from starch which in the presence of iodine turns blue or purple. In water aelurone softens into a sticky, nearly transparent mass.

It is this quality of aelurone which has caused the aelurone layer to be erroneously called gluten layer, and aelurone cells gluten cells. The name gluten is only properly applied to a combination of the two principal proteids, gliadin and gluterin, found in the starchy endosperm, and should not be used in connection with the aelurone layer.

Aelurone is rich in nitrogen and phosphorus and contains much oil. It also contains considerable quantities of magnesia and small quantities of lime, silica and iron.

Nucellus or perisperm. The nucellus is the perisperm of Bessey, the ligmen of Snyder, Dondlinger and others.

Surrounding the aelurone layer is found a thin, hard layer composed largely of crushed cell walls, the remains of the nucellus of the ovule. The nucellus of the ovule is at first comparatively large as compared with the embryo sac and its contained endosperm which are embedded in the nucellus tissue. As the ovule develops the embryo sac and its endosperm encroach more and more upon the tissue of the nucellus until the latter is reduced to a thin layer of crushed cells whose cavities entirely disappear, their contents having been absorbed by the developing embryo and endosperm. The nucellus marks the outside boundary of the ovule as distinguished from its enteguments, the testa.
Fig. 9. Portion of stem of culm of wheat. X 1.

Fig. 10. Palet of wheat and the flower which was enclosed within it. X 5.

Fig. 11. Germinating grain of Wheat. X 5.
It is possible that in some cases the nucellus is completely absorbed and is wanting entirely in the mature grain.

**Testa or Episperm.** The testa is called the episperm by some writers (Snyder) and the spermoderm by still others. It is also often known as the seed coat, especially where it is the outside covering of the seed. The testa is found inside of the pericarp and surrounding the nucellus. In the developing wheat grain the testa consists of a double layer of tissue consisting of the two integuments of the ovule.

The testa as found in the mature grain consists of two rows of cells, the outer more distinct and not so much flattened as the inner. According to True, these represent the two layers of cells of the original inner integument, the outer one having been absorbed entirely by adjoining tissue in the maturation of the grain. The walls of the testa which are at first cellulose become slightly lignified in the mature grain.

The coloring matter of the grain is found in the inner integument. It is of two kinds,—pale yellow and orange yellow. The degree in which one or the other of these colors predominate is said to determine whether the wheat is white, yellow or red.

**Pericarp.** The pericarp is the ripened ovary wall. In the embryo it is attached to the integuments only at one point, the chalaza, but in the maturing grain it becomes firmly attached to the seed and consists of simply
a hardened scale of merely the remnants of the cavity contents and walls of the three layers of cells of which it is composed. The original cavities can scarcely be distinguished. They are much thickened, cuticularized and lignified, forming an indigestible mass with little or nothing nutritious in it. It is composed largely of lignocellulose and comprises the main part of the bran layer. The pericarp forms a layer much thickened and larger than the testa and nucellus together.

The three layers of the pericarp are the cuticle, the external layer or epidermis which may be removed by rubbing the grain, the epicarp, the middle layer from which spring the hairs of the grain and the endocarp, the internal layer.

**Bran layer.** The bran of wheat has been defined to include the three outer layers of tissue, viz., pericarp, testa and nucellus. The pericarp constitutes the larger proportion of the bran which consists largely of mineral and lignified material, the protein content if any being due to aleurone cells and starch cells which adhere to it in the milling process.

Ordinarily or commercially speaking, bran consists of the scale-like, flaky outside covering which is removed from the wheat in the milling process and usually contains in addition to the three layers mentioned above, all or part of the aleurone layer and some starchy endosperm which may adhere to it.
Composition of bran. Wheat bran varies considerably in chemical composition, and hence in feeding value, according to the kind of wheat used and the milling process employed in grinding it. It may contain as low as 14% and as high as 18% crude protein with an average of about 15% as shown in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Water (%)</th>
<th>Ash (%)</th>
<th>Protein (%)</th>
<th>Fiber (%)</th>
<th>Ether (%)</th>
<th>Extract (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bran, all Analyses</td>
<td>11.9</td>
<td>5.8</td>
<td>15.4</td>
<td>9.0</td>
<td>53.9</td>
<td>4.0</td>
</tr>
<tr>
<td>Bran, Spring Wheat</td>
<td>11.5</td>
<td>5.4</td>
<td>16.1</td>
<td>8.0</td>
<td>54.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Bran, Winter wheat</td>
<td>12.3</td>
<td>5.9</td>
<td>16.0</td>
<td>8.1</td>
<td>53.7</td>
<td>4.0</td>
</tr>
</tbody>
</table>

If wheat is closely or exhaustively milled whereby an attempt is made to remove and recover in the flour all of the starchy endosperm and part of the aleurone layer the bran will be of much poorer quality than if the wheat is loosely milled. Bran now being produced by our mills is much lower in feeding value because wheat is being milled much more closely than was formerly the case.

Wheats may have the same composition without yielding brans of equal composition due to the differences in composition of the different parts of the wheat grain and difference in the distribution of the chemical elements.

Two samples of bran may contain the same percentage amount of protein and not have the same feeding value. For

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instance, one wheat containing 13% protein can be ex-
hauostively milled and yield a bran of 16% protein, while
another wheat with 14% protein, loosely milled may yield
a bran with 16% protein. While both brans contain the same amounts
of crude protein, 16%, the second sample would contain the
larger amounts of available non-nitrogenous nutrients and
with the same per cent of crude protein would produce better
results in feeding than would the first sample.

Spring wheat bran has been found usually to contain
more protein than winter wheat bran due likely to the fact
that spring wheats are usually higher in protein than winter
wheats.

Protein of Wheat. A larger number of proteids have
been found in wheat than in any other cereal, and also pro-
teids of an entirely different character.

In 310 analyses of American wheats compiled in 1890,
the protein (N x 6.25) varied from 3.1%, to 17.2% with an
average of 11.9% in samples containing 10.5% water, making
the protein 13.3% of the dry matter of the grain.

Osborne and Vorhees have recognized five proteids of
wheat which contain most if not all of the nitrogen of the
grain. They are present in about the following proportions
of the grain by weight.

Globulin, .6 - .7 per cent. Gliadin, 6.07-7.05 per cent
Albumin, .3 - .4 per cent Glutenin, 3.04-4.05 per cent
Proteose, .2 - .4 per cent
The latter two proteids compose gluten which later investigators report as containing a third proteid con-glutin, the effect of which is little understood and comprises not more than 1½ of the weight of the gluten.

Following is a general description of the above proteids:

**Globulins**: Insoluble in water but soluble in dilute salt solution.

**Albumins**: Soluble in water and easily coagulated by heat.

**Proteose** or **piptones**: Drives from other proteids by ferment action, and are the first products formed when the proteids of food undergo digestion; are soluble in water and are not coagulated by heat or precipitated by acids or alkalies.

**Gliadin**: Is a glue-like, sticky medium which, forming a NUCLEUS, BINDS TOGETHER THE flour particles, making the gluten tough and coherent and giving tenacity and adhesiveness to the dough. These qualities permit the dough to expand and retain the gases produced in bread making. In water containing salts or mineral matter, gliadin is plastic and may be drawn out into sheets or strings. By being handled properly chemically, it may be reduced to a snow-white powder which on the addition of water becomes sticky and if the water was distilled the gliadin will be dissolved. The saltiness of the water determines the amount which will be brought into solution. If a ten per cent salt solution (of sodium chloride) is added to gliadin powder, it becomes non-adhesive but plastic.

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1. American Miller, V. 40, Ph. 1, p 363.
Gliadin is soluble in distilled water and very soluble in 70-80% alcohol, the gliadin remaining after evaporating the liquid in the form of thin, transparent flakes which resemble gelatin. It is insoluble in water containing salts or in absolute alcohol but is soluble in dilute acid and alkali and may, therefore, be soluble in wheats which have fermented and as a result contain acids. Gliadin and starch mixed in the proportion of 1:10 form a dough but do not produce gluten, the gliadin being washed away with the starch. Flour deprived of its gliadin has no gluten there being no binding material to hold the particles together so that they may be brought into a coherent mass. An excess of gliadin gives a soft, sticky dough, while a deficiency gives a dough which lacks expansive power.

Glutenin is a fine, gray material which unites mechanically with gliadin to form gluten. It remains after extracting the gliadin from the gluten with dilute alcohol. It forms a light gray mass which may be reduced to a fine powder when dry and pure. It differs principally from gliadin in being less soluble, darker in color and by being non-adhesive and non-plastic. It is insoluble in dilute alcohol and salt solutions and only sparingly soluble in water, but is readily soluble in dilute acids and alkali solutions from which it may be precipitated by neutralization.

Glutenin combines mechanically with gliadin, forming the gluten to which it imparts solidity evidently by serv-
ing as a nucleus to which the gliadin adheres and from which it is consequently not washed away by water. It prevents the dough from becoming too soft and sticky.

A later investigation reports that gluten contains a third proteid, congluten, the effect of which is little understood. It does not make up more than 1/3 of the weight of the gluten. It is likely closely associated with one of the other two proteids and accompanies one of them in the separations which have so far been made. Con-

It is the gluten which imprisons the carbonic acid gas caused by the fermenting of the yeast. The elastic qualities of the gluten allow it to expand resulting in porous bread.

**Gluten.** Gliadin and Glutenin together form gluten. It does not exist as such in the flour, but is readily formed when the flour is wetted. Gluten is insoluble in water and may be obtained in a more or less crude state from either ground wheat or flour by washing the dough made by kneading the meal or flour with water which removes starch and other non-gluten compounds. Depending on the quality, moist glutens are said to contain about 65%

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1. Century Dictionary

2. Congluten is not considered in this discussion because little or nothing is known about its effect on gluten and breadmaking.
of water, another write stating that gluten will absorb 72-75 of its weight in water. In addition to the water, gluten will contain certain other impurities which are in fairly constant proportions in different samples.

Glutens which are considered the most valuable for good bread making are elastic and tenacious, light yellow in color and possess a smooth, uniform surface. Poor glutens are dark in color, sticky but not elastic, have little power to recoil and have an uneven surface.

Gluten forms about 35% of the proteids of wheat and usually contains from 60-70% gliadin and 20-40% glutenin. When 60-65% of the protein is gluten and these two proteids are present in proportion of 60-65% gliadin to 34-40% glutenin the gluten is considered to be best suited for good bread making in America. E. E. Fleurant, a French chemist, states that the most favorable ratio of gliadin to glutenin is 75% of the former to 25% of the latter. 1

It seems to be true that a wheat may produce a good quality of bread and at the same time contain a low percent of gluten, while on the other hand poor bread making qualities can be associated with a high percent of gluten due to its possessing poor quality caused by the wrong proportion of gliadin and glutenin. An abnormally large amount of gluten does not yield a correspondingly large loaf.

Two samples of wheat may contain the same amount of

1. Cereals in America, Hunt, p 41
gluten and make flour with corresponding amounts and possessing a high nutritive value and the one flour may produce good bread and the other bread of poor quality because of the lack of proper balance between the gliadin and glutenin. This question is of much importance in the milling of wheats and especially in the blending of flours which has become to be an important part of the milling business.

When gluten possesses too much gliadin, the dough rises well, but falls in the baking, and when the glutenin is in excess the bread does not develop porosity, the glutenin being without elasticity.

Fleming found that the gluten contains a higher percentage of glutenin as the center of the grain is reached. In milling wheats examination may show a greater amount of glutenin in flour loosely milled than would be shown if the wheat had been milled more closely.

The function and importance of gliadin were determined at the Minnesota Experiment Station by comparing bread from normal flour with bread from other flour of the same lot, but having part of its gliadin extracted. "Dough made from the latter was not sticky but felt like putty, and broke in the same way. The yeast caused the mass to expand a little when first placed in the oven; then the loaf broke apart at the top and decreased in size. When baked it was less than half the size of that from the same weight of normal flour, and decidedly inferior in other respects. The

1. Utah Bul. No. 103
removal of part of the gliadin produced nearly the same effect as the extraction of the whole of it, and even when an equal quantity of normal flour was mixed with that from which part of the gliadin had been extracted, the bread was only slightly improved.\footnote{1}

In bread making acids are formed. These act on the gliadin and cause the bread to contain a larger amount of alcohol, soluble nitrogen or gliadin than the flour from which the bread was made.

The composition of the gluten of a number of wheats is shown in the following table:\footnote{2}

<table>
<thead>
<tr>
<th>Wheat Type</th>
<th>Protein (N x 5.7)</th>
<th>Gluten-Gliadin</th>
<th>Glut-atin</th>
<th>Glia-din</th>
<th>Glut-atin</th>
<th>Glia-din</th>
<th>Glut-atin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Scotch fife</td>
<td>14.76</td>
<td>12.46</td>
<td>7.26</td>
<td>5.20</td>
<td>58.3</td>
<td>41.7</td>
<td></td>
</tr>
<tr>
<td>2. Wellman's fife</td>
<td>12.80</td>
<td>10.18</td>
<td>6.14</td>
<td>4.04</td>
<td>60.3</td>
<td>39.7</td>
<td></td>
</tr>
<tr>
<td>3. Red winter wheat</td>
<td>10.73</td>
<td>8.63</td>
<td>5.60</td>
<td>3.08</td>
<td>64.5</td>
<td>35.5</td>
<td></td>
</tr>
<tr>
<td>4. Early Genesee winter</td>
<td>7.93</td>
<td>6.31</td>
<td>3.71</td>
<td>2.60</td>
<td>58.8</td>
<td>41.2</td>
<td></td>
</tr>
<tr>
<td>5. Ladoga</td>
<td>9.34</td>
<td>8.25</td>
<td>5.64</td>
<td>2.61</td>
<td>68.5</td>
<td>31.5</td>
<td></td>
</tr>
<tr>
<td>6. Blue stem</td>
<td>14.20</td>
<td>11.75</td>
<td>7.34</td>
<td>3.91</td>
<td>66.7</td>
<td>33.3</td>
<td></td>
</tr>
<tr>
<td>7. Crimean</td>
<td>11.03</td>
<td>9.49</td>
<td>5.77</td>
<td>3.72</td>
<td>60.3</td>
<td>39.2</td>
<td></td>
</tr>
<tr>
<td>8. Frosted spring wheat</td>
<td>12.33</td>
<td>6.39</td>
<td>4.25</td>
<td>2.14</td>
<td>66.5</td>
<td>33.5</td>
<td></td>
</tr>
<tr>
<td>9. Calcutta (India)</td>
<td>8.13</td>
<td>6.70</td>
<td>4.90</td>
<td>1.80</td>
<td>73.1</td>
<td>26.9</td>
<td></td>
</tr>
<tr>
<td>10 No. 1 Chili</td>
<td>7.01</td>
<td>5.62</td>
<td>2.92</td>
<td>2.70</td>
<td>52.0</td>
<td>48.0</td>
<td></td>
</tr>
<tr>
<td>11 La Plata (Argentina Rep.)</td>
<td>15.33</td>
<td>11.34</td>
<td>4.99</td>
<td>6.35</td>
<td>42.1</td>
<td>57.9</td>
<td></td>
</tr>
<tr>
<td>12 Nicolaeff Azima (Russia)</td>
<td>10.23</td>
<td>8.74</td>
<td>5.70</td>
<td>3.04</td>
<td>65.2</td>
<td>34.3</td>
<td></td>
</tr>
<tr>
<td>13 Oregon White winter</td>
<td>9.23</td>
<td>7.65</td>
<td>5.42</td>
<td>2.23</td>
<td>70.5</td>
<td>29.2</td>
<td></td>
</tr>
<tr>
<td>14 No. 2 red winter wheat</td>
<td>7.01</td>
<td>5.56</td>
<td>3.77</td>
<td>1.79</td>
<td>67.3</td>
<td>32.2</td>
<td></td>
</tr>
<tr>
<td>15 No. 2 hard winter wheat</td>
<td>3.33</td>
<td>7.31</td>
<td>3.99</td>
<td>3.52</td>
<td>54.6</td>
<td>45.4</td>
<td></td>
</tr>
</tbody>
</table>

\footnote{1} Human foods, Snyder, p. 170.  
\footnote{2} Chemistry of Plant and Animal Life, Snyder, p. 177.
Emmer, Speltz, and other wheats are said as a rule to be lower in gluten and the gluten is of a poorer quality than is found in common wheats. Emmer and the other very hard wheats contain more crude fiber which makes them harder.

Germination of Seed. The time required for germination depends largely upon external conditions. The optimum temperature for the germination of wheat is close to 84°F., and the minimum 40-53, and the maximum 108. Germination will take place under field conditions usually within from 4 to 10 days. Nobbe finds that wheat will begin to germinate in 1 3/4 days at 65°F., 2 days at 60°F., 3 days at 50°F., and 6 days at 40°F. The primary root is the first to appear. It ruptures the coleorhiza which remains as a collar about the root at the point where it breaks through the grain coats. Very soon two lateral roots appear; hence the primary root system consists of a whorl of three roots. The plumule elongates, the first flat young leaf being enclosed by the leaf sheath. The younger leaves soon appear coming from within the older ones in order. The cotyledon is left below ground. The age of wheat affects its germinating ability. Experiments show that there is no truth in the assertion that wheat taken from the Egyptian tombs germinated. Lourd found that its vitality and Hoberlandt has verified these results.
PHYLOGENY OF WHEAT

There has been much speculation as to the origin of cultivated wheats (genus Triticum).

At one time it was thought that Genus Aegilops, a wild grass common in Southern Europe. However, this view seems to have been gradually dropped by botanists.

_Triticum monococcum aegilopoideae_, which is considered to be the prototype of _Triticum monococcum_ (Einkorn) was discovered over 55 years ago by Balansa. However, from the failure to obtain but a very limited number of crosses, none of which were fertile, between _T. monococcum_ and the other species of _Triticum_, Einkorn cannot be considered the progenitor of other species. Furthermore, its origin on account of its primitive nature and lack of mention in history is considered to be much more recent than that of the other wheats.

For the same reasons, Spelt ( _T. Spelta_ ) likely has no claims to being the prototype of other wheats.

From records of antiquity and the occurrence of seed in the old tombs, Emmer is the species which has the greatest claims to being the progenitor of cultivated wheats.

On June 16, 1906, Aaron Aaronson, Director of the Jewish Agricultural Experiment Station, discovered at Rosh Pinar, Palestine, found a wild wheat ( _Triticum dicoccum dicoccoides_ ) for which he had been searching for some time. It was the same plant which had been discovered by Kotscky —

1. Cook suggests the name _T. hermonis_ for this species.
on the northwestern side of Mount Hermon in 1855 and which had been mentioned and named \( \text{Triticum vulgare dicoccoides} \) by Kornicke in 1835. At that Kornicke declared it to be the prototype of cultivated wheats, and the evidence so far seems to bear out this conclusion.

There is nothing to indicate that this species is emmer \( (T. dicoccum) \) escaped from cultivation, all the evidence pointing to the opposite conclusion.

A great variety of forms have been found. Some resemble in some respects \( T. \text{ monococcum} \), others \( T. \text{ monococcum aegilepoideae} \), \( T. \text{ polonicum} \), and even \( T. \text{ durum} \). These forms very considerably in color, hairiness, shape of glumes, and in other ways.

**HISTORY OF WHEAT**

Records show wheat to be of the very earliest origin. Emmer is the grain of the cultivation of which there are the oldest records. It has been found in the tombs of Egypt, which date back 4000 years before Christ. Durum wheat has also been found in some of these same tombs, although in smaller amounts, indicating that it is of more recent origin.

Emmer has also been found "in lake dwellings of Tangen and Robenhaussen, which date back to the end of the neolithic epoch, a littler before the bronze age."

Wheat was cultivated in China at least 3000 years B.C.

There is some claim that wheat originated in central
Asia or in Europe.

The most plausible theory seems to be that of Kornicke, Schweinfurth, and Ascherson, and later reiterated by A. de Candolle that the cultivation of wheat originated in western Asia in the region of the Euphrates. Aaronsohn\(^1\) seems to concur in this view when he quotes A. de Candolle to the effect that the principal habitation of the species (*Triticum*) was probably "the Euphrates Valley, lying nearly in the middle of the belt of cultivation which formerly extended from China to the Canaries."

From here the different species have gradually become distributed until they are now widely scattered, constituting the principal food of the people of many countries.

**GEOGRAPHICAL DISTRIBUTION**

Wheat is second cereal in the world in production of bushels, oats coming first and corn third. In the United States, corn comes first and wheat third, while in Europe oats are third and corn fourth.

In all civilized countries wheat in the form of flour is one of the principal foods. If not raised locally, it is shipped in either as grain or flour.

\(^1\) Bureau of Plant Industry, Bul. 180, p. 50.
Key to Economic Types of Wheat (Triticum)

A. Spikelets 2-flowered, 1 sterile, 1 fertile; palet dividing longitudinally when mature

...... T. monococcum (Emmer)

AA. Spikelets more than 2-flowers, 2 or more fertile, palet remaining entire at maturity.

B. Empty glume as long as or usually longer than lemma; palet about 2/3 as long as lemma

...... T. polonicum (Polish Wheat)

BB Empty glume shorter than lemma, palet nearly as long as lemma...... T. sativum (Common wheat)

(T. sativum is divided into the following three races)

C. Rachis brittle, breaking at nodes when threshed, segments remaining attached to spikelets; spikelets 2-grained, sometimes 3.

D. Spike open, spikelets arched on inner side, adhering portion of rachis thick, blunt

...... T. sativum spelta (Spelt)

DD Spike very compact; spikelets flattened on inner side; adhering portion of rachis slender, pointed, T. sativum dicoccum (Emmer)

CC Rachis tenacious, remaining entire in threshing, spikelets usually more than 2-grained

...... T. sativum tenax

(T. sativum tenax is divided into the following four sub-races)

D. Empty glumes sharply and broadly keeled at the base, lemma bearded, spike very compact.

E. Spike with sides parallel or nearly so; glumes with a bloom, usually glabrous; grain very hard, horny, long...... T. sativum tenax durum (Durum wheat)

EE Spike short, crowded, long ovate (egg-shaped); glumes usually pubescent (hairy); grain short, blunt and softer than T. durum...... T. sativum tenax turridum (Toulard wheat)

DD Empty glumes keeled in upper half; rounded below. (Sometimes slightly keeled in lower half); lemma sometimes bearded.
E. Spikes very short (rarely over 2 inches) =
very compact or crowded; thicker at apex
than center or base; stiffer, or long
thru spikelets; grains small, short...
T. sativum tenax compactum (Club wheat)

EE. Spikes longer than 2 inches, open, sides
usually parallel or nearly so, narrower
on the furrow dies.....
T. sativum tenax vulgare (Common bread wheat)

The word sativum is from the Latin sativus, meaning
cown or planted. The word tenax is Latin meaning holding
fast, tenacious. It refers to the rachis which does not
break up at maturity. Instead the grains are free from
the spikelets and fall out at maturity.

These terms are usually dropped in common usage, the
wheats being referred to botanically by their generic and
sub-specific names only, i. e. Triticum durum in place of
T. sativum tenax durum.

I
THE SPECIES OF WHEAT

T. monococcum (Einkorn). Specific name monococcum
means one kernel and refers to the number of kernels
in a spikelet. The German name is Einkorn and the French
eingrain.

Owing to the fact that this wheat will not cross
readily with other species, this type is considered to be
entirely distinct from all other wheats. No fertile crosses
have ever been produced. The heads resemble einkorn some-
what.

1. The descriptions of wheat species are largely from
Carleton as given in Division of Vegetable Phys. and Path.
Bul. 24.
Description. Plant short, thin, and narrow leaved, presenting a peculiar appearance in the field; height seldom more than 3 feet; stem hollow, thin, very stiff; leaves usually quite narrow, sometimes hairy, those of the young plant sometimes bluish-green, and after flowering become yellowish green, portions of the stem may also be brown; heads slender, narrow, very compact, bearded, much flattened on the two narrow sides, always stand erect even when ripe, but break in pieces easily; spikelets flat on inner edge, or form a concave surface with the projecting edges of the empty glumes (outer chaff), arranged very compactly in the head, usually one grain except in variety Eingrain, double where they possess two grains, empty glumes (outer chaff) deeply boat shaped, rather sharply keeled, the keel terminating in a stiff tooth; palet splitting into two parts longitudinally when disturbed after maturity; grains tightly enclosed in the glumes, light red, extremely flattened, becoming thus blunting two-edged and possessing an exceedingly narrow furrow.

Uses and Adaptability. Einkorn may prove useful in crossing with other wheats to introduce into the progeny some of its valuable qualities such as hardiness, constant fertility, rust resistance, etc. However, only one or two men have ever been able to produce a hybrid of einkorn and another species of wheat and this hybrid was not fertile, hence it is doubtful whether T. monococcum can ever
be used to improve other wheats. Is the hardest of all cereals and as far as Carleton has ever observed is absolutely proof against orange leaf rust.

Is entirely unknown in this country, excepting among a few experimenters; is grown to a limited extent in Spain, France, Germany, Switzerland and Italy. Two chief varieties are common, Binkorn and Engrain double.

Desirable Qualities of Binkorn.
1. Power of holding grain in the head.
2. Resistance to orange leaf rust.
3. Hardiness.
4. Resistance to drought.
5. Stiffness of straw

Undesirable Quality of Binkorn
1. Brittleness of the head.

_T. polonicum_ (Polish). The name refers to Poland. It is considered a misnomer since this species did not originate in Poland and is little grown there. Its native home is more likely in some part of the Mediterranean region. This species is also locally called Giant rye, Astrakhan rye, and Jerusalem rye. It is, however, a true wheat and the name rye should be dropped.

There are said to be several sub-species and varieties but only one variety, White Polish, is very widely known.

Description. Plant usually rather tall; stems smooth, more or less pithy within; does not stick exten-
nively; heads extremely large, loosely formed, before ripening are bluish green in color; peculiar glumes, empty or outer glume larger than the flowering glume or lemma, narrow, papery in structure, standing out slightly from the head instead of being rigid and closely applied to the spikelets as in other wheats; palet usually somewhat shorter than flowering glume; grains large when normal, proportionately quite long, yellowish white or dark amber in color, very hard.

**Uses and Adaptability.** In the few cases where tried in this country Polish wheat has proved a success in yield and quality of grain. Is raised in some few localities in semi-arid sections for stock feeding with good yields. No market for grain. It is thought that it would be excellent for macaroni making and that a good market could be created for it but up to the present time no progress has been made in this direction. Is not well adapted for bread making if used alone.

Though requiring considerable moisture at seed time is admirably adapted to arid districts; produces best quality of grain under arid conditions. Are somewhat sensitive to changes of environment. Is somewhat resistant to orange leaf rust but not so much so as durums.

Grown chiefly in Italy, Spain and other portions of the Mediterranean region, and in southern Russian and Turkestan. Also said to be raised some in Brasil.
Special qualities of Polish Wheat.

1. Quality of gluten content for making macaroni.
2. Resistance to drought.
3. Resistance to orange leaf rust.

T. spelta (Spelt). The word spelta is likely from Spelt, which means to split or break. It probably refers to the rachis which breaks up at maturity. Spelt is called in different languages as follows: English Spelt, German Spelz, sometimes Dinkel, French spéculaire.

Description. Grows to average height of wheat or perhaps a little higher; hollow stem; leaves of ordinary size; usually smooth, sometimes with scattering hairs; heads loose, narrow, rather long, bearded or beardless (bald); rachis very brittle, breaks up in threshing just below the point of attachment of the spikelet, the glumes remaining attached to the spikelets; spikelets usually far apart in the head, arched on the inner side, contain usually 2 grains; empty glumes (outer chaff) oval, four angled, boat shaped, only slightly keeled; grains red in color, somewhat compressed at the sides, narrow furrow, walls of the furrow flattened, with sharp edges; grain held tightly within the chaff, cannot be removed in threshing.

Adaptability and Uses. Spelt is used very little for human food; generally fed to stock. Its importance in this country lies in crossing with bread wheats to introduce into the latter its (speltz') quality of holding the
grain tenaciously. Garton Brothers of England have demonstrated that this can be done. This quality is particularly desirable for wheats of the Pacific Coast and Rocky Mountain States where harvesting is often done after the grain is dead ripe. "The few varieties possessing this quality that are now grown in these districts are sometimes not desirable in other respects. Certain introduced varieties which are most excellent from the standpoint of yielding capacity and hardiness are rendered worthless because of the great loss from shattering. The quality of constant fertility or of producing "well filled", heads, has been found to be greatly increased by the introduction of the spelt element. Undoubtedly a great loss occurs every year through the inability of the variety to fill out its heads.

There are winter and spring varieties. Some of the former are very hardy. Certain varieties are also rather drought resistant. Nearly all sorts are more or less susceptible to rust attacks.

"While the experimenter is endeavoring to secure the qualities of non-shattering, drought resistance, etc., it is equally important to select from the progeny of such crosses in such a way as to eliminate the characteristics of rust liability and brittleness of the head."

Chiefly grown in Germany, Italy, Spain, France, Switzerland and perhaps to a small extent in Brazil. Not grown in this country except mainly in an experimental way.
Desirable Qualities of Spelt.

1. Power of holding grain in the head.
2. Constancy in fertility.
3. Hardiness of certain winter varieties.

Undesirable Qualities of Spelt

1. Brittleness of head
2. Rust liability

_Th. dicoccum_ (Emmer). The specific name means two-kernelled and refers to the number of grains in the spikelet.

It is sometimes called two-grained wheat and starch wheat. Why the latter term should be used is a mystery since the grains are very hard and have all the characters of grains low in starch. Possibly this is not true of all emmers.

This species is known by the following names in different countries: German, Eimel; French Amidonnier, Russian polba. The Russian name is invariably translated spelt, which likely accounts for the application of the latter name to these wheats in this country and Russia. The German name emmer is best known and easily pronounced and should be used and the name spelt should be applied where it properly belongs to _T. spelta._

Description. Stems pithy or hollow with an inner wall of pith; leaves, sometimes rather broad, usually velvety hairy; heads almost always bearded, very compact, much flattened on the two sides; appearance in the field
quite different from that of spelt, spikelets (unhulled grains as they come from the thresher) look considerably like those of spelt, but differ principally in the presence always of a short pointed portion of the rachis (the pedicel), which if attached at all to the spelt spikelets is always very blunt and much thicker; in emmer this pedicel is present almost invariably extends below the point of attachment to the spikelet while in spelt it usually extends above the point of attachment; emmer spikelets are flattened on the inner side and not arched as in spelt, so that they do not stand out from the rachis as the spelt spikelets do, but lie close to it and to each other, forming a solid compact head; spikelets usually two-grained, one being located a little higher than the other; empty glumes (outer chaff) boat-shaped, keeled, toothed at apex; grain somewhat similar to spelt, usually harder, more compressed at the sides and redder in color.

Uses and Adaptability. For production of new varieties by crossing emmer has qualities similar to spelt, but still more valuable. Hasharder grain, is more resistant to drought and usually rather resistant to orange leaf rust.

It is well adapted for cultivation in northern states of Plains where it has proven valuable as a hardy forage plant besides giving a good yield of grain. Grain is used for stock feed. Most varieties are spring grown. There are two common varieties in this country, black winter and white spring; the former has a much larger head and is more commonly grown in the southwest.
Cultivated chiefly in Russia, Germany, Spain, Italy, Servia and to some extent in France and Western United States.

Emmer of this country descended from seed originally obtained chiefly from Russia, where a considerable portion of the food of the peasants of the Volga region is a sort of gruel ("Kasha") made from hulled and cracked emmer.

Desirable qualities of Emmer:
1. Power of holding the grain in the head.
2. Drought resistance.
3. Resistance to orange leaf rust.

Undesirable quality of Emmer
1. Brittleness of the head.

T. turridum (Foulard). The name turridum means swollen and refers to the compact condition of the spikelets which causes them to extend outwards from the rachis.

In Europe this type is sometimes called English wheat, a very misleading name as they are said to be little grown in England. A few varieties are known in England as rivet or turged wheat. In the United States it is known as Egyptian or English wheat as well as Foulard. In German it is bouchiger Weizen, meaning bulged or swelled; in French Blé petanuois, meaning the same as the German word.

To a small section of T. turridum having compound or branched heads the name T. compositum (composite wheats) has been applied. Some well known names for this group are Seven-headed, Wonder, Hundred Fold, Miracle, and Alaska.
However, emmer (T. dicoccum) includes varieties with compound heads, hence a separate sub-species is questionable. This is the wheat which was exploited a few years ago as being an enormous yielder.

The yield is no larger than other wheats and the quality is very poor for bread making. "Many facts known in connection with the existence of these closely allied forms, together with that of the intergrading sorts between poulard and durums afford strong evidence of occurrence of natural hybrids among the varieties of these groups."

Description. Usually rather tall, with broad, in most varieties velvety, hairy, or often glaucous hairs; stems thick, stiff, sometimes pithy within; heads long, often squarely shaped, with long beards that are white, red or bluish red in color, or sometimes black; spikelets 2-4 grained, arranged rather compactly; outer chaff strongly and sharply keeled; grains, large, proportionately short and rounded, sometimes almost semi-circular in middle cross section, rather hard and glutinous in some varieties, softer in others, light yellowish red in color, sometimes nearly white and becoming glassy in varieties allied to the durum group, or on growing on certain soils.

Uses and Adaptability. Foulard wheats are sometimes used in the manufacture of macaroni and other pastes. Are also occasionally used in bread making, but are more often mixed with common bread wheats in grinding in order to give the quality of flour that is desired in the French markets.
Poulard wheats are native usually in hot, dry regions, and are therefore often rather drought resistant, but not so much so probably as the durums. Many of the varieties also very resistant to orange leaf rust. Grown chiefly in France, Egypt, Italy, Turkey, Greece, Southern Russia, and other districts bordering the Mediterranean and Black seas. In this country only rarely grown; so far in an experimental way.

**Special qualities of Poulard Wheats:**

1. Excellence of certain varieties of making macaroni.
2. Resistance to orange leaf rust.
3. Resistance to drought
4. Stiffness of straw.

*T. durum* (Durum). The specific name *durum* means hard or flinty and refers to the character of the grain. In Europe they are often called simply hard wheats. On account of some resemblance of the heads to those of barley they are sometimes called, in German, gerstenweizen, or barley wheats. In America this type is often called macaroni wheat because it is used for making macaroni.

**Description.** Heads usually not so thick as poulard varieties; grains longer and much harder; plants rather tall; stems either pithy within or hollow with an inner wall of pith, or in a few varieties simply hollow as in the common bread wheats; leaves usually smooth, with a hard cuticle, almost always resistant to orange leaf rust; heads rather slender, compactly formed, occasionally very
short, always bearded, with the longest beards known among wheats; spikelets 2 to 4 grained; outer chaff (empty glume) prominently and sharply keeled, the inner chaff (lemma or flowering glume) somewhat compressed and narrowly arched in the back; grains usually very hard and glassy; mostly clear amber but sometimes yellowish white in color and occasionally inclining to reddish; proportionally rather long. "In the variety Arnautka the grains are almost or fully as large as those of Polish wheat, and are sometimes actually mistaken for the latter."

They are the hardest-grained wheats known. The Fifes, Velvet Bluestem, Turkey and others of that class usually called hard wheats in this country are not, strictly speaking, hard wheats at all when compared with these.

The varieties generally raised (Kubanka and Arnautka) have smooth yellowish glumes (chaff) and yellow beards.

The kernels are clear amber. In some varieties the glumes and beards are black and either smooth (Black Don) or pubescent (velvety) Velvet Don).

Varieties intermediate between these are known as are varieties with white spikelets and beards.

Uses and Adaptation. Durum wheats are particularly sensitive to changes of environment and quickly deteriorate when grown in soil or climate to which they are not well adapted. Such changes may be found with the distance of a few miles. "For example, it is well understood in South Russia that the excellent variety Arnautka gives the best results only when grown within a very limited area border-
ing the Sea of Azov. So also the best Kubanka is found
east of the Volga on the border of the Kirghiz Steppes.
In the Caucasus this variety has actually developed into
a red winter wheat, thought the original is a yellowish-
white spring wheat."

Tests show that the Kubanka variety is best for the
drier central and western parts of the Dakotas. On the
other hand, the Arnautha variety was superior in eastern
parts of Dakota and western Minnesota. These varieties
have also done well in northeastern Colorado and in the
Judith Basin of Montana, although they have been slightly
exceeded in yield by closely related varieties such as
Beloturka, Yellow Charnovka, and Pererodka.

Durum group furnishes the great bulk of the world's
supply of macaroni wheat, though a considerable amount of
these pastes is made from Poulard and Polish varieties and
a still small proportion from the common bread wheats.

It is thought that most if not all of these durum
sorts can be grown in this country. The variety Nicaragua
succeeded in Texas prior to 1900.

Carleton said in 1900, "At the same time the idea that
these wheats cannot be successfully used for bread has
never yet been shown to be more than a mere assumption."

Up to 1900 they had been successfully ground by sev-
eral mills in this country and in southern Russia, where
milling has developed to a high degree of perfection.
They are no longer an experiment. In that region durum
Wheat has become actually the most popular for bread making though it is usually mixed with a small per cent of ordinary red wheat before grinding. In France there was about 1900, and likely is still an increasing demand for durum wheat for all purposes.

While the development of the market has been slow, there has been a constantly increasing use of durum wheat flour for blending with soft wheat flours.

In 1913 the increasing price for durum wheat caused it to sell at a premium as high as 6 1/4 to 9 1/2 cents over No. 1 northern at Minneapolis and Duluth respectively.

Durum wheat is adapted for soils rather rich in nitrogenous matter but somewhat alkaline; give best results in a very hot, dry climate; are, therefore, quite drought resistant; most varieties adapted only for spring planting; young plants of this and poleard group are very light green in color first and grow up rapidly.

Durum wheats are grown in Spain where they predominate over all other groups, and in other Mediterranean countries and in south and east Russia, Asia Minor and to some extent in Mexico, Chile, and Argentina. Up to 1900 one variety, Nicaragua, was grown to a limited extent chiefly in Texas.

Special qualities of Durum Wheat:

1. Excellence of gluten content for making macaroni and other pastes.
2. Resistance to drought.
3. Resistance to orange leaf rust.
**T. compactum** (club or square head). The name refers to the character of the head which is very compact and dense with the parts pressed together. It is also known as Hedge hog and Dwarf wheat.

By most writers, this group is not ranked as a separate sub-species but is placed with *T. vulgare*. However, it is about as distinct as other groups and is here considered as a separate sub-species.

**Description.** Plant very erect with stiff usually rather short culm, average height probably little more than 2 feet; heads extremely short as a rule, often square-ly formed in some varieties much broader and flattened on the furrow side, usually thicker at apex than base, commonly white, sometimes red; bearded or bald, the bearded varieties usually being native in hot countries; spikelets set extremely close together, often standing almost at right angles to the rachis; three or four grained, sometimes with four grains nearly throughout the entire head; outer and inner chaff (glumes) much the same as in bread wheats, chaff usually very tenacious; grains usually short and rather small, white or red, often boat-shaped and occasionally appear like those of naked barley.

Most important quality is the comparatively large yield due to the very close, compact arrangement of spikelets on the short heads.

The tenacity of the chaff permits the harvesting of most of these wheats long after ripening without loss from
shattering. This quality makes these varieties particularly adapted to Washington, Oregon and California where the combined header and threshing is used. Damage from lodging is quite rare due to short, stiff straw.

**Uses and Adaptability.** Club wheats are adapted to localities where harvesting is delayed until grain is completely ripe or later. Produces the class of flour desired in certain places, particularly the South where it is used for biscuits. Considerable quantities of Club wheat flour are milled in Colorado and other western states enroute from the Pacific region to the southern states. Club varieties are very good for cracker making and for the more starchy kinds of breakfast foods. Club wheats are cultivated chiefly in the Pacific Coast and Rocky Mountain states of this country, in Chili, Turkestan and Abyssinia, to a slight extent in Switzerland, Russia and a few other districts of Europe.

**Special Qualities of Club Wheats:**

1. Great yielding power
2. Stiffness of straw
3. Freedom from shattering.
4. Early maturity (in some varieties)
5. Drought resistance (in some varieties)

**T. vulgare (Common).** The name means of or pertaining to the common. This is the popular type of the wheat and is usually referred to as common bread wheat.
Description. Heads long in proportion to thickness, as compared with those of some other groups. Broader in the plane of the rows of spikelets, as a rule, and narrower on the sides of the furrow between the rows; taper toward apex, but may be very blunt or even thicker above; are usually loosely formed comparatively speaking; bearded or beardless, smooth or velvety chaff. Spikelets usually contain 3 grains but sometimes 2 and less often 4. The empty glumes are slightly keeled above and arched below. Stem of the plant usually hollow, but occasionally somewhat pithy within and varies greatly in strength and height in different varieties. Leaves rarely as wide as those of durum and pulsed groupal velvety only in a few instances.

Groups of Common Bread Wheat. For purposes of commercial and market study common bread wheats have been divided into 5 groups as follows:

(1) Soft winter wheats; (2) Hard winter wheats; (3) Hard spring wheats; (4) White wheats; and (5) Early wheats.

Description and Approximate Distribution of Common Wheat.

(1) Soft winter wheats,—Color of grain varying from amber to white; produced under influences of considerable moisture and mild even temperatures; distributed in Eastern United States, Western and Northern Europe, Japan, and in portions of China, India, Australia, and Argentina.

(2) Hard winter wheats,—Red grained, usually bearded; relatively high gluten content; more limited in their distribution.
Crowned frequently on black soils, under influences of climate characterized by extremes of temperature and moisture, but especially dry, hot summers. Found in this country chiefly in the states of Kansas, Nebraska, Iowa, Missouri, Oklahoma and Eastern Colorado; are gradually becoming adapted to Minnesota, the Dakotas and Southern Canada.

(3) Hard spring wheats,—red or dark amber grained; rich in gluten content; adapted to conditions of soil and climate of hard winter wheats with the exception that the growing season is shorter and the winters too severe for winter varieties.

Found in Central and Western Canada, our Northern states of the plains (Wisconsin, Minnesota, North and South Dakota, and northern Iowa and Nebraska), East Russia and western and Southern Siberia.

(4) White wheats,—soft and very starchy; grains a little harder and much drier than those of soft winter wheats; either fall or spring sown, sometimes at both seasons in the same locality.

Crowned chiefly in the Pacific Coast and Rocky Mountain states of this country, in Australia, and in Chile, Turkestan, and the Caucasus.

(5) Early wheats,—soft or semi-hard; generally amber to red in color of grain; distinguished from other groups chiefly in their ability to ripen early.

Found in Australia and India; represented in this country by a few varieties in the Southern states; include
some of the dwarf wheats of Japan.

Uses and Adaptability. The characters of the varieties of common wheat are very diverse because of cultivation under so many diverse conditions. Their principal characteristic is the quality of their grain for production of bread, hence often called "bread wheats."

Hard, red-grained varieties are by far the best in food content and for the production of flour for white, light, raised bread. They include the Fifes, Velvet Blue stem, Turkey, Kharkov, Mediterranean, Red Russian, and Fulcaster of this country and Canada; the Chirkas, Ulka, Crimcan and Balvola, of Russia; and the Theise and Banat of Hungary and Roumania.

The white wheats and soft winter wheats give the best success in the manufacture of crackers and the making of biscuits. Several of the most popular breakfast foods are also made from white wheats. In a few instances macaroni is made from the hard spring wheats and the white wheats. No varieties of the bread wheat group are well adapted for this purpose.

Special qualities of Bread Wheats:

1. Excellence of gluten content for bread making.
2. Excellence of certain varieties for cracker and biscuit making.
3. Yielding power of certain sorts
4. Rust resistance in some varieties.
5. Hardy winter varieties.
6. Resistance to drought (in some varieties).
7. Early maturity (in some varieties).

CHEMICAL COMPOSITION OF WHEAT

The following composition of wheat is given by Henry:

<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Ash</th>
<th>Protein</th>
<th>Crude free fiber</th>
<th>Extract</th>
<th>Ether extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat, all analyses</td>
<td>10.5</td>
<td>1.9</td>
<td>11.9</td>
<td>1.3</td>
<td>71.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Wheat, spring</td>
<td>10.4</td>
<td>1.9</td>
<td>12.5</td>
<td>1.8</td>
<td>71.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Wheat, winter</td>
<td>10.5</td>
<td>1.8</td>
<td>11.8</td>
<td>1.8</td>
<td>72.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Wheat, screenings</td>
<td>11.6</td>
<td>2.9</td>
<td>12.5</td>
<td>4.9</td>
<td>65.1</td>
<td>3.0</td>
</tr>
</tbody>
</table>

PHYSICAL PROPERTIES OF WHEAT GRAINS

Specific Gravity. Parmelee and Stewart found the specific gravity of American wheats to vary from 1.146 to 1.518. Lyon found kernels varying from 1.235 to 1.463 in specific gravity, the densities occurring most frequently being between 1.36 and 1.39 with an average of 1.375.

In studying the relationship between specific gravity and protein content he found that kernels having a high percentage of proteid material have a low specific gravity, weight slightly less, and occupy a smaller volume than kernels having a smaller percentage of proteids.

The grams of proteid nitrogen in the kernels on the spikes and in the average kernels was found to increase with the specific gravity.

No constant relation was found between the specific gravity and the number of kernels on the spike, an increase in weight of kernels on the spike and with some exceptions an increase in the weight of the average kernel was accompanied by an increase in the specific gravity.

The Kansas Station found¹ that in general there was a tendency for the larger kernels to have the higher specific gravity. In some groups, when they placed all grains above the average in size in one class and those below the average in another class, they found that the smaller average grains had a larger specific gravity than the larger grains. In one class such grouping of the grains showed no difference in specific gravity. In view of the great irregularity among individual wheats there did not seem to be any definite correlation between the size of kernel and the specific gravity so far as Kansas wheats were concerned.

The following table shows the specific gravity of a number of wheats:²

---

1. Kansas Bul. 177, p. 71
2. Kansas Bul. 177, p 81.
<table>
<thead>
<tr>
<th>Source of Wheat</th>
<th>Year</th>
<th>No. grains per 10 grams</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kansas-McPherson</td>
<td>1906</td>
<td>335</td>
<td>1.3506</td>
</tr>
<tr>
<td>Kansas-Manhattan</td>
<td>1906</td>
<td>335</td>
<td>1.3664</td>
</tr>
<tr>
<td>Kansas</td>
<td>1907</td>
<td>375</td>
<td>1.3250</td>
</tr>
<tr>
<td>Minnesota</td>
<td>1907</td>
<td>347</td>
<td>1.3537</td>
</tr>
<tr>
<td>Tennessee</td>
<td>1907</td>
<td>333</td>
<td>1.3307</td>
</tr>
<tr>
<td>Washington</td>
<td>1907</td>
<td>236</td>
<td>1.3719</td>
</tr>
</tbody>
</table>

RELATION BETWEEN LENGTH OF GROWING SEASON, MOISTURE SUPPLY AND蛋白 CONTENT

Work done on this problem by the Minnesota Experiment Station resulted in the following conclusions:

"A comparatively long growing season results in decreased protein content."

"A relatively high rainfall, particularly between flowering and ripening, results in the plants being lower in protein and higher in starch than when the opposite is the case."

"Wheat grown on a retentive soil will contain less protein than when grown on a proue well-drained soil, the rainfall being the same in both cases."

The Kentucky Station found that early maturing varieties of wheat contain more protein than do late varieties; furthermore, flinty kernels were found to retain

1. Minn. Bul. 151, p. 11
more moisture when stored in a dry place than did the starchy ones and the starchy wheat was found to absorb moisture more rapidly in moist air than flinty wheat.

The Washington Experiment Station reports that a long, slow ripening period increases the percentage of starch and decreases that of protein.¹

Thatcher says² that from the figures which he presents it is apparent that under conditions of uniform soil, growing season, distribution of annual rainfall, elevation, etc., with the total rainfall the only variable, the average protein content of wheat varies inversely with the total rainfall received. When the whole United States was considered, however, this conclusion did not hold true since the Pacific coast wheats which were the softest were grown under much less rainfall than some of the harder wheats of central United States. Thatcher says the unusual softness of Pacific Coast wheats is due, undoubtedly, to the cool harvest weather, inducing slow ripening in spite of the low moisture supply.

He further states that "There is ample evidence, -- to support the view that the relative protein content of the grain is determined chiefly, if not wholly, by the rapidity of ripening of the kernel after it is formed."²

The Utah Station found⁴ that when a variety of wheat which has been grown under irrigation is taken to

¹ Washington Bul. 100, p. 23.
² American Society of Agronomy, Vol. 3, p 44.
³ " " Vol. 3, p 45.
⁴ Utah Bul. 103, p. 256.
arid land its protein content increases.

The Kentucky Station found that when seed wheat is brought from other parts of the country and grown in Kentucky, the grain produced contains a larger proportion of mealy looking or starchy kernels than the original seed. That is the wheats get softer by being grown in the Kentucky climate. This change has been found to go on from year to year, although it has not been found to be complete in any of the varieties.

3. SWEATING OF WHEAT

Little seems to be known as to what the process commonly referred to as "sweat of wheat" consists of. Doudlinger states that English writers have nothing to say concerning the process, and very little has been written in this country.

Wheat is usually considered fit to thresh after currying in the shock for about ten days. The length of time required will vary with the degree of ripeness of the grain when cut and the climatic conditions, which vary greatly in different sections of the country. In the Club wheat sections of the Pacific coast, the wheat matures completely before being cut, and what sweating occurs takes place in the bin or sacks. In the semi-arid southwest where humidity is lower, less time is needed after harvest for preparing wheat for threshing. When wheat is stacked in about it begins to sweat three days and continues for

1. Kentucky Bul. 115, p 3
2. The Book of Wheat, Doudlinger, p. 97
about 3 or 4 weeks. Millers invariably hold that sweating in the stack improves wheat for milling, especially weathered grain, and is very desirable. The claim has been made that sweating is beneficial in that the wheat feeds from the straw resulting in plumper, heavier grains possessing a better color.

Wheat growers of northwestern U. S. have maintained that sweating would occur in the bin if it did not take place in the stack. This claim seems to have some foundation. It is likely that bin sweating will be reduced or perhaps entirely obliterated by proper handling of the grain before threshing.

Fitz has the following to say as a possible explanation of the process:

"It is known that even after wheat is cut the straw contains sufficient plant food to keep the kernels in a growing condition for some time, and a chemical or enzyme action within the plant by means of which this is transferred to the grain and stored as starch may continue for a considerable period. Then when wheat has been threshed before going through the sweat, it is probable that a rearrangement of the chemical constituents of the kernel takes place, and this will account for the sweating of shock-threshed grain in the bin."

It is suggested that this chemical action may account for the heat usually generated during the sweating process. This amount of heat generated appears to be influenced by

the percentage of moisture present. Very dry, fully ripened grain has been found to give little indication by change in temperature that it is going through the sweat- ing process. However, wheat out in the hard dough stage, or containing considerable moisture, goes into the sweat much more quickly when stacked; the straw becomes very tough and much heat is evolved. Wheat of this character should not be stacked before it is allowed to cure in the shock for a few days, otherwise sufficient heat may be evolved to injure the grain in which case "stack burnt" wheat will result.

Cutting the grain seems to act as a check upon this biological action, and it appears to remain in a dormant state until the assembling of the grain in large bulks brings on a condition favorable to activity.

The straw of stacked grain permits to a limited extent the circulation of air through the stack, which affords a means of conducting away considerable of the heat generated.

When wheat with high moisture content is placed before sweating in large bulk in the bin, there being little chance for air circulation, the heat generated by biological action is retained in the grain until finally the temperature becomes so high as to cause other chemical changes within the kernels resulting in the common grain trade phrase of heat damaged or "bin-burnt" grain.

This injury may extend simply into branzy coats and produce slightly "bin-burnt" wheat or may extend throughout
endosperm and produce badly "bin-burnt" wheat. Wheat badly "bin-burnt" is practically unfit for flour making purposes. There is little evidence as to whether changes of sweat in bin is identical with what takes place in the stack. Some farmers follow the practice of sinking an iron rod in the bin of newly threshed grain, removing it each day to determine its temperature which would be the same as the grain. If the grain becomes very hot, it is shovelled over to prevent bin-burning.

Sweating in the bin appears to have the same effect on milling and baking qualities as sweating in the stack, provided wheat is not allowed to heat enough to become injured by "bin-burning."

Investigations point to the conclusion that stacking wheat improves its milling quality. Ageing of flour improves its quality but ageing of wheat before grinding seems to be more favorable than ageing the flour.

Shock threshed wheat did not equal the lot from stack-threshing. Shock threshed wheat improved considerably as it "aged," the absorption and loaf volume both improving. Freshly milled flour from shock-threshed wheat which had aged two months was better than two months' old flour from same wheat.

Wheat seems to improve with age more than does flour during the same time.

None of three samples milled from shock-threshing were as good as stack-threshed wheat. The average loaf
volume from shock-threshing was 2610 cc.; from stack-
threshing 2700 cc. The former samples gave a slight
advantage in bread color but the latter had somewhat
higher water absorption.

**Affect of Stack-sweating on Appearance and Test
Weight.** A load of bundles exposed to two rains was
threshed and stored in a small elevator. The balance of
the field was stacked and threshed after six weeks. Fifty
bushels were placed in another small bin in the same ele-
vator. The shock-threshed wheat had 14.6% moisture and
weighed 55.5# per bushel. The grain felt damp and tough
and would scarcely have been considered in-safe condition
for shipment to market. When the shock threshed Wheat
was received at the mill the other wheat had decreased to
13.9% moisture. Both lots were graded at this time by
the Minnesota State Grains Ins. Dept. and the shock-
threshed graded #2 Northern spring wheat and the other
wheat #1 Northern spring wheat. This experiment indicates
that when wheat goes through sweat properly in stack, the
color and test weight per bushel may be improved enough
to raise it one grade.

**MILLING VALUE OF WHEAT GOVERNMENT MEALS**

Olson gives the following conclusions based on the
work done on this problem by the Washington Experiment
Station:

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"Wheat which has been allowed to sprout loses in weight as length of time for germination advances.

Milling value of germinated wheat decreases as the length of the epicotyl (stem) increases.

Length of time required for conversion of starch decreases as the length of the epicotyl (stem) increases to at least twice the length of kernel.

The amount of gluten which can be recovered in flour from germinated wheat is less than that from ungerminated wheat. Yield of gluten decreases rapidly as length of epicotyl increases.

Expressed in per cent total N, the alcohol soluble N has not been affected by germination of wheat. Most marked changes were observed in the glutenin and amide nitrogen. In former there was a sudden decrease in amount from period where the epicotyl was equal to length of kernel to that where epicotyl was twice the length of kernel. The amide N. increased rapidly from time when the epicotyl was equal to length of kernel.

Using germinated wheat flour only the quality of the bread was impaired, being particularly noticeable in flours made from germinated wheat where the epicotyl was equal to and twice length of kernel. The volume of loaf increased, being of exceptionally large capacity in the bread made from partially germinated wheat flour.

Using small quantities of germinated wheat flour with other flour, it was found that the volume of the loaf could be increased without impairing loaf texture.
Each particular flour requires a different amount of germinated flour in order to produce best results. Too large an amount of diastatic flour is less beneficial than none.

A water soaked wheat is not necessarily spoiled and can be used for milling purposes, providing it has been thoroughly cleaned and dried."

Bailey says 1 that—"Damp or tough wheat is more difficult to mill since the endosperm is soft and fails to granulate properly, resulting in a loss of flour in the feeds. In milling damp wheats the percentage of invisible loss through evaporation of moisture is greater than when normal wheats containing 11-11.5% moisture are used, the difference sometimes amounting to from 2-3%."

MILLING OF WHEAT

Our present day milling methods are the result of a long evolution which probably had its beginning in the mortar and pestle with which the work was done by grinding and rubbing. The next step consisted of "some form of machine having two roughened surfaces between which the grain was crushed or cut through the motion of one, and sometimes of both of the surfaces." 2 The highest type of milling, the roller system which is in common use today, involves "a gradual reduction or granulation process in which the grain of wheat is separated into particles and

1. Minn. bul. 131, p 18.
reduced to successive degrees of subdivision by being passed between rolls, first corrugated and then smooth, each successive series of which has an increased approximation of surfaces." There are likely many variations from each of these types of milling.

**Source of Wheat and Flour through the Mill.** The wheat passes through three general processes in milling, (1) cleaning, (2) tempering (3) grinding or milling proper.

**Cleaning.** This step involves three different objects:

1. The removal of foreign seeds and other large foreign matter.
2. The removal of dust, apex hairs and other adherent foreign matter.
3. The removal of small particles of bran which would drop off afterwards and get into the flour.

For each of these processes special machines have been designed. There are two general methods of removing the attached foreign matter.

1. Dry cleaning in which the wheat is passed through scourers where it comes in contact with brushes which remove the dirt.
2. Wet cleaning in which the wheat is washed then

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dried. Each method has its advantages for different conditions of grain, although in some mills only one of the methods is used for all wheat.

Tempering. This process consists in putting the cleaned grain in the best condition for milling. The bran layer must be so tough that it will separate in one large piece in the grinding, and the endosperm must be in such condition that it will give the largest yield of flour. Tempering varies according to the final result desired and the condition and nature of the grain. It consists mainly in heating the grain to a certain temperature and in one or more applications of moisture, in the form of water or steam or both. When wheat is wet cleaned it is completely dried and then the proper amount of moisture is added in the tempering.

Milling proper. After tempering wheat passes on to the corrugated steel rolls, each set of which is known as a break. On the first break the grain is partially flattened and slightly crushed and a small amount of flour, known as break flour, is separated by means of sieves, while the main portion is conveyed through elevators to the second break, where the kernels are more completely flattened and the granular flour particles are partially separated from the bran.

The interior of the berry which has been separated from the branny portion is known as "middlings." This term has been incorrectly applied to the by-product oth-
wise known as shorts, consisting of fine bran particles and coarser flour particles which are not separable into bran and lower grades of flour.

The middlings are passed through the middlings purifier which removes by means of sieves, aspirators and other devices, particles of bran, the internal cellular structure and the germ of the grain. The latter would give the flour a yellow appearance and impair its keeping qualities due principally to the higher percentage of oil which becomes rancid with age.

After purifying the middlings are passed on to smooth rolls known as reduction rolls where their reduction is completed and they are again purified. The flour finally passes through the silk bolting cloth containing upwards of 12,000 meshes per square inch.

The branney residue from the first break is passed over the second and additional breaks each succeeding pair of rolls being set a little nearer together. This process is known as the gradual reduction process. After each break separations are made into bran and other impurities and middlings, the latter being purified in each case.

The chief object is to separate as much as possible of the grain endosperm from the bran part with as little impurities as possible in the finished flour. The term closeness of milling indicates the degree to which this separation has been reached.

According to the number of reductions which the middlings and stock undergo, the milling is designed as a
long or short reduction system, the term 4, 6, 8, or 10 break process indicating that the stock has been subjected to that number of reductions.

With an eight-break system the process is more gradual than with a four-break and greater opportunity is afforded for completely removing the bran. An expert miller can determine the quality of flour largely by feel and color. In some large mills, the wheat is separated into forty or more different products, or streams, as they are called, so as to secure a better granulation, and more complete removal of the offals after which many of these streams are brought together to form the finished flour. That is known as patent flour is derived from the reduction of the middlings, while the break flours are recovered before the offals are completely removed, and consequently are not of so high a grade.

No absolute definition can be given, however, of the term "patent flour", as usage varies the meaning in different parts of the country.

The Dust Collector. The ignition of flour dust suspended in the air caused disastrous explosions in Minneapolis Mills during 1877-78, killing a number of people and wrecking mills. This led to the development of the dust collector the essential principle of which is the vertical or rotary air current which masses and precipitates the smallest dust particles.
TYPES AND GRADES OF FLOUR

Definition:--Flour has been defined as "The purified, refined and bolted product obtained by reduction and granulation of wheat during and after the removal of the branry portion of the wheat kernel."

The Secretary of Agriculture has defined flour as follows: "Flour is the fine, sound product made by bolting wheat meal and contains not more than 13½% moisture, not less than 1.25% nitrogen, not more than 1.0 ash, and not more than .5% of fiber."

Generally speaking, flour is divided into high and low grade. However, the following four main grades are commonly recognized by millers and dealers: Patent, straight, clear, low grade or "red dog."

In the high grade have been included as a rule the first and second patents and according to some a portion of the straight grade or standard patent flour and the first clear, and to the low grade belong the second clear and the "red dog."

There is little uniformity among the different grades of flour bearing the same name. Some attempt has been made to standardize the grades but little has been accomplished. Some mills have ceased to recognize the common grade names in making their flours.

The grades of flour are in general as follows:

Patent. Made from the part of the grain containing the higher percent of starch and which is farthest re-
moved from the bran layer and the germ. It is whiter in color than the other grades, contains less impurities, contains a higher quality of gluten and brings the highest price. Patents are sometimes divided into firsts and seconds.

Clear. Made from the part of the kernel left after the patents and the lowest grades of flour or red dog have been removed. Clears are darker in color than the patents and are not as good for making the highest quality of bread. They contain more impurities or debris than the patents. They are usually divided into first and second clears.

Straight or Straight Patent. Usually includes the two patents and the first clear grades. However, in some mills the term straight is applied to a clear grade containing no mixture of patent flour. Whenever only a straight or straight patent flour is made by a mill it includes what would otherwise be the first and second patents and first clear.

Red Dog. Is the lowest grade of flour. It is very dark in color, contains large amounts of debris particles and is used largely for stock food.

The large mills of Minneapolis as a rule recognize and make four grades of flour: Patent, first clear, second clear and red dog. Different markets recognize different grades and have different trade names. In St. Louis, for example, the grades are given in descending order of qua-
lity and whiteness as patent, extra fancy, fancy, choice and red dog white. In New York we find the following grades quoted: spring, patents, winter straights, winter patents, spring clears, extra No. 1 winter, extra No. 2 winter and Kansas straights.

There is so much difference between the grades put out by different mills that the straight or second patent of one mill may be better than the first patent of another mill. The milling equipment, process and ability of the miller determine largely the flour grades.

The requirements of some buyers are for a flour that is sharper and more granular, while those of other buyers are for a flour with fine, soft granulations and very white color. As a rule, the wholesale baking trade generally demands a sharp, granular flour with a great capacity for absorbing water, whereas the household trade requires a finer granulation and a whiter color. Foreign trade prefers a strong granular flour with little regard to color since it bleaches during the time consumed in transportation.

A 95½ patent means that 95½ of the total flour made from the wheat is included in the patent. An 85½ patent means that 85½ of the total flour made is included in that particular patent. If all the flour was purified and blended into a single patent grade, it would be a 100½ patent. The lower the patent percent the higher the quality because a smaller amount of the choicest part of
the grain has gone into the flour. About 72½ of the cleaned wheat as milled is recovered in the higher grades of flour and about 2–3½ as low grade,¹ the larger proportion of which is used for animal food.

The higher grades of flour are lighter in color, have a more elastic gluten, a finer and more uniform granulation, are lower in ash and contain a smaller amount of impurities. Lower grades of flour contain more protein but are not as valuable for bread making because the gluten is not as elastic and of as high as quality.

The principal differences between high and low grade flours seems to be in the amount of impurities in the latter. Flours decrease in ash content as the grades get higher, the decrease being practically proportional to the grade. This is due to the fact that the debris found in low grade flours consists largely of fine bran particles which are high in ash. The more completely the bran and other impurities are removed the lower the ash content.

Snyder says that the grade of flour can be determined more accurately from the ash content than from any other constituent, although he says it is not an exact grade determiner on account of the varying amounts of ash found in different wheats. Some starchy wheats are often found to be lower in ash than the hard wheats grown on rich soil in a short season, and a straight flour made from the soft wheat may contain as little ash as a first patent flour made from the hard wheats. Patent flours rarely contain more than .55½ ash and the better grades usually less than .5½.

¹ Office of Experiment Stations Bul. 101, p 9.
<table>
<thead>
<tr>
<th>Milling Product</th>
<th>Water %</th>
<th>Protein (N x 5.7) %</th>
<th>Fat %</th>
<th>Carbohydrates %</th>
<th>Ash %</th>
<th>Phoric Acid %</th>
<th>Oxalic Acid %</th>
<th>Heat of Combustion Per gram %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Patent</td>
<td>10.55</td>
<td>11.08</td>
<td>1.15</td>
<td>76.85</td>
<td>0.37</td>
<td>0.15</td>
<td>0.08</td>
<td>4.03</td>
</tr>
<tr>
<td>Second Patent</td>
<td>10.49</td>
<td>11.14</td>
<td>1.20</td>
<td>76.75</td>
<td>0.42</td>
<td>0.17</td>
<td>0.08</td>
<td>4.01</td>
</tr>
<tr>
<td>Straight or standard patent</td>
<td>10.54</td>
<td>11.99</td>
<td>1.61</td>
<td>75.36</td>
<td>0.50</td>
<td>0.20</td>
<td>0.09</td>
<td>4.05</td>
</tr>
<tr>
<td>First clear</td>
<td>10.13</td>
<td>13.74</td>
<td>2.20</td>
<td>73.13</td>
<td>0.80</td>
<td>0.34</td>
<td>0.12</td>
<td>4.10</td>
</tr>
<tr>
<td>Second clear</td>
<td>10.08</td>
<td>15.03</td>
<td>3.77</td>
<td>69.37</td>
<td>1.75</td>
<td>0.56</td>
<td>0.27</td>
<td>4.27</td>
</tr>
<tr>
<td>&quot;Red Dog&quot;</td>
<td>9.17</td>
<td>18.98</td>
<td>7.00</td>
<td>61.37</td>
<td>3.48</td>
<td>0.59</td>
<td>4.49</td>
<td></td>
</tr>
<tr>
<td>Shorts</td>
<td>8.73</td>
<td>14.87</td>
<td>6.37</td>
<td>65.47</td>
<td>4.56</td>
<td>0.14</td>
<td>4.41</td>
<td></td>
</tr>
<tr>
<td>Bran</td>
<td>9.99</td>
<td>14.02</td>
<td>4.39</td>
<td>65.54</td>
<td>6.06</td>
<td>2.20</td>
<td>0.23</td>
<td>4.20</td>
</tr>
<tr>
<td>Entire-wheat</td>
<td>10.81</td>
<td>12.26</td>
<td>2.24</td>
<td>73.67</td>
<td>1.02</td>
<td>0.54</td>
<td>0.32</td>
<td>4.03</td>
</tr>
<tr>
<td>Graham</td>
<td>8.61</td>
<td>12.65</td>
<td>2.44</td>
<td>74.58</td>
<td>1.72</td>
<td>0.71</td>
<td>0.18</td>
<td>4.15</td>
</tr>
<tr>
<td>Wheat Ground in laboratory</td>
<td>8.50</td>
<td>12.65</td>
<td>2.36</td>
<td>74.69</td>
<td>1.80</td>
<td>0.75</td>
<td>0.18</td>
<td>4.14</td>
</tr>
<tr>
<td>Gluten flour</td>
<td>8.57</td>
<td>16.36</td>
<td>3.15</td>
<td>70.63</td>
<td>1.29</td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The above table gives the composition, acidity, and heats of combustion of flours and other milling products of wheat.

1. Office of Experiment Stations Bul. 101, p. 9
FLOUR YIELD OF WHEAT

The amount of flour obtained from wheat has been found to depend largely upon the plumpness and texture of the kernels and the percentage of moisture which they contain. The closeness of milling is an important factor also and one which is largely in the miller's hands.

Plump kernels have a large proportion of endosperm from which the flour is obtained, in proportion to their total weight, and other things being equal, will yield more flour.

The soft or "yellow berry" kernels yield less flour largely because it has been found to be mechanically impossible to mill them as closely as the harder kernels. That is, it is impossible to free the bran from the floury portion so completely as when the endosperm is hard and vitreous.

A miller in Kent, England, is authority for the statement that a barrel of flour required 4.2 bushels of wheat in 1876. Two centuries ago in New England it required 6 to 7 bushels of wheat to make a barrel of flour.

In 1905, 4-5/6 bushels of wheat made a barrel of flour (196# net) in Minneapolis, while in previous years it required only 4/1/3 bushels.

There has been a continual increase in the amount of high grade flour obtained from a bushel of wheat due to improved machinery and improved methods of milling.

---

1. The Book of Wheat, Dondlinger.
Fitz says\(^1\) that many mills in Kansas make a barrel of flour from 4 bushels and 27 pounds of wheat and sometimes with even less of Turkey Red wheat.

The Minnesota Station found variations of 60.4-76.1%\(^2\) total flour with a considerable number of samples. Flour at $5.25 per barrel, mixed feed at $25.00 per ton and 2% milling loss gives the following value of milled products as obtained for different wheats:

<table>
<thead>
<tr>
<th>Flour Percent</th>
<th>Feed Percent</th>
<th>Total Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>38</td>
<td>$1,252</td>
</tr>
<tr>
<td>65</td>
<td>33</td>
<td>1.295</td>
</tr>
<tr>
<td>70</td>
<td>28</td>
<td>1.338</td>
</tr>
<tr>
<td>75</td>
<td>23</td>
<td>1.381</td>
</tr>
</tbody>
</table>

According to these figures, wheat which yielded 76.1% total flour was worth 13 cents per bushel more to the miller than that which gave 60.4%, assuming the flour to be of equal value in both cases.

It is estimated by Snyder that about 72% of the cleaned wheat as milled is recovered in the high grades of flour and about 2 or 3% as low grade, the large proportion of which is sold as animal food.

---

1. American Miller, V. 39, p. 750  
3. Human Foods, Snyder, p 142.
Dondlinger gives the following flour yields of 1 wheat:

<table>
<thead>
<tr>
<th>Kind of wheat</th>
<th>Weight per bushel</th>
<th>Percent Flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft</td>
<td>64 lbs.</td>
<td>80</td>
</tr>
<tr>
<td>Soft</td>
<td>54 lbs.</td>
<td>65</td>
</tr>
<tr>
<td>Heaviest wheat</td>
<td></td>
<td>74</td>
</tr>
<tr>
<td>lightest wheat</td>
<td></td>
<td>67</td>
</tr>
<tr>
<td>India</td>
<td></td>
<td>77-31</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td>67</td>
</tr>
<tr>
<td>American</td>
<td></td>
<td>72</td>
</tr>
</tbody>
</table>

Ladd obtained the following results with the 1907 2 crops:

<table>
<thead>
<tr>
<th></th>
<th>Weight per bu.</th>
<th>Patent 1st clear</th>
<th>2nd clear</th>
<th>Total flour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Fife and Bluestem</td>
<td>59.28</td>
<td>47.47</td>
<td>16.92</td>
<td>5.66</td>
</tr>
<tr>
<td>Durum</td>
<td>61.85</td>
<td>41.51</td>
<td>19.01</td>
<td>10.16</td>
</tr>
</tbody>
</table>

In this case the durum wheat gave a rather larger percent of flour than did the Fife and Bluestem and had a higher weight per bushel of clean wheat, yet the amount of high grade flours were in favor of the other wheats.

The exact flour, bran and shorts yield of the wheat was as follows:

1. The Book of Wheat, Dondlinger, p. 277
<table>
<thead>
<tr>
<th>Kind of Wheat</th>
<th>Percent of Flour</th>
<th>Percent of Bran</th>
<th>Percent of Shorts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Bread Varieties</td>
<td>53.21</td>
<td>35.11</td>
<td>10.95</td>
</tr>
<tr>
<td>Durum</td>
<td>50.23</td>
<td>31.97</td>
<td>17.27</td>
</tr>
</tbody>
</table>

These results show that it took slightly less durum wheat to produce a barrel of flour than for the fife and bluestem varieties. Less bran was produced from the durum than from the other wheats but the proportion of shorts is higher. The durum kernels are somewhat larger than the others.

The Utah Station obtained quite different results as shown by the following table:

1. Utah Bul. 103, p. 253
Kansas found\(^1\) that soft wheats averaged lower in flour yield than the hard wheats. A number of reasons are given for this. Soft wheat flour is found to be more impalpable and to posses a peculiar adhesive property absent in hard wheat flour. In good milling, hard wheat bran is of a very clear, amber color, while soft wheat bran is covered with a fine flour dust. The endosperm clings harder in the bran in soft wheat, consequently it is possible to mill hard wheats closer and more of the endosperm is recovered in the flour. Hard wheat bran coats have a springy stiffness which enables the rolls to shave off the endosperm quite close to the bran coat.

---

1. Kansas Bul. 177, p 74.
Thatcher gives the following results from five years' (1905-09) work with Washington wheats:

<table>
<thead>
<tr>
<th></th>
<th>No. of Samples</th>
<th>Yield of Flour</th>
<th>Milled Products</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluestem</td>
<td>126</td>
<td>71.31</td>
<td>16.01</td>
<td>12.68</td>
</tr>
<tr>
<td>Little Club</td>
<td>65</td>
<td>71.95</td>
<td>15.64</td>
<td>12.41</td>
</tr>
<tr>
<td>Turkey Red</td>
<td>55</td>
<td>70.48</td>
<td>16.04</td>
<td>13.48</td>
</tr>
<tr>
<td>Jones Fife</td>
<td>43</td>
<td>71.31</td>
<td>15.79</td>
<td>12.90</td>
</tr>
<tr>
<td>Forty fold</td>
<td>27</td>
<td>73.26</td>
<td>14.91</td>
<td>11.83</td>
</tr>
<tr>
<td>Red Allen</td>
<td>17</td>
<td>73.26</td>
<td>15.02</td>
<td>11.70</td>
</tr>
<tr>
<td>Red Russian</td>
<td>16</td>
<td>71.35</td>
<td>16.38</td>
<td>12.27</td>
</tr>
<tr>
<td>Macaroni</td>
<td>13</td>
<td>71.70</td>
<td>15.25</td>
<td>13.05</td>
</tr>
<tr>
<td>White Amber</td>
<td>8</td>
<td>71.09</td>
<td>16.06</td>
<td>12.35</td>
</tr>
<tr>
<td>Sonora</td>
<td>8</td>
<td>72.01</td>
<td>15.14</td>
<td>12.35</td>
</tr>
</tbody>
</table>

Considerable variation was found between the different samples of the same variety grown in different sections during the same season, or in different seasons in the same locality. Consequently the averages shown here cannot be applied too closely in judging individual lots of grain.

Thatcher obtained the following results with his 1905 crop:

---

<table>
<thead>
<tr>
<th>Variety</th>
<th>Percent yield of</th>
<th>Wheat required for bbl flour (200# of straight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bran</td>
<td>Shorts</td>
</tr>
<tr>
<td>Bluestem</td>
<td>15.49</td>
<td>12.46</td>
</tr>
<tr>
<td>Little Club</td>
<td>15.29</td>
<td>11.91</td>
</tr>
<tr>
<td>Fife</td>
<td>15.53</td>
<td>12.69</td>
</tr>
<tr>
<td>Red Chaff</td>
<td>15.10</td>
<td>11.57</td>
</tr>
<tr>
<td>Red Russian</td>
<td>16.27</td>
<td>12.03</td>
</tr>
<tr>
<td>Turkey Red</td>
<td>15.35</td>
<td>12.76</td>
</tr>
<tr>
<td>Macaroni</td>
<td>15.10</td>
<td>12.73</td>
</tr>
</tbody>
</table>

RELATION BETWEEN THE OFFICIAL STATE GRADE OF WHEAT AND THE FLOUR YIELD AND OTHER QUALITIES

The Minnesota Experiment Station did some work on this problem, with 1911 samples of wheat. The following table shows the results which they obtained:

<table>
<thead>
<tr>
<th>Grade of wheat</th>
<th>Total flour %</th>
<th>Test on Middlings flour</th>
<th>Crude Protein in Wheat %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C.C.</td>
<td>Vol. used</td>
<td>Color score</td>
</tr>
<tr>
<td>No. 1 Northern</td>
<td>72.9</td>
<td>2545</td>
<td>55.6</td>
</tr>
<tr>
<td>No. 2 Northern</td>
<td>71.2</td>
<td>2590</td>
<td>53.0</td>
</tr>
<tr>
<td>No. 3 Northern</td>
<td>67.6</td>
<td>2625</td>
<td>55.2</td>
</tr>
<tr>
<td>No. 4 Northern</td>
<td>66.9</td>
<td>2600</td>
<td>55.3</td>
</tr>
<tr>
<td>Rejected</td>
<td>67.4</td>
<td>2540</td>
<td>60.6</td>
</tr>
</tbody>
</table>

1. Minnesota Bul. 131, p. 35
This table shows that the percent of flour decreased as the grade became lower except in the cases of the Rejected northern which gave a higher yield than the No. 4 Northern. Since a large proportion of the Rejected Northern was so graded because of the damp or tought condition of the grain, its high flour yield is easy to explain. This condition did not reduce the flour percent as though the kernels had been shrivelled as in the case of the No. 4 Northern. The one lot of wheat was rejected because it would not be likely to keep in storage and not because it lacked milling quality.

This experiment indicates that the Minnesota grain grading department is grading wheat in such a manner that the grade indicates the flour yield which might be expected.

**SPRING VS. WINTER WHEAT**

Work was also done in Minnesota comparing one winter and two spring wheats of the crop of 1911 with the following results:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Total flour</th>
<th>Loaf Vol.</th>
<th>Water used</th>
<th>Color score</th>
<th>Acid-</th>
<th>Crude Protein</th>
<th>Crude Protein in wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>c.c.</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>T.R. Winter</td>
<td>63.7</td>
<td>1935</td>
<td>56.8</td>
<td>100</td>
<td>.080</td>
<td>8.87</td>
<td>10.21</td>
</tr>
<tr>
<td>#163 Fife</td>
<td>69.5</td>
<td>2490</td>
<td>53.2</td>
<td>98</td>
<td>.130</td>
<td>13.00</td>
<td>14.28</td>
</tr>
<tr>
<td>Spring</td>
<td>71.3</td>
<td>2520</td>
<td>57.0</td>
<td>99</td>
<td>.145</td>
<td>12.03</td>
<td>13.08</td>
</tr>
</tbody>
</table>

1. Minnesota Bul. 131, p 38
This experiment shows the Turkey Red Winter Wheat to be decidedly inferior to the hard spring wheats of Minnesota in flour yield and baking quality.

Average results of Montana Wheat Samples, Crop 1911:

<table>
<thead>
<tr>
<th>Class of wheat</th>
<th>Total flour %</th>
<th>Loaf Vol. c.c.</th>
<th>Water %</th>
<th>Color score</th>
<th>Acid-ity %</th>
<th>Crude Crude Protein %</th>
<th>Protein % in wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Spring</td>
<td>72.8</td>
<td>2516</td>
<td>56.3</td>
<td>98.9</td>
<td>.101</td>
<td>11.36</td>
<td>12.38</td>
</tr>
<tr>
<td>Hard winter</td>
<td>73.8</td>
<td>2348</td>
<td>56.8</td>
<td>98.0</td>
<td>.094</td>
<td>10.12</td>
<td>11.12</td>
</tr>
<tr>
<td>Soft winter</td>
<td>73.5</td>
<td>1797</td>
<td>51.7</td>
<td>100.0</td>
<td>.078</td>
<td>9.16</td>
<td>10.47</td>
</tr>
</tbody>
</table>

Soft wheat samples were quite uniformly low in protein (gluten), and correspondingly low in baking strength as evidenced by small loaf volumes. In fact, these soft wheats are hardly considered as suitable for bread making and the comparatively small quantity which is produced is used to a considerable extent for special purposes, as in the manufacture of breakfast foods and pastry flour and for stock feeding.

COMPOSITION AND FOOD VALUE OF FLOURS

Snyder gives the analysis of wheat flour as follows:

\[
\begin{align*}
\text{Water} & : & 12.00 \\
\text{(Potash} & & ) \\
\text{(Soda} & & ) \\
\text{(Lime} & & ) \\
\text{(Magnesia} & & 2.25 \\
\text{(Phosphoric anhydrid} & & ) \\
\text{(Sulphuric} & & ) \\
\text{(Other substances} & & )
\end{align*}
\]

1. Minnesota Bul. 131, p. 42
Percent

<table>
<thead>
<tr>
<th>Protein</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Albumin</td>
<td>0.4</td>
</tr>
<tr>
<td>Globulin</td>
<td>0.9</td>
</tr>
<tr>
<td>Gliadin</td>
<td>6.0</td>
</tr>
<tr>
<td>Glutenin</td>
<td>5.3</td>
</tr>
<tr>
<td>Other proteins</td>
<td></td>
</tr>
</tbody>
</table>

Other nitrogenous bodies, as amids, lecithin... 0.25
Crude fat, ether extract... 2.25
Cellulose... 2.25
Sucrose, dextrose, soluble carbohydrates, etc... 2.00

He gives the composition of a number of flours and breads in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Pro.</th>
<th>Fat</th>
<th>C-H</th>
<th>Fuel value per lb.</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roller process flour</td>
<td>11.9</td>
<td>12.6</td>
<td>0.8</td>
<td>74.3</td>
<td>1650</td>
<td>0.4</td>
</tr>
<tr>
<td>Spring wheat flour</td>
<td>11.6</td>
<td>11.8</td>
<td>1.1</td>
<td>75.0</td>
<td>1660</td>
<td>0.5</td>
</tr>
<tr>
<td>Winter wheat flour</td>
<td>12.5</td>
<td>10.4</td>
<td>1.0</td>
<td>75.6</td>
<td>1640</td>
<td>0.5</td>
</tr>
<tr>
<td>White Bread</td>
<td>31.0</td>
<td>9.9</td>
<td>1.4</td>
<td>57.1</td>
<td>1306</td>
<td>0.6</td>
</tr>
<tr>
<td>Graham</td>
<td>32.2</td>
<td>9.5</td>
<td>2.5</td>
<td>54.7</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Crackers</td>
<td>8.2</td>
<td>10.7</td>
<td>9.9</td>
<td>68.8</td>
<td>1895</td>
<td>2.4</td>
</tr>
</tbody>
</table>

1. Chemistry of Plant and Animal Life, Snyder, p. 397
Ladd gives the following average composition of the different grades of flour milled in the College Experimental Mill: (Crop of 1907)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Grade of flour</th>
<th>Moisture</th>
<th>Ash</th>
<th>Fat</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>N.x6.25 Gliadin</th>
<th>Percent of Pro. in Gliadin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fife</td>
<td>Patent</td>
<td>7.188</td>
<td>.519</td>
<td>1.11</td>
<td>13.16</td>
<td>78.04</td>
<td>7.35</td>
<td>56.06</td>
</tr>
<tr>
<td>Durum</td>
<td>&quot;</td>
<td>7.680</td>
<td>.630</td>
<td>1.16</td>
<td>12.42</td>
<td>78.08</td>
<td>7.21</td>
<td>58.35</td>
</tr>
<tr>
<td>Velvet Chaff</td>
<td>&quot;</td>
<td>7.740</td>
<td>.450</td>
<td>.98</td>
<td>10.53</td>
<td>80.30</td>
<td>6.09</td>
<td>58.80</td>
</tr>
<tr>
<td>Fife</td>
<td>1st clear</td>
<td>7.040</td>
<td>.770</td>
<td>1.53</td>
<td>14.17</td>
<td>76.47</td>
<td>7.63</td>
<td>53.86</td>
</tr>
<tr>
<td>Durum</td>
<td>&quot;</td>
<td>7.430</td>
<td>.990</td>
<td>1.86</td>
<td>13.83</td>
<td>75.88</td>
<td>7.43</td>
<td>53.98</td>
</tr>
<tr>
<td>Velvet Chaff</td>
<td>&quot;</td>
<td>7.590</td>
<td>.650</td>
<td>1.39</td>
<td>12.09</td>
<td>78.27</td>
<td>6.40</td>
<td>53.10</td>
</tr>
<tr>
<td>Fife</td>
<td>2nd</td>
<td>7.050</td>
<td>.930</td>
<td>1.87</td>
<td>15.03</td>
<td>75.00</td>
<td>7.79</td>
<td>51.17</td>
</tr>
<tr>
<td>Durum</td>
<td>&quot;</td>
<td>7.350</td>
<td>1.050</td>
<td>2.13</td>
<td>14.51</td>
<td>74.95</td>
<td>7.64</td>
<td>52.91</td>
</tr>
<tr>
<td>Velvet Chaff</td>
<td>&quot;</td>
<td>7.350</td>
<td>.650</td>
<td>1.46</td>
<td>12.24</td>
<td>78.28</td>
<td>6.46</td>
<td>53.19</td>
</tr>
</tbody>
</table>

1. N. D. Bul. 82, p. 768.
Ladd gives the following composition of a number of additional kinds of flour:¹ (Crop 1907)

<table>
<thead>
<tr>
<th>Kind of flour</th>
<th>Moisture</th>
<th>Ash</th>
<th>Fat</th>
<th>Protein N x 6.25</th>
<th>C-H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial flours</td>
<td>11.08</td>
<td>.458</td>
<td>1.22</td>
<td>12.81</td>
<td>74.61</td>
</tr>
<tr>
<td>Fife and Bluestem patent (mill)</td>
<td>7.19</td>
<td>.519</td>
<td>1.11</td>
<td>13.16</td>
<td>78.03</td>
</tr>
<tr>
<td>First Clear</td>
<td>7.04</td>
<td>.770</td>
<td>1.53</td>
<td>14.17</td>
<td>76.47</td>
</tr>
<tr>
<td>Durum, all kinds Patent flour (mill)</td>
<td>7.68</td>
<td>.630</td>
<td>1.16</td>
<td>12.42</td>
<td>78.08</td>
</tr>
<tr>
<td>First Clear Flour (mill)</td>
<td>7.43</td>
<td>.990</td>
<td>1.86</td>
<td>13.83</td>
<td>75.83</td>
</tr>
</tbody>
</table>

The commercial flours consist of 136 samples collected from the markets of the state. The other flours were milled in the college experimental mill.

ADULTERATION OF FLOUR

Flour is not easily adulterated. Adulterants lessen the expansive power of the flour and are easily detected.

Corn which has been used to some extent can be detected by the microscope since the grains of corn starch and wheat starch are quite different in mechanical structure.

It is said that chalk and barytes² have been used as flour adulterants to some extent but this does not seem to be at all general.

The pure food law regulates the adulteration of flours.

1. N. D. Bul. 82, p 793.
2. Native sulphate of barum, BaSO₄; a common name for the mineral barite or heavy spar.
BLEACHING OF FLOUR

Considerable difference of opinion has been expressed by writers concerning the bleaching of flour. French and English interests as well as some Americans have taken a negative position as the result of their investigations.

Ladd\(^1\) comes to the conclusion that "by bleaching, the absorptive and expansive powers of the glutens are decreased" and that a smaller loaf will result; that "the presence of nitrous acid in the flour not only gives the bread a decided odor and taste," but indicates that the amount present in the bread might prove harmful physiologically; that there would be no loss whatever in the process of baking and the amount in the bread would be equal to the original amount in the flour. His experiments indicate that nitrous acid will not form in flour from the air, although he states that there can be no doubt that unbleached flour lying along side of bleached flour or unbleached flour from a mill where bleaching is done will become contaminated.

Snyder on the other hand, says\(^2\) that "bleaching whitens and improves the color; that bleached flour differs neither in chemical composition nor in nutritive value from unbleached except that bleached flour contains a small amount (about one part in one million parts of flour) of nitrate reacting material which is removed in the process of bread making. He tells us that the amount of nitrate

---

produced in the flour during bleaching is less than is normally present in saliva or is found naturally in many vegetable foods or in smoked or cured meats or in bread made from unbleached flour and baked in a gas oven where nitrates are produced from the combustion of gases.

THE USES OF FLOURS

*Durum Wheat Flour* differs slightly from common wheat flour. It has a more decided yellow color making a bread which is usually not as white as common wheat bread. The South Dakota Station found that bread made from durum (Macaroni) wheat is somewhat darker than that made from bread wheat.\(^1\) In some cases it had somewhat the resemblance of rye bread, although some of the better varieties of durum wheat (Kubanka) made bread that was scarcely darker than bread made from the best grades of common (blue stem) wheat flour,\(^2\) and in quality can scarcely be equalled by the best common wheat breads. In fact, everyone consulted preferred the Kubanka bread to any other. The durum wheat bread was found to be very sweet and to possess a fine flavor.

The bread made from this wheat is likely to be more nutritious because the wheat contains a higher percentage of protein. Gluten tests have shown that some of the durum wheat flours have water holding power that is all that could be desired.

Experiments have shown that the yield of flour from the better varieties of durum wheat is fully equal to that

1. *S. D. Bul*. 77, p. 31
obtained in milling ordinary bread wheat\(^1\) and in many cases it exceeds that obtained from other wheats. The percentage of high grade flour is, however, less than that from the best common wheats.

It has been found that while the durum wheats contain more protein than bread wheats, the gliadin content is usually lower.\(^2\) The fact seems to be that the greater percent of gluten offsets to a certain degree the lack of gliadin when the flours are made into bread. It has been found that in baking durum flour makes a sticky dough which is harder to handle that common wheat dough.

The South Dakota Station found little difference between the milling of durum and common wheats. The principal difference was in the additional power required in reducing the durum wheats. Slight modifications might be made in bolting silks if a mill was to be modified for milling durum wheats. Aside from this slight variation, no especial difficulties were encountered in utilizing the durum wheats.

Millers have estimated that it costs 15 cents per barrel more to mill durum wheat than common hard wheats.

Entire Wheat Flour is the product resulting when the germ and a portion of the bran are retained in the flour and the particles are not completely reduced.

Graham Flour is coarsely granulated wheat meal. It contains the whole grain and is only reduced to a moderate degree of fineness. No sieves or bolting cloths are used in its manufacture and many coarse unpulverized particles

\begin{enumerate}
\item S. D. Bul. 82, p. 15
\item S. D. Bul. 99, p 113.
\end{enumerate}
are present in the products. Soft wheat is more suitable for making graham flour.

Graham flour gets its name from a temperance worker of a century ago by that name who advocated bread made from unbolted meal as an aid in curing alcoholism.

Cracker and Biscuit Flour. Extreme whiteness is not desirable in crackers because the baker wishes to put a bloom on his goods which is indicative of freshness and good flavor. This is done largely by the way the mixing and baking is done and a high grade of flour does not necessarily give the desired result.

Color is not of as much importance to the cracker baker as the bread baker. In fact extreme whiteness is not desirable, as indicated above.

Strength is not so important, either, since the ability to raise is not essential in cracker making and the water absorbing quality is not essential since in manufacturing all the water added to the flour in mixing the dough is expelled in addition to some of the original moisture contained in the flour.

Flours strong in gluten are likely to cause the crackers to twist out of shape in baking and to crack in cooling. The best cracker and biscuit flours are made from soft, white wheats which have rather a poor quality of gluten.
BREAD YIELD OF FLOUR

There is some actual loss of dry matter in bread making, due to the formation of gases which are driven off at baking time. This loss has been determined by experiment to be about 2%. These losses include not only the carbohydrates but the proteids and other compounds. Roughly speaking, one pound of bread can be made from about 3/4 of a pound of flour.

Dondlinger says a barrel of flour will make nearly 300 loaves of bread but this seems to be considerably more than is usually obtained.

Ladd obtained the following bread yield of flour:

<table>
<thead>
<tr>
<th>Kind of Flour</th>
<th>Grade of Flour</th>
<th>Flour used (Grams)</th>
<th>Loaf Weight (grams)</th>
<th>Yield from 1 bbl. (196#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fife and Blue-stem</td>
<td>Commercial</td>
<td>362.4</td>
<td>520.0</td>
<td>2372</td>
</tr>
<tr>
<td>Fife and Blue-stem</td>
<td>Patent</td>
<td>343.1</td>
<td>510.5</td>
<td>2003</td>
</tr>
<tr>
<td>Durum</td>
<td></td>
<td>350.6</td>
<td>524.8</td>
<td>2003</td>
</tr>
<tr>
<td>Fife and Blue-stem</td>
<td>1st clear</td>
<td>341.9</td>
<td>513.7</td>
<td>2044</td>
</tr>
<tr>
<td>Durum</td>
<td></td>
<td>348.3</td>
<td>523.4</td>
<td>1875</td>
</tr>
<tr>
<td>Fife and Blue-stem</td>
<td>2nd clear</td>
<td>339.6</td>
<td>510.9</td>
<td>1905</td>
</tr>
<tr>
<td>Durum</td>
<td></td>
<td>347.4</td>
<td>520.9</td>
<td>1737</td>
</tr>
<tr>
<td>Velvet chaff and winter</td>
<td>Standard patent</td>
<td>345.2</td>
<td>511.3</td>
<td>2211.5</td>
</tr>
</tbody>
</table>

1. N. D. Bul. 82, p. 781, etc.
BAKING QUALITY OF FLOUR

Experimental milling has determined that the three most important factors in baking quality of flour are: (1) "Strength or elasticity of dough, i.e. the ability to produce a loaf of good texture; (2) "Absorption" or the relative quantity of water which can be added to the flour in making the dough; (3) Color of flour and of the bread made from the flour. Bailey of Minnesota discusses these points as follows:¹

"The volume of loaves made from uniform quantities of flour and raised to the maximum before being baked may be considered as expressing the relative strength of the flours from which they were produced. While it is not desirable to raise dough to this extent in commercial or

¹ Minn. Bul. 131, p. 18.
household baking, those flours which will yield large loaves when tested will not only make bread of unusually good quality and texture when baked in the usual way but will stand rough treatment and inattention during the process of bread making as well."

"Absorption or quantity of water used in making the dough is of importance from the commercial standpoint, since, other things being equal, the more water which can be worked into a given weight of flour the more bread it will produce, is of more importance to baker than housewife, but some flours will not permit of sufficient water being worked into them to make the crumb of the resulting loaf as moist as to be desired. Rarely found in hard spring wheat, however."

Color is of importance as the housewife and the baker prefer flour for bread-making which is decidedly white in color. Bleaching was resorted to, but the use of sound grain, proper cleaning or wheat-washing machinery and the modern long-system roller milling process will enable any experienced miller to produce flour sufficiently white for the most fastidious.

Flour users can regulate bleaching by refusing to use artificially bleached flour.

Strength of flour. This quality is not due to any one constituent alone. There are several regulating factors, the principal of which seem to be:
(1) Proteins of flour, their percentage, and the proportion in which the individual proteins are present; the effect of acids, bases and salts upon their physical properties, and the effect or proteolytic enzymes upon them during fermentation.

(2) The food for the yeast cells, including the quantity and nature of sugars, soluble proteins, and salts originally present and the sugars developed by enzymatic processes during fermentation.

The percent crude protein is of considerable value in indicating relative flour strength and other things being equal, the baking strength of a sound, high-grade flour is usually high if the percent of protein (gluten) is high, and vice versa, although there are some exceptions.

Relative acidity of flour indicates its apparent soundness or freedom from fermentative changes. Sound flours are usually low in acidity, whereas flours which have been fermented or spoiled usually show a higher percent. Acidity of normal flour is obtained and others are compared with it.

In sound flours made from the spring (hard) wheats of Minnesota, the acidity should not exceed 0.125 percent.
VALUE AND DIGESTIBILITY OF BREADS.

According to the method of preparation there are several kinds of bread. Some of these are the flat bread of the Scandinavian countries, salt rising bread, unleavened bread, Vienna bread, common white bread, etc.

It is found that bread made with baking powder differs in no essential way from that made from yeast except in the presence of a residue from the baking powder.

Practically no difference is found in the digestive and nutritive value of flour in the different forms in which it is used for food.

Crackers, biscuits, wheat cakes, bread and other food materials made principally from flour have about the same food value.

Digestibility of Bread. Experiments show that bread is an exceedingly digestible food, nearly 98% of the starch of carbohydrates nutrients and about 83% of the gluten or proteid constituents.

Although graham and entire wheat flours contain a larger total amount of protein the nutrients are not so completely digested and absorbed by the body as those of white flour. The relative digestibility of bread from different flours was found to be as follows by the Office of Experiment Stations:

<table>
<thead>
<tr>
<th></th>
<th>Digestible Protein</th>
<th>Digestible Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard patent flour</td>
<td>83.6</td>
<td>97.7</td>
</tr>
<tr>
<td>Entire wheat flour</td>
<td>82.0</td>
<td>93.5</td>
</tr>
<tr>
<td>Graham flour</td>
<td>74.9</td>
<td>89.3</td>
</tr>
</tbody>
</table>

The greater digestibility of the protein and carbohydrates of the patent flour is thought to be due largely to the fineness of the flour particles which permit the flour to be acted upon more readily by the digestive fluids. It has also been suggested that the cell walls in the layer of the grain directly under the bran, more of which would occur in the graham and whole wheat flour, are more resistant to digestive fluids than the walls of the cells nearer the center of the kernel.

The same general relative results noted in the above table were obtained in experiments with hard northwestern spring wheats grown in Minnesota and Dakota, hard winter wheat grown in Oklahoma and soft winter wheats grown in Michigan, Indiana and Oregon.

In cases where finely pulverized bran was added to white flour in the same proportion as is removed in milling, it was found that the flour was not changed materially in digestibility and that the amount of total digestible nutrients and available energy was about the same in the germ flour and white flour. The germ flour produced a

smaller sized, sweeter but less porous, less attractive loaf than the white flour.¹

A comparison of flours has shown that when considering price, digestible nutrients and available energy, white flour is much cheaper than the coarse flours, which frequently sell for one-third to three-fourths more than the white flours, and at the same time contain less food material. The following table gives the comparative amounts of digestible nutrients obtained for 10 cents in different grades of flour when white flour cost $4.50 per barrel and entire wheat and graham $6.00 and $8 per barrel.¹

<table>
<thead>
<tr>
<th>kind of flour</th>
<th>Price per pound</th>
<th>Total quantity obtainable</th>
<th>protein obtainable</th>
<th>Carbohydrates obtainable</th>
</tr>
</thead>
<tbody>
<tr>
<td>White flour</td>
<td>2.25</td>
<td>4.4</td>
<td>.60</td>
<td>3.16</td>
</tr>
<tr>
<td>Entire wheat</td>
<td>3.00</td>
<td>3.3</td>
<td>.44</td>
<td>2.18</td>
</tr>
<tr>
<td>Graham</td>
<td>3.00</td>
<td>3.3</td>
<td>.43</td>
<td>2.09</td>
</tr>
</tbody>
</table>

Composition of Flour and Bread made from it in different ways:

2. Human Foods, Snyder, p. 177
<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Protein</th>
<th>Fat</th>
<th>C.H.</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>10.11</td>
<td>12.47</td>
<td>0.86</td>
<td>76.09</td>
<td>0.47</td>
</tr>
<tr>
<td>Bread from flour and water</td>
<td>36.12</td>
<td>9.46</td>
<td>0.40</td>
<td>53.70</td>
<td>0.32</td>
</tr>
<tr>
<td>Bread from flour, water and lard</td>
<td>37.70</td>
<td>9.27</td>
<td>1.02</td>
<td>51.70</td>
<td>0.31</td>
</tr>
<tr>
<td>Bread from flour and skim milk</td>
<td>36.02</td>
<td>10.57</td>
<td>0.48</td>
<td>52.63</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Average of the Bread

**PER CAPITA CONSUMPTION OF WHEAT**

The chief use of wheat is for human food. The bread eating countries now consume about 3,000,000,000 bushels annually. Since 1901 the world's consumption has increased approximately 100,000,000 per year due to more bread eaters rather than to a greater per capita consumption. There is an increasing tendency in per capita consumption in some countries but this is not true of the United States or the United Kingdom.

In Germany and Russia where the food of the agricultural and working classes is largely rye and in S. E. Europe where rye and Indian corn are largely used, any change toward a more luxurious diet would include white bread first.

In America and the United Kingdom where the standard of living is higher, the first indication of increasing prosperity is not in the greater consumption of white bread, but of a mixed diet consisting of more meat, eggs, fish and fruit. The U. S. and United Kingdom are the
the smallest consumers of wheat per capita of the bread eating countries. In the U. S. this is in some degree due to the larger use of corn in the southern states.

Per Capita Consumption of Wheat and Rye, by four leading nations in 1903:\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>Wheat lbs.</th>
<th>Rye lbs.</th>
<th>Wheat and Rye lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>275</td>
<td>20</td>
<td>295</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>350</td>
<td>6</td>
<td>356</td>
</tr>
<tr>
<td>Germany</td>
<td>200</td>
<td>325</td>
<td>525</td>
</tr>
<tr>
<td>France</td>
<td>473</td>
<td>77</td>
<td>550</td>
</tr>
</tbody>
</table>

While the statistics of meat consumption are not available, the amount paid for meat, poultry, fish eggs, milk, butter and cheese is much greater in the U. S. and Great Britain than in Germany and France.

In 1911 the whole U. S. consumed 5.3 bushels of wheat per capita. This is on the basis of 4 bu. 30\# of wheat for one barrel of flour. The largest consumption, 6 bu. per capita was in the far western states, while the smallest consumption 4.6 bu. was in the South Atlantic States. The largest single state was New Mexico with 7.9 bu., while Georgia, Alabama, Mississippi and Arkansas each had an average of 4 bushels per capita.\(^2\)

\(^1\) Wheat Fields and Markets, Smith p. 6
\(^2\) American Miller, Vol. 40-1, p. 202
LOCATION OF MILLING INDUSTRY

Minnesota is easily the first state in milling. In 1909 this state produced 15.7% of the milling product of the entire country. In 1904 this was 17.1% and in 1899 16.6%. In 1909 the flour milling products in Minnesota were worth $139,136,000 or one-third the value of all the manufactured products of all industries. There were 322 mills employing on an average 4345 wage earners, or an average of 14 per mill. Twenty-four of these mills had 3155 employes and produced $108,669,408 worth of the products, or 78.1%. The 86 mills that produced 93% of the flour of Minnesota in 1909 produced one-fifth of all the white flour made in the United States.

1. American Miller, Vol. 40-1, p. 458
BARLEY (Hordeum)

**Habit.** Barley is an erect growing annual varying in height from about 12 to 60 inches, averaging somewhat shorter than rye or wheat.

**Root, Stem and Leaves.** The root system of barley is more limited and weaker than the root systems of wheat, oats or rye. The roots of barley do not penetrate as deeply as the roots of these crops. However, they are finer and have a better effect on soil tilth. The primary root system consists of a whorl of 3 roots.

The number of stems produced varies with the variety and stand from one to as many as 15 to 20.

The leaves are broader than those of other grains and are of a grayish green color. In leafiness and feeding value the barley straw and hay is similar to oats. They have considerable value for animal feeding.

**Inflorescence.** The Inflorescence is a spike consisting of many groups of spikelets borne along an elongated zigzag axis or stem (rachis). The spikelets are grouped in threes, the groups alternating at the notches on opposite sides of the rachis.

The spikelets give the heads a two, four or six-rowed appearance according to whether or not the lateral spikelets are fertile and produce grains, and according to the arrangement of the lateral grains when present.

The spikelets appear to be sessile but they are really
Fig. 12. Groups of spikelets of 2-rowed and 6-rowed barleys. At the left 1 joint of the rachis of 2-rowed barley bearing a single grain and 2 sterile spikelets. At the right 1 joint of the rachis of 6-rowed barley bearing 1 central and 2 lateral grains.

1. Portion of rachis bearing the 2 glumes; 2. Palet; 3. Grain; 4. Lemma; 5. Lateral grain; 6. Central grain; 7. Lateral grain. Note that the central grains 6, are straight, while the lateral grains, 5 and 7, are twisted at the ends. In a lot of 6-rowed barley there should be approximately twice as many twisted grains as there are stright ones.

Fig. 13. A. One joint of the rachis of 6-rowed barley with the 3 grains; B. Same as A, with the grains removed leaving the 3 pairs of glumes; C. A complete barley spikelet, dissected; D. Three grains of a group of hooded barley; E. Three grains of a group of bearded barley.
borne on a primary branch (the rachilla) which has two opposite branches, each bearing a lateral spikelet. The third or center spikelet of the group is borne on the primary branch itself.

The rachilla or stem bearing the spikelets is prolonged and appears as a small bristle-like structure lying within the furrow of the grain. It is commonly called the basil-bristle. It may be covered with long, stiff hairs or with short, soft, wooly hairs according to the grain on which it is found.

**Spikelet.** Each spike is one flowered. Occasionally, spikes are found bearing spikelets which have a secondary flower. This secondary flower is always smaller than the first and may be misshapen. The production of grains in these flowers is doubted. The two glumes of each spikelet are very narrow and awnlike.

The lemma is broad, rounded on the back and five-nerved at the apex. It may be entirely awnless, or bear a long, slender awn or a very much reduced, usually 3 parted (trifoliolate) extension of the lemma, which is referred to as the hood, on account of its resemblance to a hood. Occasionally the hood bears a fertile flower. Some of our best barleys have the longest, harshest awns or beards. The lemma and palet are pale yellow in the white barleys and blue or black in the other types. In some cases the grains will be blue while the lemma and palet remain nearly white or are bluish with darker longitudinal stripes. The palet is nearly as long as the lemma, somewhat
narrower and bears 2 longitudinal keels near the edges. Between the keels the palet is nearly straight. In the hulled barleys the palet becomes drawn down into the groove of the kernels. The lemma and palet constitute the hull of the grain.

**Flower.** There are 3 stamens, 2 short styles, and 2 lodicules which are more or less conspicuous according to type of barley.

**Pollination.** Barley is self-pollinated. Little is known about the details of this process. Artificial pollination is rather easily affected altho it is somewhat more difficult than in wheat and rye. Emasculation must be done about the time the beards begin to show above the leaf sheath and while the anthers are still quite green in color. Delay will permit the anthers to ripen enough to be easily ruptured in removing, thereby scattering the pollen and pollinating the stigmas.

**Fertilization and Ripening of the Grain.** These processes have not been studied in the case of barley. In a general way they will no doubt resemble wheat.

**Fruit.** The fruit is a caryopsis and is commonly known as the grain. In most cultivated barleys the lemma and palet become firmly attached to the grain and do not separate from it in thrashing. In some varieties known as "naked or hulless" barleys, the hull separates from the grain as in common wheat.

The kernel of barley resembles wheat to some extent. They are usually broader at the center and more pointed at the ends than wheat. The grains of the 2 rowed barleys are somewhat larger and broader as a rule than those of the
Fig. 14. Heads of beardless barley. Produced by Derr by crossing a hooded and a bearded barley. Note that some grains are bearded while others are entirely without beards. An absolutely beardless strain does not seem to have been produced yet from this cross.

Fig. 15. Barley spikelets in which secondary infertile florets have developed.

Fig. 16. Group of 3 grains of a 6-rowed barley. X 2½.
rowed types.

The hull may form 10 to 25 percent of the weight of the grain, being somewhat thicker and heavier in the 6-rowed types.

The embryo of barley is very similar to that of wheat. The endosperm contains no gluten as does wheat. It varies from mealy to glassy, flinty or translucent. In general, mealiness may be said to be associated with a high percentage of starch while translucency usually indicates a higher percentage of protein. Hulled barley has about the same composition as wheat.

**Germination of barley.** Barley has about the same maximum, optimum and minimum germinating temperatures as wheat. In malting much emphasis is placed upon the "germinating ability and energy" of the grain since if the grain fails to germinate it is worthless for malting or if it germinates too slowly it requires too much time on the malting floor. In germination the plumule becomes twisted. This is characteristic of barley. The twisted plumule is known as the "acrospire".

**PHYLOGE'TY OF BARLEYS**

Cultivated barleys all belong to one species, *Hordetum sativum*, which is supposed by some botanists to have been derived from a 2 rowed species *H. spontaneum*, which is found growing wild in western Asia, where wild forms still exist. Others incline to the belief that there was a wild 6 rowed form as all of the ancient inscriptions are of the 6 rowed type.
HISTORY OF BARLEYS

It is very likely that this grain was first cultivated in some portion of Western Asia. It is one of the oldest cultivated plants. This belief is substantiated by the fact that barley is mentioned in the earlier books of the Bible, and that carvings of heads of barley are found on the ancient tombs of Egypt. It is at least 6,000 years old because pictures of sheaves and heads of barley (H. hexastichon) are found on Egyptian coins that old. According to Dr. Lauth it was grown in China some 2,000 years ago.

Its culture is likely as ancient as wheat and much more so than oats and rye. History states that barley was brought to Massachusetts and Virginia by the early colonists. Many importations of old and new strains and varieties have been made since the first seed was introduced.

GEOGRAPHICAL DISTRIBUTION

Barley was raised on the continents of the world in 1912 as follows:

<table>
<thead>
<tr>
<th>Region</th>
<th>Bushels</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>274,338,000</td>
</tr>
<tr>
<td>Europe</td>
<td>1,034,307,000</td>
</tr>
<tr>
<td>Asia</td>
<td>104,872,000</td>
</tr>
<tr>
<td>Africa</td>
<td>40,710,000</td>
</tr>
<tr>
<td>Australia</td>
<td>3,080,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,457,807,000</strong></td>
</tr>
</tbody>
</table>

1. Bureau of Chemistry Bul. 124, p. 17
The ten leading countries of the world in 1912 are as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>Bushels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia in Europe</td>
<td>320,959,000</td>
</tr>
<tr>
<td>United States</td>
<td>223,824,000</td>
</tr>
<tr>
<td>Germany</td>
<td>159,924,000</td>
</tr>
<tr>
<td>Austria Hungary</td>
<td>149,120,000</td>
</tr>
<tr>
<td>Japan</td>
<td>90,559,000</td>
</tr>
<tr>
<td>Spain</td>
<td>59,994,000</td>
</tr>
<tr>
<td>Northern Cacasia</td>
<td>55,296,000</td>
</tr>
<tr>
<td>France</td>
<td>50,646,000</td>
</tr>
<tr>
<td>Canada</td>
<td>44,014,000</td>
</tr>
<tr>
<td>England</td>
<td>42,951,000</td>
</tr>
</tbody>
</table>

**KEY TO ECONOMIC SPECIES OF HORDEUM (Barley)**

A. Spikes with 6 rows of fertile spikelets.

B. Rows of grains arranged equidistantly around the rachis; internodes short...*H. Hexastichon* (Six rowed barley.)

BB Rows of grains not arranged equidistantly around the rachis; lateral rows overlapping, forming 2 irregular double rows; internodes long.....*H. vulgare* (Four rowed barley)

AA Spikes with 2 rows of fertile spikelets... ..lume

.....*H. distichon* (Two rowed barley)

B. Spikes short (about 2 inches long), internodes very short, long ovate (egg shaped), beards widely spreading....

*H. Dist. Zeocriton* (Peacock or Fan barley)

BB. Spikes longer, narrow, sides about parallel, slightly tapering at apex; internodes longer, grains not crowded.

1. 1911 figures.
C. Dorsal side of base of grain not excavated but often pinched with a transverse crease or furrow. Spikes usually erect. *H. dist. erectum* (Erect barley)

CC Dorsal side of base of grain with a slight horse-shoe-like excavation or depression. Spikes usually, nodding (bending over and hanging parallel with culm) *H. Dist. Nutans* (nodding barley)

Six-Rowed Barley (*H. Hexastichon*)

**Stem and spike.** The straw is short, the spikes are erect and very short. The internodes of the rachis are very short, causing the grains to stand out from the head at a considerable angle, and making the head very firm and compact.

While the grains are really in groups of 3 at the rachis joints, they are so arranged that they appear to be placed around the rachis at equal distances from each other (equi-distantly). This plan gives the spike, in cross section, the appearance of a six-pointed star. The plants are very hardy and under some conditions give a fair yield of grain.

**Spikelet, Flower and Fruit.** The flowers of all 3 spikelets of each triplet are fertile, producing mature grains. The grains are thin and of very poor quality, and are used little or none for feeding.

**Distribution and Economic Importance.** True six-rowed barley is not grown commercially in the United States to any extent. There is a variety grown in the west principally in Utah, and Idaho and known as Utah winter, also called White Club, which has 6 symmetrically arranged rows of grains and is likely of this species (*H. hexastichon*).

This type is raised to some extent in England largely
for spring pasture, and likely also in Europe and other parts of the eastern Hemisphere, both for grain and pasture. It is probably better adapted to some of the poorer agricultural sections where the growing conditions are not the best.

**FOUR ROWED BARLEY (H. vulgare).**

This species is known in England also as Bere and Bigg.

**Stem and Leaves.** The stems and leaves of this group usually reach on the average, a greater degree of development in size than those of the six-rowed type and possibly of the two-rowed type. Otherwise no differences have been observed.

**Spike, Spikelet, Flower and Fruit.** All the flowers of each triplet of spikelets are fertile resulting in 6 rows of grains, which are not, however, arranged regularly and equidistantly around the rachis. The central grains of each triplet of grains from 2 regular rows on opposite sides of the rachis; but the lateral spikelets or grains of the 2 rows of triplets which in true 6 rowed barley for 4 straight single rows, in this type form, from overlapping, 2 irregular double rows, the whole spike appearing irregularly 4 rowed.

The grains average longer and thinner than grains of 2 rowed types. They are broader at the tips and elongated at both the tips and bases.

The lateral grains are smaller than the central grains and are usually twisted at the tip, while the latter are uniform and straight. This twist is likely caused by the beards of the lateral grains being pressed into the same plane as the beards of the central grains, when in the "boot", while the grains are not in the same plane.
The awns when present are very stiff and harsh, and usually adhere more firmly to the lemma in handling than do the beards of 2 rowed barley.

**KEY TO TYPES OF FOUR-ROWED BARLEY (H. vulgare)**

Tip of lemma projected into long slender awn.

Lemma and palet adnate to grain (grain retained in glume when thrashed); Four rowed bearded, hulled.

Lemma and palet free from grain (grain falling out when thrashed); Four rowed bearded, hulless.

Tip of lemma projected into a very short three parted (trifoliate) structure, the hood.

Lemma and palet adnate to grain; Four rowed hooded, hulled.

Lemma and palet free from grain; Four rowed hooded, hulless

Beard and hood absent. Four rowed beardless (white).

The hooded types have been classified as *H. trifurcatum* Jacq. (Himalayan Barley) and *H. algicaras* Royle. Since the hooded character is found in both the 4 and 2 rowed types the botanical terms must be applied to both types. In order to avoid confusion these names are not recognized for the present at least. In England hooded barley is known as Nepal Wheat.

**Beardless type.** The lemma has neither beard nor hood. This type is comparatively recent having been produced by Deer of the U S Department of Agriculture in crossing a hooded and a bearded type. This type has not yet become entirely "fixed". Deer proposes the name "hooded" for the type with the reduced
Beard on account of the resemblance of the trifoliate structure to the hood, in order to distinguish it from the true beardless type which he originated.

Each of the two types, bearded and hood, will include most if not all of the types given below. The true beardless type is found at present only in the white hulled, 4 rowed type.

**Hulled type.** The lemma and palet, the hull, are adnate to the mature grain; they are not removed in handling or thrashing.

**Hulless type.** The grain free from the hull and falling out on thrashing or rough handling. This type is also known as naked or bald barley. The latter term seems to be applied in some cases to beardless barley. The use of this word , bald, is more or less confusing since it is occasionally used for 2 different type characters, hulless and beardless.

Hulless barley was classified by Linnaeus as *H. coelesta*. However, since barleys are classified primarily according to form and number of parts and since hulless barleys are found in both the 4 and six rowed types and in black and white, it may lead to very long and cumbersome botanical names and possibly endless confusion to attempt to apply botanical names to the types of *H. vulgare*.

**White Type.** With both grain and hull white. Some writers use the sub-species name pallidum, meaning pale, to distinguish the ordinary 4 rowed white barley, the complete botanical name being *H. vulgare* (or *testrachon*) palladum. The full description is, bearded, hulled, white, 4 rowed.
White-hulled blue type. With hull white or nearly white, and grain blue. In blue grained barleys the coloring matter is in the aleurone layer.

Blue or black type. With hull and grain both dark, varying from light blue striped to almost black.

Four rowed hooded and hulled type. This type of barley is most profitable in the high altitudes of the Rocky Mountain States. Some strains are also most successful in parts of the semi-arid west.

Four rowed hulless type. Strains of this type of barley have been successful in the Southwest without as well as with irrigation. No well defined varieties are known for the above two types.

Varieties of H. vulgare in U.S.

The principal varieties of 4 rowed in the U.S. are as follows:

Four rowed bearded and hulled type. The varieties Manchuria, Oderbrucker, and Odess do best in Minnesota, Wisconsin, Illinois, Iowa and Nebraska which comprise the largest barley growing district. Tennessee witner is the most profitable variety in Kansas, Oklahoma, Texas and the southern states generally. In the Pacific coast states Bay Brewing and California are the leading varieties; the former is used extensively for malting, the latter for feeding. The California Feed is the leading feeding barley for the Southwest in general.

Two ROWED BARLEY (H. Tistichon)

Habit, root, stem and leaves. In these essentials 2 rowed
barleys do not differ to any noticeable degree from the 4 rowed types.

**Spike, Spikelet, Flower and Fruit.** In this type only the middle spikelet of each triplet is fertile, the lateral ones being staminate or nonsexual. This condition results in the spike having but 2 opposite rows of grains. These grains are nearly all of the same shape, those of the tip and base usually being somewhat smaller than those nearer the center of the spike.

When fully matured 2 rowed barley grains average shorter in length and larger in diameter than grains of 4 and 6 rowed types. Two-rowed barley grains usually average higher in starch and lower in protein and are somewhat softer than grains of the other types. The awns when present are very long, stiff, and harsh, being often longer than those of the other types. When the grains are mature the beards in some varieties break off easily at the tips of the grains.

The heads of 2 rowed barleys vary greatly in compactness. Experiments to determine the relation between compactness and erectness of heads and stiffness of straw have shown that no constant relation exists between these characters. Furthermore it has been shown that compactness and erectness of heads are not necessarily hereditary characters. Moss, a variety, which was produced from and belonged to the erect type (*H erectum*) possessed a decidedly nodding head.

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This occurrence shows why the position of the head cannot be made one of the determining characters in a system of classification. The same general conclusions were reached in working with wheat.

**Types and Varieties of *H. distichon***

There are 3 principal sub-species or races of 2-rowed barley.

**FAN TWO ROWED BARLEY (H. dist. geocci-iton)**

This type is also known as peacock, battledore or sprat barley. The spike with its long, spreading awns has some resemblance to an outspread peacock's tail or a fan which have given rise to the above common names.

**Description.** The straw is stiff. The spikes are erect and short, being about 2½ inches long. They are broadest below the center, gradually narrowing toward the tip and base (long ovate).

Excepting the lower ones the grains are usually thin and of poor quality. The beards are long and spreading.

**Distribution and Economic Importance.** This type is of no agricultural importance in the U.S. or England. It may be cultivated to some extent in parts of Europe and Asia.

**NODDING TWO ROWED BARLEY (H Dist. mutans)**

This type is known in England as Bent or Nodding eared Barley.

**Description.** The ripe heads usually bend over on one side and hang down so as to become almost parallel with the stem.

The heads are narrow, long and low. The smaller width is due to the fact that the grains are farther apart on the rachis and consequently fit closer to the rachis at their tips.
The dorsal side of the grain contains at the base a slight horseshoe like excavation or depression which distinguishes the grain of the nodding barleys from the grain of the erect barleys.

Varieties and Distribution and Importance. This type of barley is raised more extensively in England and Europe than in America. The principal varieties of nodding barley in England are Chevalier, Old Common and Nottingham Long-ear; in Sweden, Chevalier, Chevalier 2 out of American Chevalier, Princess out of the old English Prentice, Hanna (or Moravian S.P.I. #5793)\(^1\) a noted brewing barley from the breeder or selector, Emanuel Ritter von Proskowetz of Kwassitz, Moravia, Austria, Hannchen\(^2\) a pedigreed sort from Hanna, Gold\(^2\) a pedigreed sort taken from the native so-called vothland barley in 1896.

In the U S Chevalier, Hanna, Hannchen and Princess and possibly other nodding barleys are grown to a greater or less extent, largely for brewing purposes.

**ERECT TWO ROVED BARLEY** (H. dist. erectum) 
Known in England as erect-eared barley.

This type has broad, usually erect heads, with sides nearly parallel but tapering slight at the base and somewhat more at the tip. The grains are packed closely on the rachis which causes them to stand out at a greater angle than the grains of nodding types. The dorsal side of the grain at the base is not excavated but is usually pinched causing a transverse crease or furrow which distinguishes it from the

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1. Bureau of Plant Industry Bul. #66 (Inv. #10) p. 33
grain of nodding barley.

Varieties, Distribution and Importance. As in the case of the nodding barley the erect type is raised to a greater extent in England and Europe than it is in the U S. In England the principal varieties are Imperial, Webb's Beardless and Goldthorpe; in Sweden, Primus and Swan-neck, sister sorts, which are selections from a mixed stock, diamond, said to be the product of a cross between a common 2-rowed sort (probably Chevalier) and Imperial, and Svanhals.

In the U S Swan-neck, Primus and Svanhals are the leading varieties of erect barley. They are raised largely for brewing purposes.

Practically all of the types of barley found in the 4-rowed group are found in the 2-rowed group. As far as is known there is no beardless 2-rowed barley. There are, however, hooded 2-rowed types. There are also hulless and blue 2-rowed types.

It is likely that many of the types now found are the result of crossing, either natural or artificial, of a few original types.

TYPES OF BARLEY BASED ON CHARACTERS OF RACHILLA AND LATERAL NERVES OF THE DEMMA

In Scandinavia barleys of the 2-rowed and 4-rowed types are classified according to a system based on certain botanical

1. Agricultural Botany, Percival, p. 488
3. Bureau of Plant Industry Bul. 137 (Inventory 14) p. 43
marks of the grains. This system was founded by Dr. Atterberg of Kalmar and subsequently improved by Neergaard and later perfected by Balin.

This system as now in vogue recognizes four distinct types present in H. dist. nutans and H. dist. erectum and H. vulgare pallidum, the common white, bearded and hulled type. These types are commonly designated in Scandinavia by the Greek letters alpha, beta, gamma and delta. They are as follows:

A. Kernels with long haired rachilla (basal bristle) and lodicules.

1. Without teeth on the lateral nerves, - Type 1 (Alpha)
2. With teeth on the lateral nerves, - Type 2 (Beta)

B. Kernels with short more or less wooly rachilla and lodicules.

1. Without teeth on the lateral nerves - Type 3 (Gamma)
2. With teeth on the lateral nerves - Type 4 (Delta)

It has been found that the constancy of the peculiar character of rachilla or basal bristle of the different sorts is remarkable.

The development of teeth on the lateral nerves has not been found to be quite so constant a character. For example in types 2 and 4, the development of teeth on certain kernels belonging to a given group may not always be well pronounced. In the same manner sorts belonging to types land 3 may produce kernels on the nerves of which an occasional well developed tooth is to be found. It has been found, however, that despite these occasional irregularities the presence or absence of these teeth is regarded as of great importance as
a distinguishing character.

The question arises as to whether or not all kernels of
the same plant invariably possess the same peculiar character
of rachilla. There is no record of either the Swedish or
German scientists having found so far a single example of such
variation. Tedin worked in Germany for 8 years with hundreds
of pure varieties and came to the same conclusion. Wahl has
done some work on this but his results do not seem to be
recorded or to be available at this time.

While these characters will not make it possible to
differentiate two sorts having them the same, nevertheless
they will often serve to determine the genuineness of a sort
by telling whether it possesses the characters of the group
to which it is said to belong.

**COMPOSITION OF BARLEY**

Henry gives the composition of barley as follows:

<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Ash</th>
<th>Protein</th>
<th>Crude Fiber</th>
<th>Nitrogen-free</th>
<th>Ether Extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>10.9</td>
<td>2.4</td>
<td>12.4</td>
<td>2.7</td>
<td>69.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Barley meal</td>
<td>11.9</td>
<td>2.6</td>
<td>10.5</td>
<td>6.5</td>
<td>66.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Barley screenings</td>
<td>12.2</td>
<td>3.6</td>
<td>12.3</td>
<td>7.3</td>
<td>61.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Brewers' grains wet</td>
<td>75.7</td>
<td>1.0</td>
<td>5.4</td>
<td>3.8</td>
<td>12.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Brewers grains dried</td>
<td>8.2</td>
<td>3.6</td>
<td>19.9</td>
<td>11.0</td>
<td>51.7</td>
<td>5.6</td>
</tr>
<tr>
<td>Malt Sprouts</td>
<td>10.2</td>
<td>5.7</td>
<td>23.2</td>
<td>10.7</td>
<td>48.5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

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Feeds and Feeding, Henry 1909, p. 620
Relation between Texture (Mealiness) of Kernel and Protein Content. Swedish investigators say that while experience seems to have given some support to the belief that the more mealy or starchy the kernel the lower the percent of protein, yet careful investigations by them indicate that the relationship is not so intimate as many have thought. In support of this contention they offer the comparison of grains as given by Tedin a German investigator in the following table:

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Protein content %</th>
<th>Average Mealiness %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1899</td>
<td>10.98</td>
<td>27.8</td>
</tr>
<tr>
<td>1901</td>
<td>9.62</td>
<td>64.4</td>
</tr>
<tr>
<td>1902</td>
<td>9.53</td>
<td>54.4</td>
</tr>
<tr>
<td>1903</td>
<td>9.55</td>
<td>50.4</td>
</tr>
<tr>
<td>1904</td>
<td>9.35</td>
<td>61.0</td>
</tr>
</tbody>
</table>

It was found that while grains which are steely before steeping are no doubt more often high than low in protein content, nevertheless the texture of the grain before steeping is not a safe guide as to what it will be after steeping. These investigations brought out the following relationships: The kernels low in mealiness are not necessarily high in protein.

The more kernels are transformed into the mealy state by steeping the less protein they contain.

The lower in protein content a barley the more mealy

in general its structure. This mealy structure may not be apparent, however, until after the grain has been steeped.

The coefficient of mealiness after steeping (but not necessarily before) increases with decreasing protein content. The degree of dissolution \(^1\) increases with a decreasing protein content.

As a general conclusion it may be said that these investigations permit it to be said that mealy or starchy grains are generally lower in protein content and that the permanently steely grains are richer in protein.

Swedish breeders state further that investigations seem to indicate that the degree of mealiness or starchiness is dependent to a certain extent upon weather conditions which is no doubt true. They find that a flinty kernel under certain conditions of moisture either before or after harvest can be changed to one which appears quite starchy. For this reason they claim that the degree of mealiness if taken into account at all should be only after the kernel has been soaked in water.

American investigations were carried on by examining the cut grains before and after steeping in warm water.

A number of explanations have been offered to account for the differences between mealy and horny barley grains. "Johannsen long ago showed that the difference was due to the

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1. Dissolution as the term is here used consists of the change of barley grains when they are steeped from a glassy, horny or steely condition to a mealy, starchy or mellow condition.

greater number of air spaces in the endosperm of the mealy grains and that in the original condition barleys show no relation between the degree of glassiness and the percent of nitrogen.\textsuperscript{1}

"In 1879 Groenlund showed that early harvested barley can be just as mellow as later harvested barley and that glassy barley may become mealy by steeping and subsequent drying.\textsuperscript{1}"

From his examination of 47 barleys he concluded that glassy grains did not always contain more protein than mealy ones but that very often the opposite is true. Schultze came to the same general conclusion.

"In 1870\textsuperscript{1} Nowacki showed that the difference between a mealy and a glassy wheat was due to the small air spaces imprisoned between the starch granules of the mealy grains and that the specific gravity of the mealy grains was less than that of the flinty ones."

"Munro and Beaven likewise showed that the specific gravity of mealy kernels is less, due to the larger amount of interstitial air, and that the nitrogen content of such grains is lower, in consequence of which they modify better than do the steeily ones.\textsuperscript{2}

Harz said in 1904 that glassiness of barley is not due to the larger protein content but to certain kinds of protein substances and to the mechanical combination with the rest of the substances forming the cell.

Prior\textsuperscript{2} found that the causes of the apparent glassiness

\textsuperscript{1} Bur. Chemistry Bul. 124, p. 11
\textsuperscript{2} Bureau Chemistry Bul., 124, p 13
are the water-soluble nitrogen-free and nitrogen-containing constituents of the endosperm, constituents which are colloidal in character and which cement the starch containing cells firmly together. When these apparently steelly barleys are steeped the cementing constituents dissolve. The real glassiness is due to the cementing of the starch containing cells by means or hordein and insoluble protein.

USE OF BARLEY FOR BREWING

The price of barley is regulated largely by the demand and quality for brewing for which purpose a large amount is used.

Not all barley investigators and brewers are agreed as to what constitutes the best brewing barley.

European brewers have until recently as a rule demanded a barley relatively low in protein. This is done on the grounds that such barleys give less extract and that this character is more or less intimately correlated with the flinty character of the endosperm. They have held that the flinty character of the endosperm is undesirable because it renders the dissolution of the barley kernels more difficult and results in a glassy malt. Some of the investigators have gradually receded from the views which they first held on this question.

The principal brewing barleys of England and Europe are of the 2-rowed type which seem to average lower in protein than the other types. American brewers and maltsters on the other hand have used more of the higher protein barleys. Whether this has been from necessity or from preference is perhaps not certain in all cases.
Wahl has shown that moderately high-protein barleys, when properly malted and brewed, may give even better results than low-protein barleys since they are possessed with high vital power and develop strong enzymatic power during malting resulting in malts especially rich in both diastase and peptase.

Wahl contends that malt from such barleys are not only able to properly saccharify more starch than they themselves contain (making them adapted to the use of brewers' grits) but during malting and washing a comparatively large quantity of protein is rendered soluble by the peptase, the beers produced being richer in nitrogenous compounds than beers produced from low-protein barley malts. American investigations show that the 4-rowed barleys (of the Manchurian and similar types) have a relatively high protein content, generally about 11%, the grains being rather small (from 25 to 32 grains per 1000), with medium thickness of hulls. They germinate on the floor in about five days, the malts having rather high enzymic power. The fact has been established (by Hayduck) that a high protein malt has a correspondingly high diastatic power. Such barley is according to Wahl, especially adapted for the preparation of chill-proof beers and for pasteurized bottled beers.

The extract from fine grist may be as high as 75%. The oederbrucker is similar to the Manchurian in all particulars and was introduced into this country about eight years ago by the Wisconsin Agr. Exp. Station. Altho the malt produced from this barley is quite generally used in brewing in this country, it is especially adapted on account of its high
enzymic powers for the production of alcohol.  

Evans shows that tho the nitrogen question is important, it is secondary to the study of the starch conversion products, produced during malting and washing. "He intimates however, that much of the color, flavor and foam of the beer is due to the presence of the nitrogenous constituents."  

One investigator found that the amount of hull (husks) increased with the nitrogen and that the loss during malting also grew larger. Another found no relation between the amount of hull and the percent of protein. Two other men found that a winter barley contains more hull than one with a shorter period of growth and a late ripening variety more than an early one. Furthermore the amount of hull was greater in the starch-poor grains than in the full, plump grains with a tendency towards an increase of hull as the weight of 1000 grains decreases.  

On an average it seems to be true that 2-rowed grains are larger, contain a higher percentage of starch and a smaller percentage of hull than the 4-rowed types. This seems to coincide with the majority of the findings of investigators regarding the correlation of size of grain and protein and hull percentage.  

EUROPEAN BREWING BARLEY STANDARDS  

In general European Standards for a brewing barley may  

be based with safety on the opinion of Swedish, Danish and German authorities.

After making a careful study of the botanical, physical and chemical characters and the brewing quality of a large number of barleys, Swedish, Danish and German investigators have concluded that an ideal brewing barley is a "pure sort having plump, perfectly developed and matured kernels which are rich in starch, clear in color, fine scaled (with thin hull) and high in weight."

Any variety which can comply with these conditions no matter what its name may be or its reputation elsewhere, must be the aim of the breeder and grower and should be encouraged by the brewer, since the three interests cannot be estranged with profitable and satisfactory results.

The Swedish plant breeders at Svalof state that the handling of more than one or two sorts at the brewery is not considered as serious a matter as the purity of the sorts. The different pure sorts may be identified and kept separate. Mixed sorts cannot be separated, however, and they fail to give an even germination in malting which is essential to a uniform product as well as to an economical one. From the brewers standpoint it is very desirable that the handling of all barley intended for brewing be under efficient control in order to keep the varieties pure and true to name. The breeder and producer must not only seek to produce still better sorts but he must also see that these are distributed and handled with every possible precaution.
The Swedish breeders at Svalof give the following points for consideration in judging a brewing barley:


AMERICAN BREWING BARLEY STANDARDS

American brewers thru the official organization in connection with the Second International Barley and Hop Prize Exhibit, held in Chicago, Oct. 12-22, 1912, published literature on the groups and standards for American barleys. The American barleys were divided into four groups with reference to variety, characteristics and zone of culture as follows:

1. MANCHURIA, ODERBRUCKER, SCOTCH, OHIO FALL types. Four-rowed barleys with relatively high albumen content, medium size and weight of berry, medium thickness of husk, derived from the Manchuria barley or from related varieties, and grown principally in the following states: Minnesota, Wisconsin, Iowa, South Dakota, North Dakota, Nebraska, Colorado, Michigan, Ohio and New York; also Manitoba, Quebec and Ontario, Canada.

2. BAY BREWING, BLUE, AND PORTUGUESE barley. Four-rowed barley of relatively low albumen content, of large size and weight of berry, with thick husk, derived from Bay Brewing barley and grown principally in the following states: California, Oregon, Washington and Idaho.

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3. WHITE CLUB or UTAH WINTER barley. Six-rowed barley of comparatively low albumen content, large size berries and high berry-weight, thin husk. Cultivated mostly on irrigated land in Utah, Oregon, Washington and Idaho.

4. CHEVALIER, SAALE, HANNA and GOLDTHORPE or similar types of barley. Two-rowed barley with relatively low albumen content, of large size and weight of berry, with thin husk, grown principally in Montana and California.

The Standards for American Brewing Barleys as prepared by the Bureau of Barley and Hop Industry, Chicago, are given below:

"The relative merit of a brewing barley is expressed in the percentage of points it receives." The percentage is based on 100 as perfect.

"The barleys shall be valued on the basis of maturity, viability (germinating ability) berry weight; uniformity; albumen (or nitrogen) content, these five divisions standing as credits, while penalties are provided for excessive amounts of moisture; for trimmings (screenings, etc.); for inseparable admixtures; damage indicated by off color, off odor or general impression (Which includes uniformity in size and form; thrashing, which refers to the injury done in thrashing; thickness or coarseness of husk or hull) and irregularity of growth.

The degrees in which the different characters are present are expressed in percentages on a schedule or score card found on another page.

The total number of points which any lot receives is
Page 126 is a printed sheet giving
Standard for Brewing Hops
Chicago, October 12 to 22, 1911
determined by deducting from the average of the sum of the credits the sum of the penalties corrected for percentage. For example if a lot receives credits 94.3 points and penalties 17 points the total points are determined as follows:

\[
94.3 - \frac{94.3 \times 17}{100} = 78.3
\]

If on any character the barley falls below the disqualifying line at 30 points or get more than ten penalties, it is disqualified as a brewing barley.

**MALTING AND BREWING**

**Brewing** is defined as the process of preparing hopped, fermented beverages, such as lager beer, ale, stout weiss beer, the materials usually employed being barley-malt, hops, and water.

**Malting** is defined as the process of preparing cereals, usually barley, thru germination, for purposes of conversion and fermentation.

**Malt** is produced from barley by the processes of cleaning, steeping in water, germinating on the floor or in compartments or drums, kiln drying. Malt yields about 64-70% of extract in the brewery, of which 4-5% are albuminoids; rice about 75-80% corn about 75-78%, wheat about 65-70% of which 2-3% is albumen. Rice and corn yield practically no albumen.

**Brewing Materials.** Materials commonly employed wherever beer is produced are hops, malt, water and yeast. In some countries, like England, sugars and other adjuncts are used in part with malt; in the U S corn is commonly employed besides rice and sugars.
In Germany the employment of any substitutes for or adjuncts to malt is prohibited.

Barley is the distinctive cereal that furnishes malt, the exception being wheat used for weiss beer malt. Barley is used chiefly because the hull (husk) acts as an excellent filtering material in the mash tun; its endosperm is readily modified and mellowed during growth, like corn; and it develops a sufficiency of enzymes during the malting process. "Oats the only other cereal which retains its hull in thrashing, contains large quantities of objectionable protein (albumen), that preclude its employment."

Corn is used with germ and outside covering (husk or pericarp) more or less removed, in the form of grits or meal in a separate cooker or in the form of flakes in the mash tun; rice either broken or as a meal in the cooker; wheat in flaked condition in the mash tun or crushed (by means of the malt mill) in the cooker.

Other cereals than barley are used frequently because they can be obtained at a lower price and yield more extract than malt. They lend themselves better to the production of beers of Bohemian and Vienna types than all malt. The resultant beers are of paler color, of greater stability when pasteurized and their brilliancy less affected by low temperatures.

The use of wheat may not be more economical, nor are the wheat beers more stable or less sensitive to low temperatures than all-malt beers. They have a peculiar palate fullness that recommends them to some localities.

Commercial glucose and other brewing sugars are prepared
from the starch of corn thru inversion by acids at high heats (under pressure). They contain dextrin and dextrose in varying quantities.

Dark malts. For preparing a beer of dark color a malt may be used which has been subjected to a special treatment in the kiln, so as to acquire a dark color, caramel malt, the hull of which is yellowish brown, while the endosperm has a decidedly brown color. In its preparation, ordinary malt of good quality is steeped for a while so as to take up a certain amount of moisture. It is then dried, and heated in suitable vessels, first at a comparatively low temperature in order to promote the formation of sugar, and later to higher temperatures at which the sugar is caramelized. Different degrees of color are obtained by different temperatures.

Malting. Broadly speaking malting consists of all manipulations from the moment the grain leaves the elevator or store house up to the time the finished malt is conveyed to the storage bin or to the hopper to be measured into the crusher mill of the brewery. According to the more restricted meaning, it consists of three main operations of steeping, germination and kiln-drying of the grain.

Cleaning the grain. The barley from the bins is automatically conveyed to the cleaning machine. The offal is sold to feed dealers.

Steeping. From the cleaning machine the barley drops into the separator underneath where it is divided into two or three grades. These go to the automatic scales and then to the
steeping tanks, which should be half filled with water. At first the water should stand 1 to 2 feet above the barley when the tank is full. The light grains and other material known as the skimmings are floated off or skimmed off with a ladle. They are dried and sold for feed.

The water is changed twice the first day and once daily thereafter. Grains are steeped for about 48 hours, modifying for dryness of air, hardness and temperature of water, type and condition of barley, etc.

Germination. After the grain has been properly steeped the water is drained off at the bottom and the barley dropped on the malting floor, or loaded on trucks and wheeled to the floor where it is spread into a heap or couch about 3 to 10 inches deep. Here it is turned from time to time by hand shovels and its depth gradually increased and reduced according to conditions from about 14 inches to 4 or 5 inches. The air temperature is kept at about 50 to 60° F. and the growing grain about 75° F. The shoveling is to prevent too high heats and to aerate the grain.

About 5 days are required for the proper growth of barleys of the common 4-rowed barleys like the Manchuria, and 8 days for Bay Brewing and 2-rowed types like the Chevalier.

When the endosperm has become mellow and the plumule (acrospire) is about three-quarters of the length of the grain, the "green malt" is conveyed to the kiln which usually has 2 or 3 floors heated by open fire assisted by closed heaters. Smokeless hard coal is commonly used for fuel.

Kilning. Air together with the products of coal combustion is sucked thru the malt by means of a fan located above the
the upper malting floor. The temperature is kept at about 90° F on the upper floor, and when hand dry, usually after 24 hours, the malt is dumped on the lower floor where it is kept about 12 hours at 120-130° F., where it is kept practically dry, when it is heated to the final temperature of 150-155° F. for beer of Munic character.

A dark substance known as caramel is formed in the kiln in proportion to the moisture contained at high temperatures. The higher the temperature the darker the caramel. The amount and darkness of the caramel determines the type of beer produced.

PROCESS OF GERMINATION AND ITS RESULTS

The traditional germination methods known as "flooring" "growing", or "germinating" are conducted on a smooth floor constructed of cement.

The modern methods are based on artificial or forced aeration (pneumatic malting) either on a perforated floor or in revolving drums. Under this method most of the work is done by machinery and the name, mechanical malting, has been suggested to distinguish it from the old method in which the work is done by hand.

In germination, the roots protrude at the germ end of the grain while the plumule (acrospire) grows out towards the other end keeping under the hull along the dorsal or back side of the grain.

Experience shows that the most desirable condition of the endosperm is present when the plumule has grown about three-quarters of the length of the grain, at which time further
growth is checked suddenly by heating in the kiln.

**THE SCUTELLUM OR MALTING ORGAN**

The part of the barley germ or embryo which functions principally in germination is the scutellum, the part of the cotyledon between the primary axis (the plumule and the radicle) and the endosperm. On the side of the scutellum next to the endosperm is a layer of elongated cells known as the epithelial cells. They stand with their long axes at right angles to the surface of the endosperm.

The scutellum has been called the "malting organ" and the epithelial cells the "malting glands."

The scutellum is an absorbing organ. It siezes upon the food stored in the endosperm, renders it soluble and transfers it to the growing stem and roots. Its broad, flat surface is pressed close against the large, stored-up mass of starch, the endosperm, and when germination has been going on for 3 or 4 days it is easy to see that the starch especially that lying nearest the scutellum is disappearing and that at the same time the young plant has commenced growth.

From this it is evident that the scutellum is absorbing the starch and transferring it to the plant.

Before this can take place, however, the walls of the starch containing cells must first be broken down and the starch grains changed into a liquid state by conversion into sugar, dextrin or some such soluble correlative.

It has been found that certain enzymes, diastase and cytase, (the diastatic and cytatic ferments) are wholly the product of the scutellum and are secreted by the epithelial layer.
Altho a minute trace of these ferments is to be found in the starch cells (as in all starch containing tissue), it plays so slight a part in the normal starch conversion that it is practically negligible. The aleurone layer has nothing whatever to do with the process.

Peptase and lactic acid also assist in rendering the food soluble and transportable to the germ.

As these enzymes and acid carry on their work the endosperm becomes modified. Particles of starch, protein (albumen) and phosphates are made soluble and transferred to the germ in the form of sugar, amides and acid phosphates and used as food.
OATS
(Avena)

Habit. The oat plant is an erect growing grass which reaches a height of from 2 to 5 feet averaging about 3 1/2 feet.

Roots. The roots are small and fibrous. Under ordinary conditions they penetrate the soil to a depth of 3 to 4 feet. In some cases they have been found to go to a depth of 5 and even 6 and 7 feet.

In general oat roots are similar to the roots of wheat. The primary root system of oats consists of 3 temporary or seminal roots as in wheat. The dense fibrous root growth which in wheat occurs in about the first foot to a foot and a half of soil was found by Ten Eyck to be somewhat deeper in oats.

Stems. The stems of oats are hollow. They are somewhat larger in diameter and softer than wheat. Usually from 3 to 7 culms are produced from a single seed but as high as 50 or more have been reported from authentic sources.

Environment is reported to have a greater influence upon the length of oat culms than of culms of winter wheat and rye.

Leaves. Compared with wheat, oat leaves are more numerous, have somewhat more distinct ligules and are broader, varying from 1/2 to 1 1/2 inches. The blades are lanceolate and from 6 to 12 inches long. The leaf sheath clasps the stem for practically the entire length of the internode. The stems,
Fig. 17. Oat spikelets and grains. A. Dissected spikelet; B. Normal spikelet; C. Spikelet with the glumes and grain spread; D. Wild oats; E. Spikelet of wild oats with parts spread. Parts named according to Figure 18.

Fig. 18. Hulless oats spikelets. A. Spikelet dissected; B. Normal spikelets; C. Spikelet with parts spread showing general structure.

leaves, the straw, are somewhat higher in feeding value than wheat or rye straw.

Inflorescence. The inflorescence of oats is a panicle varying from 9 to 12 inches long. It consists of a rachis bearing a number of branches arranged seldom singly, but usually in whorls at from 3 to 5 different heights on alternate sides of the rachis.

The position of the branches determines the type of panicle. If the branches of the different whorls extend out from the rachis at the same angle on their respective sides, the result is a symmetrical type known as the spreading panicle or the panicle oat. If on the other hand the branches on one side of the rachis twist around and nearly coincide in position with those attached on the opposite side, the result is the side or mane oats. Both types may vary in compactness of panicle altho the former are usually quite open while the side oats are usually more compact. The branches of the side oats are shorter than those of the paniced type.

At the Svalof Experiment Station (Sweden) four main types of the spreading form have been distinguished as follows:

1. Panicle upright, stiff.
2. Panicle pyramid-like with long, slender, weakly rising branches.
3. Panicle widely spreading.
4. Panicle with branches weak and dropping.

The spikelets are borne singly at the ends of slender
pedicels of variable length. They vary in number from 25 to 100 altho 40 to 75 are usually found. The branches of the rachis which bear the pedicels have been referred to as the "rays." \(^1\)

**Spikelet.** The spikelets are 2 to 6 flowered. Usually the lower 1 or 2 are fertile, producing grains, altho 3 fertile flowers are not uncommon. The upper flowers are often staminate or imperfect and often only rudiments of organs are present or they are lacking entirely. The lowermost grain is always the largest and the uppermost one the smallest. The flowers with their accompanying parts are borne singly on alternate sides of the very slender rachilla.

Where only 1 grain matures in the spikelet it is referred to as "single oat", when 2 mature they are designated "twin oats."

The glumes are thin, membranous and many-nerved. They are considerably longer than the lemma, varying from 3/4 to 1 inch. They extend beyond the end of the uppermost grain. They frequently completely envelop the other parts of the spikelet. The lower glume is the larger and slightly overlaps the edges of the upper one at the end of attachment.

**Flower.** The flower consists of three stamens, with

\(^1\) There appears to be no real authority for this use of the word.
Fig. 19. Oat Spikelet. X 5.
Parts named according to Figure 20.

Fig. 20. Double, normal and pin oat kernels. X 6

1. Lemma of first or lower oat; 2. Palet of first or lower oat; 3. Kernel of first or lower oat;
9. Awn or beard. 10. Lower glume 11. Upper glume

A double oat consists of two oat grains, the first and second grains of a spikelet fastened or held together in such a way that they appear as 1 grain.
thread-like filaments, tipped with large anthers, and an ovary bearing a two-branched style with feathery (plumose) stigmas. There are 2 lodicules which are very evident at flowering time.

Each flower is enclosed on one side by a lemma which is rounded on the back, acute, and usually bears an awn a little way above the middle of its back, excepting in some of the highly developed types. The lemma is usually hard and shiny and varies in color being white, yellow, reddish brownish, reddish-brown, black or striped.

The awn bends nearly 90 degrees at a point less than one half its length from the point of attachment. The part below is straight while the part above is twisted. On the opposite side of the flower from the lemma is the palet which is shorter and narrower and slightly less tenacious than the lemma. The palet is 2 keeled. It is partly covered by the overlapping edges of the lemma. It is of the same color as the lemma.

The lemma and palet completely and tightly enclose the kernel or grain (caryopsis) from which in most varieties they do not separate on being thrashed. In the hulless types the hull is thinner and more membraneous and falls free from the kernel at thrashing time.

Opening of Flowers and Pollination. Oats are normally
self-pollinated altho it is thot that cross-pollination
occurs occasionally. It is said that pollination occurs
usually before the flowers open. However, it is likely that
in most cases at least it occurs simultaneously with the
opening. At this time the filaments of the anthers elongate
rapidly pushing themselves and the anthers outside of the
palea. The filaments are attached near the base of the anthers,
and in elongating they invert the anthers permitting the pollen
to fall from the outer ends to the stigmas. As the flowers
open the stigmas spread out. The flowers open in the morning
or afternoon remaining open only a few hours.

Artificial pollination of oats is somewhat more difficulty
than of the other grains because of the tenacity of the hulls
and the difficulty of holding the individual grains while work-
ing with them.

Fertilization and Development of the Fruit. Oats are
probably very similar to wheat in fertilization. The grain
passes thru the milk and dough stages as in wheat altho True
points out that the grain has a development markedly different
from what and corn. After fertilization there is greater
absorption of ovary wall, such that in the mature fruit the
pericarp consists of outer epidermis and a layer or two or
adjacent cells. As in what the inner integument alone per-
sists. There seems to be a less marked fusion of pericarp,
seed and seed coats (testa) than in corn and wheat.

Fruit and Seed. Usually the grain of oats consists not only of the true fruit or seed but also of the enveloping hull which in most types completely and tightly envelopes the seed, and from which it does not separate at maturity nor at thrashing time.

The hull consists of the lemma and palet. In the hulless types of oats the hull is thinner and more membranous than the hulled types and is readily removed from the kernel at maturity. Hereafter the naked seed (caryopsis) will be referred to as the kernel while the kernel bearing the hull will be called the grain.

The oat kernel is more slender and longer than that of wheat. It is softer and is thickly covered with fine hairs (pubescent). The kernel usually makes up 67 to 75% of the weight of the grain.

Richardson found from averaging 166 varieties that 100 grains weighed 2.5 grams, the variations being from 1.75 to 3.75 grams for 100 grains.

A cross section of the grain shows the following parts:

1. Lemma ) The hull
2. Palet )
3. Pericarp, hairy, three layers of cells.
4. Testa (Episperm) two layers of inner integument
5. Nucellus (Perisperm) remains of nucellar tissue.
6. Aleurone layer, two rows of cubical cells (sometimes one)
7. Starchy endosperm.

The embryo of oats is similar to that of other cereals. The starchy endosperm unlike wheat possesses no gluten. The pericarp, testa and nucellus are similar to those of wheat.

1. U. S. Dept of Agriculture, Bureau of Chemistry, Bul. 9
Fig. 21. Oat culms. At left, section of culm; Upper right, Longitudinal section of culm, X 1 1/4; lower right, cross section of culm, X 4.

Fig. 22. Longitudinal section of oat grain, X 6

Fig. 23. Spikelet of wild oats. X 2

Fig. 24. Wild oats X 3

Fig. 25. Panicle of wild oats X 3/4
The aleurone layer differs from wheat in usually consisting of a double layer of cells.

In many cases, kernels, especially the uppermost ones of the spikelets, will be so poorly developed that the grains will be long, sharp-pointed and slender, with the edges of the lemmas coming together and entirely hiding the palets or even rolling down into the grooves. Such grains have been designated "pin oats." They are relatively light in bushel weight and low in value.

Frequently the secondary grain of a spikelet will remain enfolded in the lemma of the first grain. The result is a double kernel or "double oat." A double oat is of course in reality 2 grains with their hulls together. What appears to be the palet of the grain is in reality the lemma of the second oat, while the palets of the 2 are face to face at the center. The kernel of the first will be found to be undeveloped which is in reality the cause of the double oat. Had this kernel developed the second oat would have been forced free from the lemma of the first oat. Many apparently excellent lots of oats have upon examination been found to contain large numbers of double oats which often escape detection of a casual glance, or the untrained eye.

Double oats are developed under different conditions and in different types. Some sorts seem to produce more double oats than others under any conditions while the same variety will vary in the number produced according to locality and
conditions of growth. A retarding of the development of the grains at the time the kernels are filling out, due to drought, will undoubtedly increase the number of double oats since it will prevent the first kernel developing to a size that will force the second oat free from the lemma of the first oat.

They may also result thru the sterility of the first kernel, as explained above. This condition has been found to arise frequently thru crossing 2 strains of widely different character.

At Svalof (Sweden) it was found that certain varieties as a rule produced few double oats while others produced a relatively high percent. At the same time varieties grown at Svalof showed usually a higher percent of double oats than the same varieties grown at Ultuna.\(^1\) It is not known at this time what the differences are between these 2 places. The results for a series of years are given below.\(^2\)

<table>
<thead>
<tr>
<th></th>
<th>Percent Double Kernels</th>
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<tbody>
<tr>
<td></td>
<td>Svalof</td>
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<tr>
<td>0386 Gold Rain</td>
<td>0.3</td>
</tr>
<tr>
<td>0329 &quot; &quot;</td>
<td>0.8</td>
</tr>
<tr>
<td>0355 Victory</td>
<td>0.9</td>
</tr>
<tr>
<td>0302 Probstier</td>
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</tbody>
</table>

1. Ultuna is just north of Stockholm, and about 230 miles north of Svalof which is in the extreme southern end of Sweden.

"Continued"

<table>
<thead>
<tr>
<th>Variety</th>
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<th>0.7</th>
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</tr>
<tr>
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<tr>
<td>Great Mogul</td>
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<tr>
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</tr>
<tr>
<td>English Potato</td>
<td>4.4</td>
<td>3.5</td>
</tr>
<tr>
<td>Average</td>
<td>1.72</td>
<td>1.26</td>
</tr>
</tbody>
</table>

The following results were obtained at the Colorado Agricultural College from a comparison of the value of three types of kernels.

Ideal oats (plump and heavy) 26.7% hull
Pin oats                      43.9% "
Double oats (large but light) 47.1% "

From these figures it is plain that double and pin oats are very inferior in actual feeding value.

Germination of Seed. In germination the young shoot (plumule) breaks out thru the pericarp at the embryo end of the kernel and grows underneath the lemma, coming out at the opposite end of the grain. Hence the young shoot lies between the lemma and the kernel on the ungrooved side opposite the palet. This method of emerging from the hull is necessitated by the persistance of the lemma. The primary root on the other hand is able to rupture the hull and grows out at the embryo end. In some cases the viability of oats has been found to be greater than of barley, wheat, flax and peas.

Saunders gives the average germination of 4 samples
for 6 years as follows: 90, 93, 73, 67, 54 and 30 percent.  

In some cases the seed has shown an increase in percentage of germination for 8 to 10 months after which it decreased.  
For a 5 year average the Ohio Station obtained 47.7 bushels of 
grain and 1859#/ of straw from seed raised the previous year,  
and 44.84 bushels of grain and 1349#/ of straw from seed which  
was one year older. The grain from the new seed averaged 29.35#/  
per bushel and that from the old seed 29.62 per bushel. 

Investigations show that the vitality of oats usually de-
creases rapidly after the second year.

GEOGRAPHIC DISTRIBUTION

Oats are grown almost entirely in the temperate zones.  
This is due largely to the fact that the crop does best in a  
cool, rather moist climate, altho the latter conditions seems  
to be of less importance than the former.

The crop is raised largely in the North Temperate zone.  
It has reached its highest development in Norway, Sweden,  
Germany, Great Britain and Canada, and in the United States  
in Montana, Idaho, Washington, Minnesota and Wisconsin. It  
also reaches a high state of development in both yield and  
quality in the cool irrigated mountain valleys of Colorado  
and other southwestern states.

Southern Europe and southern United States seldom pro-
duce good spring oats. The northern limit of production is

1. Canada Exp. Farms report 1903, p. 14
2. Ohio Bulletin # 138 (1903) p. 50
near the Arctic Circle, in Norway and Alaska.

Oats of good quality are grown in large quantities in Australia and neighboring islands and they are grown in limited quantities in Africa and Southern America.

HISTORY OF OATS

The original wild form from which the cultivated developed is not definitely known, but evidence indicates that it existed in Tartary in western Asia and in eastern Europe, probably within what is now the Russian Empire. The literature of China, India and other parts of southern Asia makes no mention of it. Records early do not show that oats were known by the Egyptians, tho it is said they were known among the Greeks and Romans. However, it appears that they were cultivated at a much later period than wheat and barley. Together with other grains oats were likely carried westward by the migration from eastern Europe and western Asia early in the Christian era. It is said that their first cultivation is likely to have been in northern and central Europe in what is now Austria-Hungary and Russia.

It is probable that the use of oats for human food was brought about by the scarcity of other feed for animals, their use for human food being still further delayed by the presence of the persistent hull which made them much harder to prepare for food with the crude methods of grinding employed by the ancient people. Wheat and rye which thresh free from the hull and barley with a comparatively thin hull could be ground much more easily. However, it is likely that scarcity of these grains occasionally caused oats to be used as a substitute.
The general use of oats for human food is thought to be of recent origin and to be due to the development of modern milling machinery.

Oats are said to have been cultivated in America since the advent of the first white settlers. Gosnold planted them with other cereals in the Elizabeth Islands in 1602 and they were introduced into Massachusetts Bay in 1629. From these places they have since been carried to many parts of the country. Many new varieties and strains have been brought to this country from time to time so that the numerous varieties now found here by no means represent the progeny of the first introductions into this country.

Phylogeny of Oats (Avena)
(See phylogeny of species)

CLOSERLY RELATED GENERA

There are no other genera belonging to this tribe (Avenae), which are likely to be confused with Avena. No closely related genera are of any great economic importance. Two genera Arrhenatherum (species elatius) tall oat grass, and Holcus (species lanatus) velvet grass, which belong to the same tribe (Avenae) are grown sparingly for forage purposes.

KEY TO ECONOMIC SPECIES OF CATS (Avena)

A. Kernels retained by the hull when mature.

B. Panicle spreading equally on opposite sides of the rachis; loose and open.
   Avena sativa (common, spreading or panicled oat)

BB. Panicle branches erect; all gathered on one side of the rachis; close and compact.
   Avena orientalis (side, mane, manner or Tartarian oat)
AA. Kernels falling from hull readily at maturity. 
   Avena nuda (naked or hulless oat) (may be 
   either spreading or side type)

DESCRIPTION OF SPECIES

Avena sativa. (Common, spreading, sprangled or panicked 
   oat.) In this species the branches of the rachis spread 
equally on opposite sides. They may be fairly erect or widely 
spreading or anywhere between. Included here are most of the 
oats commonly grown in the U. S. There may be both spring and 
winter types altho the latter type is limited to a very few 
varieties grown to a limited extent in the southern and Pacific 
states.

The Ohio Station has divided the varieties belonging 
to this species, which have been tested at the Station, into 
three groups based on certain grain, head and straw characters.¹ 
The groups are named for a typical variety in each one and with 
descriptions as follows:

1. Welcome group. With open panicle, course but 
   usually weak straw, short, plump grain. Includes 
such varieties as American Banner, Bonanza King, 
   Lincoln, and Welcome.

2. Wide awake group. Resembles Welcome group in 
general form, excepting that the berry is longer, 
   more pointed, usually lighter and the straw 
   stronger. Some varieties are Banner, Early 
   Dakota, Potato oats, and Wide awake.

3. Mixed group. Includes a number of balck and 
mixed oats not clearly belonging to either 
of the main groups but having characters quite 
similar to the Welcome group, tho the oats are 
lighter as a class.

¹ Ohio Bul. #138, p. 40
Contains among other varieties Big Four, Michigan Wonder, Black Beauty, and Monarch.

*Avena orientalis* (side, mane, horse-mane, banner, closed panicle or Tartarian oat.)

In this species the branches on one side of the rachis twist around to the other side in such a way that the spikelets all appear to be borne on one side of the rachis. The branches are shorter than in *A. sativa* are nearly erect and parallel to the rachis giving the head a compact one-sided appearance.

The Ohio Station has placed all the types with more or less one-sided panicles in a single group under the name Seizure. Some of the varieties are Black Tartarian, Excelsior, New Zealand and Seizure.

In comparing the different types of oats it was that that the one in which the panicle assumed a rigid, upright position was usually the most productive. However, at Svalof (Sweden) this conclusion was abandoned since an investigation of records covering many years showed that in the stiff panicled groups were many which were among the lowest yielders of all those tested. Consequently the type of panicle cannot be taken as a sure index to the yielding ability.

*Avena nuda* (hulless or naked oats). In this species the kernels are not tightly enclosed by the hull. When ripe they are easily removed and in thrashing they fall free. The lemma and palet are somewhat larger, thinner and more membraneous than in the hulled types.

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1. Plant Breeding in Scandinavia, Newman p. 34.
Norton reports that the naked or hulless type has a larger number of lower per spikelet, than have the hulled varieties. The former have 3-7 flowers with usually 4 or more, while in the latter there are usually 1-3 flowers per spikelet. With the exception of the above differences hulless oats are not essentially different from hulled types. Both spreading and side panicked types are reported altho the former are undoubtedly the more common.

PHYLOGENY OF SPECIES

Practically all of the cultivated varieties of oats are those to have been developed from Avena sativa. Some botanists claim that the common wild oats Avena fatua or the bristle pointed wild oat, Avena stigosa, of Europe and England was the parent species. It is possible that the oats commonly grown in our southern states and in southern Europe such as Red Rust roof were derived from Avena sterilis called the Animated or Fly oat of England, or some other wild type native to southern Europe or northern Africa.

Altho the side oat and the naked or hulless oat differ widely from the common or panicked type, yet they are believed to have had the same origin. They are usually classed as varietal forms of Avena sativa altho here they are classed as different species.

CLOSELY RELATED SPECIES NOT OF ECONOMIC IMPORTANCE

There are a number of wild species of oats in the United States. However, there is only one, the common wild oat (A. fatua), which is of any consequence and tives any particular

trouble as a weed.

In general the plant characters of this species are similar to the common cultivated oats. The culms are very long and are frequently much coarser and harsher than stems of cultivated types. The panicles are larger and spreading.

The spikelets usually contain 3 flowers. The lemmas are more or less dark in color and covered somewhat with longitudinal brownish stripes. Each bears a long, stiff, harsh, sharp-pointed awn. The grain is usually small and poorly developed.

The rachilla and base of the lemma are covered with long, reddish-brown hairs which extend up some distance along the edges of the lemma. The base of the grain is elongated and widened some distance below the base of the rachilla and contains an oval depression into which fitted the end of the pedicel. The rachilla is frequently larger than in common oats.

Wild oats. They are considered worthless for feeding purposes, are widely distributed in this country and give considerable trouble in oat sections. While they are not usually hard to distinguish from cultivated types yet they are not always easy to eradicate. They usually mature some days before other oats and even by cutting other oats green it has been found almost impossible to harvest the wild oats before they have shattered enough seed to insure a crop the following year. Care in buying and selecting seed, and crop
rotation are among the best preventatives for wild oats.

In England a number of other species of oats are recorded as follows:

*Avena strigosa*, similar to *A. fatua* but having one-sided panicles and fewer branches. Sparingly cultivated in Scotland for seed and fodder.

*Avena sterilis*, sometimes grown in gardens as a curiosity. Spreading panicle, with grain resembling that of *A. fatua*, excepting hairs are longer.

*Avena brevis*. A species with thin grass-like stems and a bulky crop of leaves. The panicle is one-sided. The kernels are plump, brownish and about 1/4 of an inch long, with short lemmas. It is sometimes grown for hay or soil ing crop.

**False Wild oats.** In cultivated oats there have appeared occasionally plants known as "false wild oats." These have been reported in Canada and in Scandinavia. They have been observed for many years in both black and white grained sorts.

These oats are like the true wild oat (*A. Fatua*) in having long twisted and bent awns, the "cup" at the base and the hairs, while in form and shape of kernels they are similar to the variety in which they appear. This characteristic often forms the basis for distinguishing between them and true wild oats. The plants of these "false wild oats" are exactly like the plants of the cultivated sort.

After extensive investigations at Svalof (Sweden) the conclusion has been reached that these false wild oats are examples of what DeVrieS defines as a Retrogressive mutation.
This phenomenon, as the result of the work done by Nelssen-Ehle at Svalof (Sweden), is explained as follows. Among the ordinary sexual cells arises one which for some unknown reason possesses certain of the wild oat characters. It is believed that the alteration in this cell is due to the dropping out or the lapsing into latency of a restraining or inhibiting factor in both egg and pollen cells which allows the typical, fully developed false wild oat type to arise at once; the presence of these factors in both cells is believed to restrain the development of the characters of the wild oat so that the cultivated form may arise while the presence of such a factor in only one of the sexual cells (egg or pollen as the case may be) allows the partially developed form to arise. Returning now to the behaviour of this mutating sexual cell (egg-cell or pollen-cell as the case may be) when fertilized by a normal sexual cell, we find that the result becomes to all intents a crossing between them. It is the $F_1$ (first generation hybrids) from this crossing............. which marks the first apparent deviation from the common oat. When the progeny of $F_1$ are sown, about 25% of the plants produced resemble the typical cultivated sort ........ and breed true in succeeding generations. About 50% possess the character of the type first found ........ These are inconstant (heterozygous) and consequently segregate in the next generation. The remaining 25% resemble the characteristic false wild oat type...... ........ These are constant, reproducing true to type in succeed-

Because the "false wild oats" do not increase materially since they lack the qualities of true species as shown above, and as a result are unable to compete successfully with the cultivated sorts, they are not regarded in Scandinavia as being so objectionable, from an economic standpoint, as the true wild species. There they are considered as a foreign variety rather than as a weed.

Possibly the claim made by some farmers that cultivated oats turn into wild oats can be in some cases at least attributed to the occurrence of the above phenomenon in their fields. More likely, however, the wild oats they find are true type from seed which has in some way been carried to the fields.

These aberrant (deviating) forms likely have their origin thru natural crossing between cultivated and wild forms and thru the result of certain spontaneous changes in sorts which may ordinarily be regarded as constant, in the manner described above. At Svalof all the changes of this nature are believed to be of a retrogressive kind that is they are reversions to characters which formerly existed in the species.

GEOGRAPHICAL DISTRIBUTION

Out of the many varieties or strains which have been tested at the Svalof (Sweden) station the following three have been designated as seeming to be most promising:

Probstier, commonly grown in the Baltic region.

Ligowo, a pedigreed sort obtained from Vilmorin of France and suitable for later districts where an earlier sort is required.

Black Tartarian, for those districts in which black
types are desired.

In the United States quite a number of varieties are found. The time to reach maturity may vary from 35 to 90 days for the earlier varieties in the southern and central parts to 125 to 140 days in the cooler portions of the north and the higher altitude.

Most varieties grown in the United States are adapted to spring planting altho a few like Winter Turf are planted in the fall in the southern states, while others like Rust Proof may be sown in the south either in the spring or fall. Fall oats are not hardy in northern states at least as far north as central Colorado.

Of the several hundred varieties grown in the U. S. only a limited number are well adapted to any particular section. It has been found that in many cases several names are applied to the same variety. Were all the duplicate names eliminated the number of variety names would be greatly reduced. New varieties are constantly listed by seed houses while older varieties are being dropped.

The northern part of the U. S. and the higher altitudes of the western and southwestern states excepting New Mexico and Arizona are generally adapted to the growing of the large grained medium to late maturing varieties. The white varieties such as Clydesdale, Big Four, Swedish Select, Lincoln, White Russian and Tartarian are usually grown.

On the dry farms of the west and southwest the early varieties like the Sixty-day and Kherson are becoming popular. Both of these varieties have long, slender grains which suggest
lightness in weight per bushel.

In the entire southern part of the U. S. and extending fairly well up along the sea coasts, the Burt and the Red Rust proof do best for spring varieties, while for fall seeding the Winter Turf, a hardy, medium-sized gray oat, and in the warmer portions the Red Rust proof, are more commonly used.

Between these two areas, in central eastern United States, the Sixty-Day and Kherson are best adapted, while in the southern part of this area, two early varieties, the Burt, with light brown grains, and Red Rust proof, with reddish-brown grains, do equally well.

It is noteworthy that as a group the darker colored varieties, including those of reddish, brownish and yellow colors seem better adapted to both heat and drought than the white varieties. The black varieties do not appear to exhibit this character.

In Colorado under irrigation the late white varieties like Colorado # 37 and Wisconsin # 4 (Swedish select products) Great Dakota and White Russian are the most popular. The Kherson a yellow, short season type also does well under irrigation.

Under dry farming the Kherson, Sixty-day and Early June do best for the short season varieties while Texas Red and Big Four are the favorites for the later maturing varieties.

NUMBER OF KERNELS IN THE SPIKELET AND THEIR SIZE

In working on this problem at Svalof (Sweden), Nilsson
divided oat spikelets into 3 groups: Three-kerneled ($S_3$), two-kerneled ($S_2$) and one-kerneled ($S_1$). The kernels from the different spikelets of the 3 groups were weighed separately. The results are shown in the following table:

<table>
<thead>
<tr>
<th>Plants from which plants were taken</th>
<th>Average Weight per kernel in mm.</th>
<th>Percent of each class of spikelets in plants studied.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In three-kerneled spikelet</td>
<td>In two-kerneled spikelet</td>
</tr>
<tr>
<td></td>
<td>($S_3$)</td>
<td>($S_2$)</td>
</tr>
<tr>
<td></td>
<td>$a$  $b$  $c$</td>
<td>$a$  $b$</td>
</tr>
<tr>
<td>robsteir</td>
<td>54  33  14.80</td>
<td>44  28.25</td>
</tr>
<tr>
<td>type</td>
<td></td>
<td>33.50</td>
</tr>
<tr>
<td></td>
<td>14  82  4</td>
<td>100</td>
</tr>
<tr>
<td>hrowo</td>
<td>60  42.3  16.75</td>
<td>52.63  32.70</td>
</tr>
<tr>
<td></td>
<td>13  83  4</td>
<td>100</td>
</tr>
<tr>
<td>ide oat type</td>
<td>50  34  10</td>
<td>33.13  20.23</td>
</tr>
<tr>
<td></td>
<td>11  74  15</td>
<td>100</td>
</tr>
<tr>
<td>other types of stiff-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>micled back oats</td>
<td>50.66  50.16  9.33</td>
<td>40.41  22.68</td>
</tr>
<tr>
<td></td>
<td>27.03  9</td>
<td>82  9</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

The following were the findings of Nilsson:

1. "That the development and weight of each kernel stand in a striking and significant relation with the number of kernels in the spikelet.

2. That with a rising number of kernels there is associated a considerable increase in weight per kernel instead of the opposite which one would expect.
"Kernel (a) is never so small and miserable as when it is alone as in S₁ and never so heavy and well developed as when it is accompanied by two other kernels as in S₃."

Continuing he concluded that "oat sorts having the highest number of kernels per spikelet are decidedly the most valuable."

Fifteen years after the above statement was made it was found that by comparing the strains or varieties being grown, that some of the best are classified as two-kerneled while other high yielders are with relative regularity three-kerneled. On the other hand it was found that certain low yielders are classified as three-kerneled while others are two kerneled. The conclusion arrived at is that "there seems to be no definite relationship between the yield of a given strain and the number of kernels per spikelet by which it is characterized."

However, in the case of fluctuating individuals within the same line and here only it has been found that a large number of kernels per spikelet is indicative of higher yield. When the variety as a whole is considered this rule has no significance.

This stand by Nilsson-Ehle and Tedin (of Svalof, Sweden) has been confirmed by Bohmer of Germany and Christie of Norway.

Christie in working during 1909 and 1910 with 42 pure lines representing 3 varieties found that the "greater the number of kernels in the spikelet the greater is the weight of kernels per plant in the case of different plants within the same pure line.

1. Plant Breeding in Scandinavia, Newman, p. 34
but in the case of different pure lines this relationship is not shown."

He says, "In comparing pure lines from the same old variety of oats I do not find any reason to attribute any special value to three-kerneled spikelets. The absolute weight of kernels per plant gives much more certain information regarding the productivity of the stock and is, moreover, essentially quicker and easier to determine."

It has been found that while the number of kernels which are borne by each spikelet cannot determine the value of different strains, at the same time a distinction can often be made on this basis between different lots of the same strain grown under different conditions.

Strains which normally produce three-kerneled spikelets will under certain conditions produce a larger percentage of two-kerneled spikelets. Hence it is seen that environment is an important factor in determining the number of kernels per spikelet.

**PERCENTAGE OF HULL AND KERNEL**

Considerable variation exists in the amount of hull and kernel in oats. The percent of kernel has been found to vary from 65-70% ordinarily, while in the poorer samples it is made up not more than 55% of the grain and in the better samples as much as 75 to 80% of the grain weight.

In general varieties with long, slender, grains usually contain a higher proportion of kernel than those with short thick grains. This difference is likely due, in part at
least, to a thicker hull on the short plump grains.

The small, early varieties like the Sixy-day and the Kherson have usually been found to contain a very high proportion of kernel. The Swedish Select, a popular variety of the northern states and the higher altitudes, has also shown up well in this respect.

The Ohio station found that the Welcome group, with short, plump grains varied from 24.6 to 34% hull with an average of 29.7% for 21 varieties. ¹

The Seizure group with grains averaging slightly smaller than those of the Welcome group varied from 26.1% to 32.6%, the average being 30.6% for 14 varieties.

In the Wide Awake group with grains larger, more pointed and slightly lighter in weight than those in the Welcome group the percent hull varied from 26.6 to 35.2 with an average of 30.9 for 26 varieties.

The mixed group containing grains averaging considerably smaller in weight than those of the other groups varied from 25.3 to 29.8% hull averaging 27.2% for 8 varieties.

The Illinois station found after 2 years work with 30 to 60 varieties from various sources, but grown under the same conditions that varieties with longer, slender, comparatively light grains generally had the largest percent of kernel. ²

Warburton reports that the seasonal variation in proportion of kernel to hull is considerable. He found that the

¹ Ohio Bulletin 57, p. 109
average of seven varieties grown in Wisconsin in 1905 was 71.97% of kernel while in 1907, a much poorer year for oats, the same varieties averaged 66.62% of kernel. In 1905 the variations ranged from 69.13 to 78.07% and in 1907 from 63.71 to 69.86%. The variety which was lowest in percent of kernel in 1905 was highest in 1907.¹

WEIGHT PER BUSHEL AND PERCENT OF HULL

That no definite relationship exists between the weight per bushel and percent of hull when different varieties are compared seems to be fully established. However, when different strains or lots of the same variety are compared there seems to be some correlation.

At the Ohio Station it was found that in the Welcome group of the six heaviest varieties averaging 37.75# per bushel the percent of Kernel averaged 71.2. In the 8 varieties with a weight per bu. of 32-35 pounds or an average of 33.5# the percent of kernel was found to be 70.2; of the 13 varieties varying from 29.5 to 31.7# per bu. with 31.1# average, the percent of kernel was found to be 67.6.

These figures indicate that in this group the heavier the weight per bu. the greater the percent of kernel. In the Seizure group, however, a different relationship was found.

Four varieties averaging 36# per bu. gave an average of 63% kernel; 3 varieties averaging 33.3 per bu. gave an average of 67% kernel; and 7 varieties averaging 30# per bu. gave an average of 69% kernel. At Swalof (Sweden) it was

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found that one variety (English Potato Oat) which had the highest weight per bushel also had the highest percent of hull while on the other hand one variety (Niggar) has a low bushel weight and a low percent hull. The weights per bushel in comparison with percent hull in oats tested at Svalof, are given in the following table:

<table>
<thead>
<tr>
<th>Sort</th>
<th>Weight per measured bushel, lbs.</th>
<th>Percent hull</th>
</tr>
</thead>
<tbody>
<tr>
<td>0701 English Potato oat</td>
<td>42.26</td>
<td>32.25</td>
</tr>
<tr>
<td>0386 Gold Rain</td>
<td>40.22</td>
<td>27.50</td>
</tr>
<tr>
<td>0353 Ligowo</td>
<td>39.95</td>
<td>26.80</td>
</tr>
<tr>
<td>0329</td>
<td>39.60</td>
<td>25.70</td>
</tr>
<tr>
<td>0926 Duppauer</td>
<td>39.37</td>
<td>33.70</td>
</tr>
<tr>
<td>0355 Victory</td>
<td>39.29</td>
<td>23.70</td>
</tr>
<tr>
<td>0302 White Probstier</td>
<td>39.06</td>
<td>27.60</td>
</tr>
<tr>
<td>0301 Hvitling</td>
<td>38.98</td>
<td>28.20</td>
</tr>
<tr>
<td>0300 Awnless Probstier</td>
<td>38.21</td>
<td>27.00</td>
</tr>
<tr>
<td>0275 Niggar</td>
<td>38.16</td>
<td>23.90</td>
</tr>
<tr>
<td>0401 Black Bell I.</td>
<td>37.44</td>
<td>31.50</td>
</tr>
<tr>
<td>0450 Great Mogul</td>
<td>35.60</td>
<td>31.25</td>
</tr>
<tr>
<td>0101</td>
<td>34.47</td>
<td>27.25</td>
</tr>
</tbody>
</table>

1. Plant Breeding in Scandinavia, Newman, P. 121
At the Montana Station\(^1\) six varieties grown under irrigation in 1906, averaged 75.79% of kernel, while in 1907 they averaged 71.81% tho the difference in average weight per bushel was less than 1\# in the 2 years.

At the Colorado station it was found in 1912 that the Sixty-Day oat had a higher percent of kernel than 2 other varieties which weighed more per bushel and considerably more kernel that several varieties that weighed slightly less per bushel. The results are shown in the following table together with the averages of 3 lots of the Seizure group obtained at the Ohio Station.\(^2\)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Weight per bushel</th>
<th>Pounds of kernels 32# oats</th>
<th>% kernel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sixty Day</td>
<td>34.5</td>
<td>24.0</td>
<td>75.0</td>
</tr>
<tr>
<td>White Russian</td>
<td>36.3</td>
<td>23.7</td>
<td>74.1</td>
</tr>
<tr>
<td>Tartarian</td>
<td>37.0</td>
<td>23.0</td>
<td>71.9</td>
</tr>
<tr>
<td>Abundance</td>
<td>33.0</td>
<td>22.7</td>
<td>71.0</td>
</tr>
<tr>
<td>White Waverly</td>
<td>33.6</td>
<td>21.2</td>
<td>66.2</td>
</tr>
<tr>
<td>Golden Custer</td>
<td>34.0</td>
<td>21.2</td>
<td>66.2</td>
</tr>
<tr>
<td>Big Four</td>
<td>36.1</td>
<td>20.6</td>
<td>64.4</td>
</tr>
<tr>
<td>Lincoln</td>
<td>34.3</td>
<td>20.2</td>
<td>63.1</td>
</tr>
<tr>
<td>Seizure Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av. of 4 varieties</td>
<td>36.0</td>
<td>21.3</td>
<td>68.0</td>
</tr>
<tr>
<td>Av. of 3 varieties</td>
<td>33.8</td>
<td>21.4</td>
<td>67.0</td>
</tr>
<tr>
<td>Av. of 7 varieties</td>
<td>30.0</td>
<td>22.1</td>
<td>69.1</td>
</tr>
</tbody>
</table>

\(^1\) Farmers Bul. 420, p. 15  \(^2\) Ohio Bul. 57, p. 109
The experiments which have been conducted both in this
country and abroad show that no definite relation exists be-
tween weight per bushel and percent of hull. The absence
of any relationship between these characters is of extreme
importance and should be clearly recognized by judges at oat
contests and especially by purchasers for feed where in both
cases there is now a great tendency to judge oat values on
weight per bushel.

KERNEL WEIGHT AND YIELD

Westergaard of Abed Experimental Station, Denmark found
that no relationship exists between the weight of 1000 kernels
and the yield of oats. He found the same to be true of wheat
and barley.

Experiments conducted in the United States at a number
of stations, principally Ohio and Nebraska, point to the
same general conclusion.

Experiments by Zavitz, of the Ontario Agricultural
College, Murray and Middleton, of the University of Wales
and Dr. N. A. Cobb, then of New South Wales, Australia, now
of the U.S. Department of Agriculture, and others, point
to the conclusion that large, plump seeds have a greater
yielding power than small seeds.

If seed from pure strains or sorts was used in all cases
possibly this great variation in results would not have
occurred.

It does not seem unreasonable to suppose that large
plump seeds would give some advantage to the seedling plants,

especially if raised under conditions that were at all adverse. It has been found, in some cases, that no such superiority exists for large seeds.

If the large seeds come from a high yielding plant and the small seeds from a low yielding plant, a difference of yield, in favor of the large seeds would not be surprising. However, if the reverse was true, and the large seeds came from a low yielding plant some experimental evidence might permit one to still expect the larger yield from the larger seeds, when as a matter of fact there is plenty of reason for expecting, under average conditions, the opposite result.

In grading ordinary lots of grain the large kernels secured are from both high and low yielding plants, hence this system does not eliminate the low yielding strains. The only advantage which can be expected must come from the mere difference in size of kernels, which advantage must under average conditions, be seriously questioned.

Westergaard and others believe, that, for ordinary mixed strains at least, plump, medium sized kernels are more desirable than either the very large or very small ones.

It is likely that the best results can be expected only, from pure, high yielding strains with grains similar in size, and in hereditary tendency regardless of size.

For the present it seems safe to say that ordinary methods of grading grains, for the largest kernels, are of little real advantage.

WEIGHT PER BUSHEL AND YIELD

At Svalof (Sweden) it was found that no relationship
exists between productivity of a sort and its weight per bushel, as shown in the following table:

<table>
<thead>
<tr>
<th>No. Years Tried</th>
<th>Average yield per acre</th>
<th>Average weight per bu.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain (lbs)</td>
<td>Straw (lbs)</td>
</tr>
<tr>
<td>0355 Victory</td>
<td>3420</td>
<td>4350</td>
</tr>
<tr>
<td>0386 Gold Rain</td>
<td>3295</td>
<td>4355</td>
</tr>
<tr>
<td>0300 Awnless Probstier</td>
<td>3260</td>
<td>4160</td>
</tr>
<tr>
<td>0301 Hvitling</td>
<td>3242</td>
<td>4195</td>
</tr>
<tr>
<td>0353 Ligowo</td>
<td>3233</td>
<td>4168</td>
</tr>
<tr>
<td>0302 White Probstier</td>
<td>3198</td>
<td>4302</td>
</tr>
</tbody>
</table>

From this table will be seen that Awnless Probstier which has the lowest weight per bushel is one of the four best in yield. According to the table on another page it is also one of the best in percent of kennel. The English Potato Oat which weighed the highest per bushel was left out of the table entirely on account of its deficiency in both yield and quality.

**LENGTH OF GROWING SEASON AND YIELD**

At Svalof it was found that contrary to the opinion which

---

1. Plant Breeding in Scandinavia, Newman, p. 121
2. Ibid, p. 129.
prevailed for many years, yield and later maturity are not necessarily correlated. A number of high yielding early maturing strains of grains have been found. Besides Gold Rain oats, Sun wheat and Hannchen barley belong to this class. In this country Kherson oats and Marquis wheat, both early maturing varieties, emphasize the error of this earlier opinion.

COMPOSITION

Oats are higher in crude fiber than wheat, barley and corn. This is due to the hull of oats. They are high in protein as is evident from the fact that altho about 1/3 off the grain is hull they contain as much of this constituent as wheat, nearly as much as barley and more than cane seed (sorghum). They exceed barley and wheat in fat and are higher in ash (mineral matter) than either wheat, barley or corn. The composition varies considerably due largely to the differences in percentage of hull.

Warburton shows that "100 pounds of a variety with 70% of kernel would have 0.57 pounds less protein, 1.44 pounds more crude fiber, 0.77 pounds less carbohydrates, and 0.305 pounds less fat than 100 pounds of a variety with 75% of kernel."¹

The following tables gives the composition of oats and oat products.²

---

2. Feeds & Feeding, Henry (1910) p. 566
<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Ash</th>
<th>Crude Protein</th>
<th>Carbohydrates Fiber N-Free Extract</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oats</td>
<td>10.4</td>
<td>3.2</td>
<td>11.4</td>
<td>10.8</td>
<td>59.4</td>
</tr>
<tr>
<td>Oatmeal</td>
<td>7.9</td>
<td>2.0</td>
<td>14.7</td>
<td>0.9</td>
<td>67.4</td>
</tr>
<tr>
<td>Oat middlings</td>
<td>8.3</td>
<td>4.5</td>
<td>16.2</td>
<td>7.1</td>
<td>56.5</td>
</tr>
<tr>
<td>Oat feed</td>
<td>7.0</td>
<td>5.3</td>
<td>3.0</td>
<td>21.5</td>
<td>55.3</td>
</tr>
<tr>
<td>Oat dust</td>
<td>6.5</td>
<td>6.9</td>
<td>13.5</td>
<td>18.2</td>
<td>50.2</td>
</tr>
<tr>
<td>Oat hulls</td>
<td>7.4</td>
<td>6.7</td>
<td>3.4</td>
<td>30.7</td>
<td>50.5</td>
</tr>
<tr>
<td>Oat bran</td>
<td>6.1</td>
<td>6.7</td>
<td>13.0</td>
<td>19.8</td>
<td>56.3</td>
</tr>
<tr>
<td>Oat straw</td>
<td>9.2</td>
<td>5.1</td>
<td>4.0</td>
<td>37.0</td>
<td>42.4</td>
</tr>
<tr>
<td>Oat chaff</td>
<td>14.3</td>
<td>10.0</td>
<td>4.0</td>
<td>34.0</td>
<td>36.2</td>
</tr>
<tr>
<td>Oat hay</td>
<td>16.0</td>
<td>7.3</td>
<td>3.8</td>
<td>52.4</td>
<td>43.3</td>
</tr>
<tr>
<td>Oat, in milk (dry)</td>
<td>14.0</td>
<td>5.7</td>
<td>8.9</td>
<td>27.4</td>
<td>41.2</td>
</tr>
<tr>
<td>Oat and pea</td>
<td>10.0</td>
<td>7.1</td>
<td>10.3</td>
<td>28.3</td>
<td>41.2</td>
</tr>
<tr>
<td>Oat and vetch</td>
<td>15.0</td>
<td>7.4</td>
<td>12.8</td>
<td>26.7</td>
<td>35.8</td>
</tr>
<tr>
<td>Oat fodder (green)</td>
<td>62.2</td>
<td>2.5</td>
<td>3.4</td>
<td>11.2</td>
<td>19.3</td>
</tr>
<tr>
<td>Wild oat forage (dry)</td>
<td>14.3</td>
<td>3.8</td>
<td>5.0</td>
<td>25.0</td>
<td>48.3</td>
</tr>
</tbody>
</table>

**USE OF OATS FOR HUMAN FOOD**

Oats in the form of oatmeal porridge or groats (cut or cracked grains), is one of the principal foods in Scotland. The latter form of preparing them seems to be much more common.

---

1. Farmers' Bulletin 420 p 16
than the former which is the form in which they are largely used in this country. In northern Europe they seem to have been used as food for many centuries but are of comparatively recent origin as a general article of food in other countries than Scotland.

Hulless oats are largely used for food in mountainous regions where they are used as porridge as well as ground into meal and used in the making of bread and cakes. Oatmeal is one of the cheapest and most valuable foods when properly cooked.

The Iowa Station reports "that the average price per pound of 3 brands of oatmeal was slightly less than that of 7 uncooked foods made from other cereals, and little more than \( \frac{1}{2} \) of that of 17 brands of prepared cereals."\(^1\) Similar results have been obtained from several other experiment stations. It has been found that long cooking not only makes oatmeal more palatable but also makes most of the protein readily digestible.

Single oats are said to be used for the best grade of oatmeal. For this purpose the grains must be plump and heavy with thin hulls. Some farmers are undoubtedly in a position to cater to the oatmeal trade, since they have the conditions for producing the desired quality of oats.

USES OF OATS FOR ANIMAL FOOD

The greater amount of oats are fed to livestock principally horses. They are especially valuable for the development of

\( \ldots \)

of young and growing animals and for the proper maintenance of animals at hard work like dairy cows and work horses. This is due to the high content of protein which furnishes the muscle building material and the mineral matter which is used in the building of bones. Oats are an excellent feed for cattle and sheep and especially for milk cows, ewes and growing calves. They are also fed to poultry with good results oftentimes being the only grain fed regularly.

The large amount of crude fiber which they contain makes them unadapted for hog feeding on account of the inability of the small stomachs of these animals to hold sufficient grain. For brood sows it has been found that ground oats mixed with swill make an excellent feed.

Oat straw is higher in total as well as digestible protein and fat than wheat, barley or rye straw and about the same in carbohydrates and of all grain straws it is considered the best for feeding.

Oat hay is not quite as valuable as barley hay being slightly lower in digestible protein and carbohydrates, altho somewhat higher in fat. It is however, higher in both digestible protein and fat than timothy hay and is consequently a slightly better feed.

The following table gives the digestibility of oats and oat products:

---

1. Feeds and Feeding, Henry (1910)
<table>
<thead>
<tr>
<th>Total Dry Matter in 100 lbs.</th>
<th>Digestible nutrients in 100 lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crude Protein</td>
</tr>
<tr>
<td>Oats</td>
<td>39.6</td>
</tr>
<tr>
<td>Ground oats</td>
<td>33.0</td>
</tr>
<tr>
<td>Oatmeal</td>
<td>92.1</td>
</tr>
<tr>
<td>Oat middlings</td>
<td>91.2</td>
</tr>
<tr>
<td>Oat feed</td>
<td>93.0</td>
</tr>
<tr>
<td>Oat hulls</td>
<td>92.6</td>
</tr>
<tr>
<td>Oat hay</td>
<td>86.0</td>
</tr>
<tr>
<td>Oat straw</td>
<td>90.8</td>
</tr>
<tr>
<td>Oat chaff</td>
<td>85.7</td>
</tr>
<tr>
<td>Oat forage in milk (green)</td>
<td>37.8</td>
</tr>
<tr>
<td>Oat forage in bloom (green)</td>
<td>25.0</td>
</tr>
<tr>
<td>Oats and peas (green)</td>
<td>20.3</td>
</tr>
<tr>
<td>Oats and vetch (green)</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Oats have always been considered by many as the best food for keeping horses in good condition and high spirits. Attempts of chemists to find the active principle which produces this stimulating effect have failed. Investigations indicate that for work horses as good results can be obtained where oats are replaced in part by corn, especially if a small amount of some
feed rich in protein such as oil meal is added to the ration.

Oat By-Products. The by-products of oatmeal manufacture are a number of cat feeds. Very often these are made up largely of hulls in which case they have about the same value as other coarse roughage and cannot be used as a concentrate. If, however, the feed contains considerable small oats and broken kernels they may have considerable feeding value. These feeds are often sold for higher prices than their real value would justify.
RYE (Secale)

There is only one species of the genus *Secale* (rye), which is of any economic importance. It is *Secale cereale*, the common cultivated rye.

Wild rye (*S. Montanum*), the supposed prototype of *S. cereale*, is found growing wild in southern Europe and western Asia.

*S. fragile* found in Hungary and southern Russia has a long beard on the glume (outer glume) extending beyond the lemma (flowering glume).

In common rye (*S. cereale*) the glume is shorter than the lemma and is tipped with a very short beard about 1/3 of an inch long.

Rye has been known in different languages by names some of which are: Anglo-Saxon, ruge, rig; Scandinavian, rugr; Old High German, roggo; Ancient Slav, rugii; Polish, rez; Illyrian, raz, etc.

The word *Secale* of the Latins recurs in a similar form, segal, among the Britons, and the Basques, cekela, zekhalea; but it is not known whether the Latins borrowed it from the Gouls and Iberians, or whether, the latter took it from the Romans.

The word *Secale* is from secare, which means, cut.

CULTIVATED RYE (Secale cereale)

Roots. Rye is able to grow on poorer soil than other grains. For this reason and the further reason that it is adapted to unfavorable climatic conditions it is called
the grain of poverty. This ability is possibly due, partly at least, to the primary root system, which differs from wheat, barley or oats, in consisting of 4 instead of 3 primary roots, thus enabling the plant to become easily and more quickly established. The roots are in general, similar to those of other grains. They branch profusely in the first foot of soil and penetrate the soil to a depth of 4 or 5 feet. They are thought to exceed other grains in their distance of ramifications and penetration. This fact together with the presence of 4 primary roots is thought to have something to do with the extreme hardiness of rye.

**Stems.** As compared with wheat, the stems of rye are tougher, slenderer and longer. The plant is annual, altho it is claimed that rye stubble in a field may sprout after long standing. If this is true, it is evidently a reversion to a perennial habit displayed by the form from which our cultivated rye came. As a matter of fact, Hackel claims that the original species is *S. Montanum* Guss, now found from central Asia to Spain. This species is perennial. Rye tillers in a manner similar to wheat.

**Leaves.** The leaves are similar to those of wheat except that they are narrower and longer. When young they are said to be more commonly closely recumbent than those of wheat.

**Inflorescence.** The inflorescence is a spike. It is usually somewhat longer than the spike of wheat, generally averaging not less than 5 inches, and is rather uniformly four-rowed. There are from 20 to 40 joints of the rachis. At each node is placed a single spikelet. All the spikelets, from base to
tip, are usually fertile.

**Spikelet.** Each spikelet consists of 3 flowers, 2 of which mature, the third being very small and rudimentary. Occasionally heads are found bearing many spikelets containing 3 or 4 fertile flowers.

The glumes are very narrow; the lemma is broad, keeled and bears a long terminal awn; the keel is strongly barbed. The palet is thin. The anthers are very much larger than in wheat. There are 2 lodicules and 2 styles.

**Pollination.** Rye is the only common cereal, besides corn, that is cross-pollinated. This may account for the fact that so few varieties have been developed. In rye, the pollen is impotent (weak, inactive) on the stigma of the same flower. Some workers indicate that the flowers open in the morning, somewhat later than either wheat, oats or barley. Artificial crossing of rye is comparatively easy. Experiments at the Colorado Station show, that between emasculation and pollination, the flowers must be protected, else stray foreign pollen is likely to effect pollination.

**Fruit and Seed.** The grain is free from the lemma and palet. It is long and narrow, more pointed at the apex and more blunt at the embryo end, and usually darker in color than wheat.

One hundred grains usually weigh between 2.25 and 3.75 grams, averaging about 2.5 grams. The cross section of the grain shows layers similar to those in wheat, altho different from them in details. For example, in rye the epidermal cells of the pericarp have very thick outer and inner walls, while the radial walls are thin. Next to the epidermis are rather
A. B.2.3.4.5.4.3.2.1.

Fig. 28. Rye spikelets, natural size. A, normal spikelet; B, spikelet dissected.

Fig. 27. Rye spikelet.

Fig. 26. Rye spikes. At the left, spike with many spikelets containing 3 and some containing 4 grains. At the right, normal spike with 2 grains per spikelet.
thin-walled cells which are followed by a layer of rather porous cells. The wrinkled surface of mature rye grains may be due to these porous cells. The integuments are feebly developed as is also the nucellus. The endosperm is similar to wheat; the outer walls of the single row of aleurone cells are thickened.

Rye contains proteins similar to wheat. Gluten is found in rye rendering it suitable for making raised or "light" bread.

The proteins in rye are usually less in quantity than in wheat. Rye gluten is of poorer quality than that of wheat, resulting in a less porous and a more tenacious bread.

HISTORY

It has been stated by early writers that rye was supposed to be native of the island of Candia (Crete)\(^1\)

Its cultivation is said to be comparatively recent. The Greeks appear to have had no acquaintance with it. The first mention of it in the Roman empire is by Pliny who speaks of secale, cultivated in Turin at the foot of the Alps.

Rye was cultivated A. D. 131 in Thrace and Macedonia under the name, briza. Its cultivation does not seem ancient in Italy since no trace of it has been found in the remains of the lake dwellings of the North of that country or of Swäitzerland and Savoy, even as late as the bronze age, wheat, barley and spelt were found, however.

It has been that that rye was unknown in the Orient.

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1. Grasses and Forage Plants, Flint (1897), p 168
No special name was known for it there, and the conclusion has been that it originated in Europe.

In 1907 Aaronsohn found stools of cultivated rye at Damascus in a field of wheat. Two days later, he found not far away, at Zebedoni, a stool of wild rye, S. Montanum.

From the fact that Damascus has so strongly resisted European influence up to the present time, he concludes, that this cultivated rye could not have been imported. Furthermore he thinks it possible that, without its being known outside, rye is being cultivated more or less, in the vicinity of Damascus.

These discoveries of Aaronsohn suggest that possibly Asia and not Europe is the country in which cultivated rye originated.

**PHYLOGENY**

According to Hackel rye was derived from wild rye (S montanum) which is found from Spain and Morocco to central Asia. Wild rye (S montanum) is perennial and the rachis breaks apart upon ripening. Both of these characters have been lost in the cultivated grain. It is stated that rye stubble after standing a long time in the field will sprout again, indicating a perennial tendency. This has not been observed in the case of wheat, barley and oats.

**GEOGRAPHICAL DISTRIBUTION**

The cultivation of rye is of minor importance in the United States. The following table shows the production in the United States and the continents for the year 1912:

<table>
<thead>
<tr>
<th>Place</th>
<th>Bushels</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>35,664,000</td>
</tr>
<tr>
<td>North America</td>
<td>38,328,000</td>
</tr>
</tbody>
</table>

---

Place          Bushels
Europe         1,329,752,000
Asia           32,953,000
Australasia    148,000

The ten leading states, in production, in the United States for 1912 are as follows:

States            Bushels
Wisconsin         6,240,000
Minnesota         6,026,000
Pennsylvania      4,935,000
Michigan          4,921,000
New York          2,112,000
New Jersey        1,260,000
Indiana           928,000
Ohio              884,000
Nebraska          830,000
North Dakota      864,000

TYPES AND VARIETIES

There are 2 main groups of rye, the fall rye and the spring rye. No botanical or other differences exist between them excepting time of planting. Fall planted rye usually gives a higher yield than spring planted rye.

Named varieties have appeared from time to time, but have not remained as fixed market varieties for any length of time.

Minnesota number 2 rye, a variety produced at the Minnesota
Experiment Station by selection since 1896, has proven the best variety in that state as well as in many other places. It has succeeded fairly well in maintaining its variety name.

COMPOSITION

Rye is similar to wheat in composition.

Henry gives the following composition of rye and its products:

<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Ash</th>
<th>Protein</th>
<th>Crude fiber</th>
<th>Nitrogen free extract</th>
<th>Ether extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye</td>
<td>11.6</td>
<td>1.9</td>
<td>10.6</td>
<td>1.7</td>
<td>72.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Rye flour</td>
<td>13.1</td>
<td>0.7</td>
<td>6.7</td>
<td>0.4</td>
<td>73.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Rye bran</td>
<td>11.6</td>
<td>3.6</td>
<td>14.7</td>
<td>3.5</td>
<td>63.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Rye shorts</td>
<td>9.3</td>
<td>5.9</td>
<td>13.0</td>
<td>5.1</td>
<td>59.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Rye fodder,</td>
<td>76.6</td>
<td>1.8</td>
<td>2.6</td>
<td>11.6</td>
<td>6.8</td>
<td>0.6</td>
</tr>
<tr>
<td>fresh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rye straw</td>
<td>7.1</td>
<td>3.2</td>
<td>3.0</td>
<td>38.9</td>
<td>46.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Rye silage</td>
<td>30.8</td>
<td>1.6</td>
<td>2.4</td>
<td>5.8</td>
<td>8.2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

USES

Rye grain is used for human and domestic animal food and for the manufacture of alcoholic liquors.

**Human Food.** As human food rye is used in the form of flour made into bread, and as cereal breakfast foods.

Rye flour contains protein which fits it for the making of raised, porous but rather dark-colored bread. The demand for this purpose in this country is small altho a century ago it is said to have been one of the principal articles of food in the New ----

1. Feeds and Feeding, Henry (1909)
England states.

In general the milling of rye is similar to that of wheat. One grade, only, of flour is made. Usually all the milling waste goes into feed which contains less protein and ash than wheat-mill products and sells at a lower price.

In Russian and other parts of Europe rye bread is one of the chief foods. It constitutes the main bread of more than 1/3 of the inhabitants of the entire continent. The following table shows the consumption per capita of wheat and rye for four leading countries.

<table>
<thead>
<tr>
<th></th>
<th>Wheat lbs</th>
<th>Rye lbs</th>
<th>Wheat and rye pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>United states</td>
<td>275</td>
<td>20</td>
<td>295</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>350</td>
<td>6</td>
<td>356</td>
</tr>
<tr>
<td>Germany</td>
<td>200</td>
<td>325</td>
<td>525</td>
</tr>
<tr>
<td>France</td>
<td>473</td>
<td>77</td>
<td>550</td>
</tr>
</tbody>
</table>

Animal Food. In combination with other grains rye is a valuable food for stock. In Germany 2-4 pounds are fed daily to work horses in combination with oats or oats and barley. For swine it is said to be equivalent to barley but should be fed with shorts, barley or other grain feed.

It is not popular with dairymen, at least to feed in large quantities. This seems to be due to the claim that it gives a bitter flavor to the butter. It is also said that it causes cows to "dry up" altho there seems to be no real foundation for this belief. For fall and early pasture, and as a soil ing crop, ----

rye is especially valuable.

As a bedding for live stock rye straw is especially sought after by horse trainers and horse exhibitors. However, as a feed it has little use being somewhat less valuable than other grain straws. This seems to be due to the stiffness and toughness of the straw.

**Industrial Uses.** Rye grain is used extensively in the manufacture of alcoholic liquors. A large part of the American crop is said to be used in this way. The refuse from the distilleries is used for feeding cattle.

Rye straw is used rather extensively in the manufacture of horse collars, paper and such articles as cheap straw hats straw board. For such purposes the grain is flailed out to prevent breaking the straw, or the grain is run thru specially designed threshing machines which keep the straw straight and in some cases bind it into bundles as it comes from the machines. It is also in demand for packing for fruit trees and other nursery stock.
CORN (Zea)

Habit. Corn is an erect growing annual grass, varying in height from 13 inches to 30 feet or more, the usual height being from 5 to 10 feet for the common corns.

Roots. When the seed germinates the primary root develops to a considerable length before the other roots are sent out. There is, however, no tap root. The root system is distinctly fibrous. Corn has been generally considered a shallow-rooted plant. The contrary is the case. At maturity the roots come to fill the upper 3 feet of soil, and under some conditions may reach to a depth of 4 or 5 feet or even more. Ten Eyck working in Kansas found corn roots at maturity fully 4 feet deep, and some were traced the depth of 5 feet. In North Dakota, Shepperd found the corn roots to a depth of 3$\frac{1}{2}$ to 4 feet for an average of 5 years. Hays reports corn roots 3 feet long although not that deep. In general it has been found that in most soils the number of roots below the first 2 feet is comparatively small. It is likely that most of these observations were made in the more humid sections of the country. Possibly deeper penetration would be more common in some of the drier sections of the Southwest, where the roots might be driven down in search of subsoil water in time of drought. In the earlier stages corn roots grow rapidly. Hunt says that a plant $\frac{3}{4}$ inch high was found with a root 3 inches long; one 3 inches high had a root 13 inches long; and 2 five inches high had roots 11 to 24 inches long. It is reported that a corn plant had in the upper 3 feet of soil a total of 1452 feet of

2. N. D. Bul 64, p 526.
3. Cereals in America, Hunt, p. 140
root. The supply of water and oxygen seem to have more to do with the root distribution than the temperature. The roots of corn are thrown off in whorls, varying in number from 2 to 10, one above the other. The internodes between whorls are very short. The entire group of whorls constitute the root-crown. Two kinds of underground roots are developed, the main vertical roots and the main lateral roots. The vertical roots curve out slightly from the crown and go directly downward. The laterals curve downward as they leave the crown, then extend horizontally for a distance, finally taking a downward course. Laterals that leave the crown at about the soil level slope gradually downward for a ways as indicated above, being about 4 to 5 inches below the soil level midway between the rows, that is about 22 inches from the hill. All main roots give off numerous finer branches and these in turn branch, so that in 3 to 10 weeks, under ordinary conditions, the soil between the hills, is completely filled with an interlacing mass of roots. From observations of a number of investigators (Sturtevant, Hunt, Newman, Ten Eyck) it appears that fully 2/3 of the entire root system occurs in the first 4 inches of soil. Ten Eyck has observed that altho the main laterals are several inches below the surface, they may send upward finer branches into within ½ inch of the surface. Thus here is a case where roots actually grow upward in the soil.

In addition to the ordinary underground roots, corn develops aerial roots, the so-called "prop" or "brace" roots. These arise in whorls at 1 or 2 and sometimes several of the nodes just above the surface of the ground. They usually start at a node 1 or 2 inches above the ground. They extend oblique-
ly downward to the ground. The portion above the surface is enlarged, but soon after entering the ground the root becomes the size of ordinary roots. A plant 43 days old and 5 feet high had 35 roots, 11 of which were brace roots. None of these had however penetrated the ground more than 1 1/2 inches. Their total length varied from 1 1/2 to 5 inches. On mature plants they have been found growing to considerable depths. As aerial roots they are unbranched, but they branch profusely when they penetrate the soil. In the soil they perform the functions of true roots in addition to bracing the plant. The aerial portions are covered with a mucilaginous material which prevents their drying out. Some observations have been made on the differences in the ability of aerial roots or varieties of corn in preventing the plants from being blown down. No practical progress seems to have been made along this line.

Stem. The stem of corn is jointed as in all grains. The internodes, however, are not hollow, but filled with a soft pith, which does not add materially to the stem strength. Thru this pith run numerous vascular-bundles. The fibers which are easily seen upon cutting a stem. The nodes are solid as in other grasses. The upper nodes are much longer than the lower ones. The nodes are alternately furrowed on the sides next to the leaf blades, and on the sides where branches or ears may occur. It has been found that the walls of the lower-internodes have been found to possess the power of assisting in erecting bent culms. This is in addition to the power possessed by the bases of the lower leaf sheaths which are supplied with a

ring of soft fast growing tissue for this purpose. As soon as
themstem is laid prostrate or bent over, this tissue begins to
grow on the lower side of the stem, forcing the culm into an
erect position.

The height of the culms is said to vary from 13 inches
for the Tom Thumb pop variety to 30 feet or more for varieties
in the West Indies. Tennessee has reported stalks 22 1/4 feet
high. The height varies with the variety as well as with the
climate, soil and moisture. In the South ears, so high they can
hardly be reached by an ordinary man are not uncommon, while
in the North in such states as North Dakota, Minnesota and the
New England states, as well as in the dry-farming sections of
the Southwest culms so short that it is necessary to stoop to
pick the ears, are common. The circumference of the average
culm, between the first and second nodes, of the dent or flint
varieties from about 3 to 4 1/2 inches.

Ordinarily 1 stem is produced from a seed. However, under
certain conditions such as thin planting, and under all con-
ditions for some varieties, the plants produce "suckers" which
correspond to the "stools" of wheat, as to their morphology.
Suckers are secondary stems or branches arising from the lower
nodes. These branches develop their own roots. Suckers of
corn are undesirable, for they do not, as a rule, produce ears.
Some varieties produce branches from the nodes higher up on
the culms. In the best varieties the only branches produced
are the very short ones each of which bears at its outer end
a single ear of corn.
Leaves. Corn leaves are arranged alternately on opposite sides of the stem. They vary in number from 3 to 20. The blade is long and flat. The ligule closely invests the stalk acting as a rain guard. Water that runs down the stem and leaf blade is prevented from entering the space between the culm and leaf sheath by this tightly fitting ligule. The leaf has a very wavy effect along the edges and at the base. This is due to the more rapid growth of the cells at these points. The result is an elasticity of the leaf which enables it to withstand wind. Corn is well adapted to dry conditions. A microscopic examination of a section of a leaf reveals large wedge-shaped (bulbiform) cells located in the upper epidermis between the prominent parallel veins. In ordinary humid weather these cells are filled with water and cause the leaf to lie flat. In hot, dry weather, as the water is lost from these cells they contract and cause the leaf blade to roll up, reducing the evaporation and enabling it to survive a certain period of drought. In addition to this method of adaptation to dry conditions, the cuticle of the lower surface of the leaf is much thickened. In Iowa it was found that the number of leaves of dent corn varied from 12 to 15 of which only about 12 were active at one time, due to the dying off of the lower leaves before the upper ones develop.  

The length of the leaves varies from 2 to 4 feet and the width from 2 to 5½ inches. At the Missouri Station the external leaf surface on 12 living leaves of a single plant was found to be 24 square feet. At the rate of 12,000 plants per acre which is not unusual, the leaf surface is found to equal

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1. Cereals in America, Hunt, p 142.
2. Ibid. p. 143
Fig. 30. Kernels of corn and teosinte.

A. Teosinte; B. Soft corn; C. Rice pop corn; D. Pearl pop corn; E. Flint Corn; F. Yellow dent corn; G. Pod corn; H. Pod corn with the glumes removed; J. White dent corn.

Fig. 29. Portion of a corn culm.

A. Leaf sheath; B. Leaf blade; C. Ligule; D. Sheath of the next leaf above.
more than 1/4 of a million square feet, or about 6 times the area on which the plants stood. The leaves have been found at the Michigan Station, to constitute more than 1/3 of the dry matter when the grains were in the milk, and a little more than 1/5 when the plant was ripe. During this time the percentage of dry matter in the culm remained about the same, the decrease in the percentage of dry matter in the leaves being offset by a corresponding increase in the ears.1

Inflorescences. Ordinarily, corn is monoecious, that is the stamens and pistils are borne in separate inflorescences on the same plane. The staminate flowers are in a panicle at the top of the stalk; this inflorescence is known as the "tassel." The panicle is made up of a number of branches in each of which may be recognized a central and several lateral spikes. The pistillate flowers are borne in a spike which is placed in the axils of the leaves lower down on the stalk. When mature, the pistillate inflorescence is called the ear.

Staminate inflorescence (tassel). This inflorescence is a panicle. The rachis are long, slender and spike-like. One may distinguish between the central and lateral spikes of the branches. In the central spike there are usually from 4 to 11 rows of spikelets in pairs. Lateral branches usually have only 2 rows of spikelets in pairs. Of each pair of spikelets, 1 is pedicellate, the other sessile or in some cases both may be sessile. The groups of spikelets may overlap. Each normal staminate spikelet bears two flowers, each producing 3 perfect stamens. The glumes are 7 to 12 nerved and about equal

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1. Cereals in America, Hunt, p. 143
in size. The lemma is 3-5 nerved, the palet 2 nerved, both being near the same size, thin and hyaline. The 2 lodicules are fleshy. The anthers are long. The upper flower of a spikelet matures first; its palet is larger than the lemma, while in the lower flower, the lemma is larger than the palet.

Pistillate inflorescence (ear). The ear is borne on a short branch the so-called "shank". This consists of a number of very short internodes with 1 modified leaf at each node. The blade has been reduced, the leaf sheath alone remaining. The collection of leaf sheaths on the shank forms the "hush" of the ear. The pistillate spikelets are arranged in rows along a fleshy axis the "cob." Each spikelet is 2 flowered, the lower one being abortive, the lemma and palet remaining. There are 2 theories as to the morphology of the ear of corn. The view of Hackel and Harshberger\(^1\) is that the ear is the result of a fusion of a number of 2-rowed pistillate spikelets. Since each spikelet is 2-flowered and the lower abortive, there is often formed 2 distinctly paired rows. The cob is said to be formed by the fusion of separate rachis. Opposed to the above theory is that of Montgomery\(^2\) who holds that the ear develops directly from the central spike of some tassel-like structure similar to the well known corn tassel. His evidence for the belief may be summarized as follows:

1. He has found tassels in which only a few pistillate flowers were found on the central spike, up to those in which the central spike had developed into a fair sized ear of corn.

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A. Portion of a tassel showing arrangement of spikelets; B. Groups of 3 spikelets each; C. Groups of 2 spikelets each; D. Single spikelets; E. Spikelet with the glumes and other parts spread; F. Spikelet dissected.

1. Glume; 2. Lemma; 3. Stamens
4. Palet; 5. Pedicel

Fig. 31. Portion of a corn tassel in bloom.
2. He observed a case in which the lateral spikes as well as the central one had developed pistillate flowers, forming a number of 4-rowed "nubbins" surrounding a central well-developed 12-rowed ear.

3. The central spike develops pistillate flowers much more readily than the lateral ones of the tassel. The central spike has the greater number of rows of spikelets.

4. He has observed the development of pistillate flowers from staminate. This development is as follows:
   
   (a) Pedicellate spikelet shortens becoming sessile, with the difference between the 2 flowers becoming greater.
   
   (b) The lower glume shortens and thickens.
   
   (c) Lemma and palet of the upper flower of each spikelet becomes reduced while the lower flower becomes abortive.
   
   (d) Sessile flower becomes pistillate.
   
   (e) Both flowers become pistillate.

Recently East and Hayes\(^1\) have expressed an opinion very similar to that of Montgomery. Quoting from them, "The ear of maize, then, is a meristic variation produced from the central spike of the tassel of the lateral branches of teosinte or of a teosinte-like plant, and not a fusion of the lateral spikelets. Hunt discusses this matter as follows:\(^2\) "It is assumed that wild maize was a branched plant containing perfect flowers (both carpels and stamens) on the terminal tassel, and also at the end of the branches. Since the plant is wind fertilized and the pollen tends to fall, the carpellate flowers in the terminal tassel would be less perfectly

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1. Conn. Bul. 127
2. Cereals in America, Hunt, p. 146
plenized than those on the branches below. The pollen on the branches would tend to fall to the ground, thus being of little value. The plants which had the greatest development of carpels on the branches and of stamens in the terminal tassels would tend to survive. As the end of a branch became laden with a collection of grains (ear) the short branch would best hold the ear from drooping. Thus the culm of the branch (now called shank) has become a succession of nodes with short internodes. Each ear still bears the sheath of the leaf, the blade being much reduced in size or aborted. This collection of leaf sheaths is called the husk. The branch has been telescoped."

Each normal pistillate spikelet has 2 flowers. The spikelet is subtended by 2 leathery, hard glumes. One flower, the lower of each spikelet is abortive, having a lemma and palet only. The other flower of the spikelet is fertile. In some varieties, especially in Zea tunicata, both flowers of a spikelet are well developed, giving rise to twin grains. There is one ovule with a single long style, the corn "silk." An opening occurs in the wall of the ovule at the base of the style. This is called the stylar canal. After pollination the silk dries up. Lodicules are absent.

Hermaphrodite flowers. In corn such flowers are common. Hermaphroditism in corn is considered to be a physiological fluctuation produced because of excessive rainfall and fertile soil. Hermaphrodite flowers are far more common on the tassel than on the ear. East and Hayes record a sterile dwarf mutation which had nothing but hermaphrodite flowers, Hermaphrodite
flowers have the stamens reduced. Lodicules are well developed in staminate flowers, reduced in hermaphrodite flowers and altogether absent in pistillate flowers. Montgomery observed hermaphrodite flowers on normal types of ears. The plants from these seeds came true to type. The seed was normal in every respect except it had 3 fully developed stamens coming from near the base of the ovary. The plants were of unusual appearance, being about 5 feet high, with short internodes and broad leaves.

**Opening of the flowers and pollination.** Cross pollination is the rule in corn. Self pollination, resulting in in-breeding, results in a loss of vigor. Wind is the chief factor in pollen dissemination, altho bees visit the flowers and are evidently concerned in pollen dispersal, altho they are relatively of less importance than wind.

In the case of the staminate inflorescence, the first flowers to open are those near the upper part of the central spike; blooming spreads both upwards and downwards, more rapidly downward. On the other branches of the tassel the same order of blooming occurs.

The time of pollen shedding depends upon weather conditions. Cold, wet or very hot weather retards or even prevents the shedding of pollen. On sunshiny days most of the pollen is shed during the forenoon and in some instances late in the afternoon of the same day. It is worthy of note that anthers of corn shed their pollen only on the first day they appear. Individual tassels usually remain in blossom from 4 to 10 days or even more, possibly depending upon the weather. Gernert has made some valuable observations on pollination in corn.

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In investigating a number (59) varieties of corn as to the time elapsing between appearance of anthers and appearance of first silks he finds marked variation. Both dichogamy (maturity of pollen and stigmas at different times) and Homogamy (simultaneous maturity of pollen and stigmas) may occur. Furthermore, in dichogamous individuals, protandry (anthers mature first) or protogyyny (stigmas mature first) may occur. Out of 2794 individuals in 59 varieties examined, he found 243 individuals homogamous, 92 protogynous, and 2459 protandrous. It appears, then that in corn protandry is the rule. In protandrous individuals, the first appearance of the silks occurred from 1 to 23 days after pollen shedding, altho the average is 2 days. Varieties dealt with in the above were pod, pop, flint, dent, soft and sweet. Collins records the discovering of protogynous habit in a variety of maize introduced from Granada, Spain.¹

The same writer has made observations as to the number of days intervening between appearance of tassel and anthers. He finds out of 3319 individuals in 57 varieties that in the greater number (514) the anthers appeared 9 days after the tassel and that in more than half of the individuals the first anthers appeared in 7 to 10 days after the tassels bearing them appeared.

Pollen is produced in great quantities. It is estimated that each tassel produces 20,000/ to 50,000,000 grains of pollen. Lazenby estimated that for each ovule in dent maize there are about 45,000 pollen grains produced.

The size of pollen grains in corn vary. Pollen produced by central spikes is larger than that produced by laterals. Livingston observed that in Leaming corn the pollen grains from the central

¹ Bureau of Plant Industry, Circ. 107.
spikes were 20/25000 of an inch larger on the average than those from lateral spikes. Cernert finds that the size of pollen grains varies in different varieties. Of 12 varieties examined he finds that the average diameter of the pollen grain of corn varies from .03 to 0.1 of a millimeter. They are not exactly spherical but more ellipsoidal in shape. Corn pollen soon shrivels after being shed, altho this does not destroy its germinating power. However, pollen does not remain viable much longer than 24 hours after shedding.

Corn "silks", the styles are long and plumose. The first to silks/appear on the ear are those from grains slightly above the base. Generally 4 or 5 days intervene between the appearance of lowest and uppermost silks. Hence it will require 4 or 5 days to pollinate all the silks of an ear. Unfavorable climatic conditions, such as cold, wet weather or extremely hot days may account for the incomplete "filling out" of ears.

The silks are receptive throughout their length.¹ Best results are obtained when silk receives the pollen within a few days after its emergence from the husk. Silk exposed by splitting down the husks proved receptive. Again fertilization is not prevented when tips of pistils are cut off.

Fertilization and Development of the Grain. Double fertilization in corn was observed for the first time by Guignard. In the mature embryo-sac of the ovule of corn there are the following nuclei: (a) Three nuclei at the micropylar end, one of which with its surrounding protoplasm constitutes the egg; the other 2 are synergid; (b) Three nuclei at opposite end of the embryo-sac.

Fig. 33. An ear of corn "in the silk" with the husks removed to show the silks (styles). A pistillate inflorescence.

Fig. 34. Corn Spikelets. At the left, a developing ear composed of many pistils, each representing a spikelet, which after fertilization develop into grains.

Fig. 35. Longitudinal section of a kernel of dent corn. X 3

Fig. 36. Transverse section of a kernel of dent corn. X 3
the antipodal nuclei; (c) Two nuclei in the central region, the 2 polar nuclei. The 2 sperm nuclei of the pollen tube are discharged into the embryo-sac. One sperm nucleus fuses with the egg nucleus; the fertilized egg develops into the embryo. The other male nucleus fuses with the 2 polar nuclei; the fusion of these 3 bodies taking place altogether. The resulting body develops into the endosperm. Hence in corn there is double fertilization.

**Xenia in corn.** Xenia is the term applied to the phenomenon in which some character of the male appears at once in the seed. For example, in crossing a strain of corn having yellow endosperm with a strain having white endosperm, the grains produced are all yellow in every case, not matter which is used as the male parent. Xenia is shown only in the event the parent having yellow endosperm is used as the male parent. Yellow endosperm character is dominant over white endosperm. Pollen from the plant bearing yellow endosperm will carry this character; pollen from the plant bearing white endosperm will carry the white character. When pollen, bearing the yellow endosperm character, is placed on the stigma of the grain having white endosperm, the pollen tube will discharge into the ovule 2 male nuclei, each bearing the character for yellow endosperm. One sperm nucleus fuses with the egg nucleus, the other sperm nucleus fuses with the 2 polar nuclei. The result of this trifle fusion is the endosperm. Now, since yellow is dominant, the grain that is formed by this double fertilization will have a yellow endosperm. Thus double fertilization explains the phenomenon of xenia. It is of course true that if in the above pollen from the white endosperm bearing plant were used, xenia would not be shown. Xenia, the visible effects of double
fertilization, has been found in the following conspicuous cases in corn:

(In each case below the plant mentioned first is the female)

Non-starchy seeded plants crossed with starchy seeded plants always give starchiness.

Non-yellow endosperm crossed with yellow show yellow.

Non-colored aleurone layer crossed with purple give purple.

Non-colored aleurone layer crossed with red give red.

East and Hays have formulated the following law regarding xenia:

"When 2 races differ in a single visible endosperm character in which dominance is complete, xenia occurs when the dominant parent is male; when they differ in a single visible endosperm character in which dominance is incomplete or in 2 characters both of which are necessary for the development of the visible difference, xenia occurs when either is the male."

Just prior to fertilization the ovary of corn is bent from the perpendicular such that the silk, instead of pointing directly out from the cob, points in a direction longitudinal to the cob. The ovary is on a pedicel (rachilla) about 2.5 mm. long. To this are attached the glumes, lemma and palet.

The ovule almost fills the ovary cavity. It is attached to the wall of the ovary by more than one-third its circumference. As in all grasses, the ovule is campylotropous. The outer integument is incomplete while the inner covers the entire ovule except the micropyle. This opening is just above the point of attachment of the lemma. The ovary wall at this time, that is before fertilization, possesses the following coats:

2. Many layers of parenchyma tissue, varying somewhat in size. Those toward the outside are smaller and longer and the other layers, except 2 or more layers next to the inner epidermis, which layers are composed of small elongated cells.


True records the presence of a pit "a short distance from the base of the style, on the posterior side." This is undoubtedly the stylar canal described by Poindexter.

The outer and inner integuments vary in thickness from 2 to 4 layers. The very large embryo sac is located at the base of the nucellus.

After fertilization the following changes take place in the maturing grain:

1. Outer integument disappears.

2. Cells of inner integument become flattened due to presence from within.

3. The middle and inner cells of pericarp become compacted.

4. Cells of nucellus disappear to a large extent.

5. Hardening of the cell walls of the pericarp.

6. Fusion of pericarp and ovule.

The mature grain of corn. The mature grain of corn varies considerably in shape. The most varieties it is flattened in a plane at right angles to the length of the cob. The broader surface is roughly triangular in outline, being broader above than at the base. Some varieties have grains that are broader than deep, others as deep and still others deeper than broad. Further discussion of kernel shape will be discussed under "types of corn."
The groove indicates the position of the embryo. At the tip of a mature grain may still be found the papery remains of the palet and lemma. The point of the grain where it was attached to the cob is the peduncle of the flower. The opposite indented end of the grain is often marked by a small point at the bottom of the depression, which point is the remnant of the style. A longitudinal section of the corn kernel parallel with the broad surface will show the following parts:

1. Pericarp of several layers.
2. Episperm, two layers of inner integument.
3. Perisperm, remains of nucellar tissue.
4. Aleurone layer, outermost layer of endosperm; a single row of cells.
5. Starchy endosperm.
6. Horn endosperm
7. Embryo
8. Tip cap

The pericarp, episperm and perisperm form the hull. It is possible to mechanically separate the starchy endosperm into 2 parts, the crown starch and tip starch.

Hopkins, Smith and East give in detail the structure and composition of the different parts of the corn kernel. The following is a fair average of the relative proportions of the divisions of the grain:

Embryo, 11%
Tip cap 1.5%
"Hull" (pericarp, episperm, perisperm) 6%

1. Illinois Bul. 37, pp 77-112.
Aleurone layer 3-14%  
Horny endosperm 45%  
Starchy endosperm 25%  

Of course there is marked variation in the proportions of these parts and their chemical composition. For example low, medium and high protein show the following total percentages of the different parts.  

<table>
<thead>
<tr>
<th>Name of parts</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tip caps</td>
<td>1.20</td>
<td>1.46</td>
<td>1.62</td>
</tr>
<tr>
<td>Hulls</td>
<td>5.47</td>
<td>5.93</td>
<td>6.09</td>
</tr>
<tr>
<td>Horny gluten (Aleurone layer)</td>
<td>11.61</td>
<td>9.51</td>
<td>13.32</td>
</tr>
<tr>
<td>Horny starch (endosperm)</td>
<td>37.15</td>
<td>47.08</td>
<td>44.89</td>
</tr>
<tr>
<td>Crown starch</td>
<td>21.26</td>
<td>17.01</td>
<td>13.88</td>
</tr>
<tr>
<td>Tip starch</td>
<td>13.71</td>
<td>8.48</td>
<td>6.28</td>
</tr>
<tr>
<td>Germs</td>
<td>9.39</td>
<td>11.53</td>
<td>11.93</td>
</tr>
</tbody>
</table>

It will be seen from the above that the aleurone layer, horny endosperm and germ contain the most protein.

Chemical analysis of the parts show that the hull contains less protein than any part of the grain, about 4%. The embryo is richer in protein than any other part of the grain, containing 20 to 25%. The horny endosperm contains about 90% starch and 10% protein. The starchy endosperm is poor in total amount of protein (5 to 8%). The germ is rich in oil, being composed of about 35 to 40% of oil and 19 to 20% protein; 80 to 85% of the total oil content of kernel occurs in the embryo. The following table from Illinois Bul. No. 87 gives the percentage distribution of  

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1. Illinois Bul. 87, p. 37.
chemical constituents among the physical parts of corn with medium protein content.

<table>
<thead>
<tr>
<th>Name of parts</th>
<th>% Total Protein</th>
<th>% Total Oil</th>
<th>% Total Ash</th>
<th>% Total Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>In tip caps</td>
<td>1.14</td>
<td>.69</td>
<td>1.06</td>
<td>1.56</td>
</tr>
<tr>
<td>In hull</td>
<td>2.07</td>
<td>1.08</td>
<td>3.06</td>
<td>6.80</td>
</tr>
<tr>
<td>In aleurone layer</td>
<td>16.67</td>
<td>12.21</td>
<td>9.56</td>
<td>7.15</td>
</tr>
<tr>
<td>In Horny endosperm</td>
<td>42.36</td>
<td>2.32</td>
<td>7.38</td>
<td>51.12</td>
</tr>
<tr>
<td>In starchy endosperm</td>
<td>17.63</td>
<td>1.27</td>
<td>4.39</td>
<td>22.41</td>
</tr>
<tr>
<td>In Germs</td>
<td>20.14</td>
<td>32.43</td>
<td>74.55</td>
<td>4.97</td>
</tr>
<tr>
<td>Total</td>
<td>100.01</td>
<td>100.00</td>
<td>100.00</td>
<td>100.01</td>
</tr>
</tbody>
</table>

In high-protein corn kernels, the horny endosperm extends up to and comes in contact with the embryo, the tip starch being entirely separated by it from the crown starch. In low-protein corn kernels, the amount of horny endosperm is reduced, tip and crown starch is continuous between it and the embryo. The embryo is much larger in high-oil kernels than in low-oil kernels.

Embryo. The embryo of corn has the same structure as that of wheat. On account of its large size the parts are readily made out. Its structure is best studied in a longitudinal section cut at right angles to the broad surface. The primary root is conspicuous; the 2 laterals may be recognized as 2 swollen areas near its base. The scutellum, or single cotyledon, is traversed by a vascular system. The hypocotyl is just beneath the plumule, being terminated at its base by the primary root.
Pericarp. This consists of an epidermal layer somewhat cutinized, below which are numerous layers of cells, the walls of which are thickened and pitted. The spisperm consists of 2 layers of thinner walled cells, which are collapsed. The perisperm is even more indistinct than the episperm.

Color of corn kernel. The yellow of a corn kernel is in the endosperm. East and Hayes have found 2 yellow colors, which behave in inheritance as separate factors, altho they are either identical or very similar in chemical composition. These colors occur as rhombic plates in the starch cells and are insoluble in water, easily soluble in either, chloroform, benzine, benzol and carbon bisulphide.

Purple and some red grains owe their color largely to a coloring material located in the aleurone layer. Both red and purple pigments are soluble in water. In some deep red grains the color is due to a red sap in the pericarp.

In white corn, there is an absence of pericarp, aleurone and endosperm colors.

Germination of Corn. The germination relations of corn may be judged from the following data: Sachs says: optimum 33° C., maximum 46° and minimum 9.5° C. Haberlandt gives the maximum germination temperature for corn as 44-50° C. Nobbe gives the following: Optimum 32° C, maximum 57° C and minimum 9.9° C. Sturtevant says that 6.5° is the lowest temperature at which corn will germinate.

Sturtevant further shows that corn germinates in from 10 to 20 days at a temperature of 6.5° C., while at from 9.2° C. to
14.70° it would germinate in from 5 to 9 days. In germination the primary root appears first, at the tip of grain; soon the plumule breaks thru the pericarp at about the middle of the grain.

At a very young stage the germinating grain consists of primary root projecting at peduncle end and the plumule emerging thru a slit in pericarp at about the middle of the grain and pointing in the opposite direction. On the sides of the primary root, 2 secondary ones soon appear making a total of 3 roots in the primary root system. The root tips form a gum on their surfaces before entering the ground. The scutellum (cotyledon) is hypogenous, remaining in the grain, underground, supplying food to the developing parts. The plumule is surrounded by a sheath thru which the first leaves emerge. Coupin thinks that the sheath is the ligule of the cotyledon.

HISTORY

There has been some claim that corn is of eastern origin. However, Humboldt, Sutrtevant and others have proven that it is a native of America.

According to tradition, Karlsefn in 1002 A.D. and Thorfin in 1006 A.D., both Norsemen brought ears of corn from what is now Massachusetts. Ears of corn have been found with Mummies of Mexico and Peru. Columbus discovered corn when he first landed on American soil. At that time it was cultivated on the continent from Maine to Chili and it is likely from all that can be learned that its native home is Mexico. Columbus took corn back to Spain with him. From there it spread into France and Italy. From Italy it was taken into Switzerland and Hungary, thence to Austria and eastern Europe.

It was taken into the valley of the Rhine from Switzerland,
and from Portugal into Asia.

Corn was first successfully cultivated in North America along the James river in Virginia in 1608. From that time its culture has increased until it is now our most important cereal.

**PHYLOGENY.**

Corn is related botanically to a native Mexican grass, teosinte (Euchloena Mexicana). It is supposed to have been gradually developed from it more or less directly. Pod corn is supposed to be a type intermediate between the original Mexican grass and other corns of the present day.

Fertile hybrids of teosinte and maize are known; the product being a plant described by Watson as Zea canina.

Bailey is inclined to think that Zea canina is the prototype of Indian corn while others believe that Zea canina and Indian corn (Z. Mays) both developed from the same plant.

**KEY TO ECONOMIC TYPES OF CORN**

A. Each grain (kernel) enclosed in a pod or husks (Formed by the enlarged glumes)...........Zea tunicata (Pod Corn)

AA Grains naked (glumes reduced to small scales at base of grains)

B. Grains with popping properties; small; smooth; endosperm entirely or nearly all corneous...Zea everta (Pop corn)

BB Grains without popping properties.

C. Corneous endosperm absent; dent absent or slight; grains soft and starchy......Zea amylacea (soft corn)

D Grains more or less wrinkled and shiivedeled.

E Endosperm entirely or nearly all translucent and horny......Zea saccharata (Sweet corn)
EE. Upper half of endosperm horny and translucent, lower half starchy. ... *Zea amyleasaccharata* (Starchy sweet corns)

DD. Grains smooth; not wrinkled.

E. Center endosperm starchy, enclosed at crown and sides corneous endosperm; dent absent or very slight.

......................... *Zea indurata* (Flint corn)

EE. Endosperm starchy thru center from embryo to crown of kernel; corneous endosperm at sides only; crown dented...................... *Zea indentata* (Dent corn)

**DESCRIPTIONS OF SPECIES**

*Zea tunicata* (pod corn)¹ Each kernel is inclosed in a pod or husks, and the ear is inclosed in husks. The husks which inclose the individual kernels are the empty glumes, floral glumes and palets which have developed and which in other types are very small membraneous scales.

Vernacular names¹: California Corn, Cow corn, Egyptian Corn, Forage Corn, Husk Corn, Oregon Corn, Pod Corn, Primitive Corn, Rocky Mountain Corn, Stock Corn.

*Zea everta* (pop corn) Characterized by the excessive proportion of the corneous endosperm and the small size of the kernels and ear. The best varieties have a corneous endosperm thruout. "The corneous endosperm gives the property of popping which is the eversion or turning inside out of the kernel thru the explosion

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1. Descriptions are largely from Office Experiment Stations, Bul. 57.

2. Office Experiment Stations, Bul. 57, p. 15.
of the contained moisture on the application of heat. A small
deposit of starch endosperm does not greatly interfere with
this property of popping but when the starchy endosperm is in
excess, as in a flint corn, the kernel does not evert, but the
corneous portion only explodes or splits leaving the starchy
portion unchanged. The true pop corn is hence tender in its
eating; the false pop corn has a tender portion of limited size
only."

Group 1. Rice pop. Ears inclined to taper considerably;
grains very sharp or pointed at the crown.

Group 2. Pearl pop. Ears only slightly tapering; grains
smooth or rounded at the crown and more compact on the cob.

*Zea indurata* (flint corn). Starchy endosperm inclosed in
a corneous endosperm. Corneous endosperm varies in thickness
and in some varieties it is very thin at the crown of the kernel
and may result in a slight depression.

*Zea indentata* (dent corn). Corneous endosperm at the sides
of the kernel, the starchy endosperm extending to the crown.

By drying and shrinkage of the starchy matter the crown of the
kernel is drawn more together and indented in various forms.
Corneous endosperm varies in height and thickness in various
varieties.

*Zea amylacea* (soft corn) No corneous endosperm. Thru the
uniformity of the shrinkage in ripening there is usually no
indentation, yet in some varieties an indentation may appear,
but splitting the kernels will determine the class to which
it belongs. Like flint in general shape.

*Zea saccharata* (sweet corn). A translucent, having kernels
in a more or less crinkled, wrinkled or shriveled condition. The
power to develop starch grains to maturity has been lost. The starch that is formed remains small, angular and does not have the appearance of the typical corn starch granule. In the sweet corns the endosperm breaks down into cane sugar and various hexoses, and probably accounts for the shrunken condition of the kernels. Sweet corns may simply be regarded as dent, flint, and pop corns that have lost the power to mature starch normally.

*Zea amyleasaccharata* (starchy sweet corn). External appearance of the kernel that of sweet, but examination shows that the lower half of the kernel is starchy, the upper half horny and translucent. The question has been raised as to whether this character of the endosperm may not be due to xenia.

**GEOGRAPHICAL DISTRIBUTION**

The production of corn by continents in 1911 is given in the following table:

<table>
<thead>
<tr>
<th>Continent</th>
<th>Bushels</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>2,740,261,000</td>
</tr>
<tr>
<td>South America</td>
<td>32,539,000</td>
</tr>
<tr>
<td>Europe</td>
<td>585,650,000</td>
</tr>
<tr>
<td>Africa</td>
<td>83,475,000</td>
</tr>
<tr>
<td>Australasia</td>
<td>13,933,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,460,820,000</strong></td>
</tr>
</tbody>
</table>

The total production for the United States in 1911 was 2,531,483,000 bushels.

The bulk of this was produced in seven states of the corn belt as follows:
<table>
<thead>
<tr>
<th>State</th>
<th>Acreage in</th>
<th>Production in Bushels</th>
<th>Ave. Yield Per A.</th>
<th>Av. yield per acre 1900-1909 Bushels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>10,150,000</td>
<td>334,850,000</td>
<td>33.0</td>
<td>34.5</td>
</tr>
<tr>
<td>Iowa</td>
<td>9,850,000</td>
<td>305,350,000</td>
<td>31.0</td>
<td>32.3</td>
</tr>
<tr>
<td>Missouri</td>
<td>7,400,000</td>
<td>192,400,000</td>
<td>26.0</td>
<td>28.6</td>
</tr>
<tr>
<td>Indiana</td>
<td>4,850,000</td>
<td>174,800,000</td>
<td>36.0</td>
<td>34.7</td>
</tr>
<tr>
<td>Nebraska</td>
<td>7,425,000</td>
<td>155,925,000</td>
<td>21.0</td>
<td>27.4</td>
</tr>
<tr>
<td>Ohio</td>
<td>3,900,000</td>
<td>150,540,000</td>
<td>38.6</td>
<td>35.6</td>
</tr>
<tr>
<td>Kansas</td>
<td>8,700,000</td>
<td>126,150,000</td>
<td>14.5</td>
<td>22.4</td>
</tr>
</tbody>
</table>

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**COMPOSITION OF CORN AND CORN PRODUCTS**

<table>
<thead>
<tr>
<th>Name</th>
<th>Water</th>
<th>Ash</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>Crude fiber</th>
<th>Nitrogen free extract</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dent corn</td>
<td>10.6</td>
<td>1.5</td>
<td>10.3</td>
<td>2.2</td>
<td>70.4</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Flint corn</td>
<td>11.3</td>
<td>1.4</td>
<td>10.5</td>
<td>1.7</td>
<td>70.1</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Sweet corn</td>
<td>3.8</td>
<td>1.9</td>
<td>11.6</td>
<td>2.8</td>
<td>66.3</td>
<td>8.1</td>
<td></td>
</tr>
<tr>
<td>Pop corn</td>
<td>10.7</td>
<td>1.5</td>
<td>11.2</td>
<td>1.8</td>
<td>69.6</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>Corn meal</td>
<td>15.0</td>
<td>1.4</td>
<td>9.2</td>
<td>1.9</td>
<td>68.7</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Corn cob</td>
<td>10.7</td>
<td>1.4</td>
<td>2.4</td>
<td>30.1</td>
<td>54.9</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Corn cob meal</td>
<td>15.1</td>
<td>1.5</td>
<td>3.5</td>
<td>6.6</td>
<td>64.8</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Gluten meal1</td>
<td>9.5</td>
<td>1.5</td>
<td>33.8</td>
<td>2.0</td>
<td>46.6</td>
<td>6.6</td>
<td></td>
</tr>
<tr>
<td>Gluten feed</td>
<td>9.2</td>
<td>2.0</td>
<td>25.0</td>
<td>6.8</td>
<td>53.5</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Hominy feed (chop)</td>
<td>9.6</td>
<td>2.7</td>
<td>10.5</td>
<td>4.9</td>
<td>64.3</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

---

2. Aleurone layer tissue.
<table>
<thead>
<tr>
<th>Name</th>
<th>Water</th>
<th>Ash</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>Nitrogen</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germ oil meal</td>
<td>8.6</td>
<td>2.4</td>
<td>21.7</td>
<td>3.3</td>
<td>47.3</td>
<td>11</td>
</tr>
<tr>
<td>Corn bran</td>
<td>9.4</td>
<td>1.2</td>
<td>11.2</td>
<td>11.9</td>
<td>60.1</td>
<td></td>
</tr>
</tbody>
</table>

**Dried Roughage:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Water</th>
<th>Ash</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>Nitrogen</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodder corn (ears if any remaining)</td>
<td>42.2</td>
<td>2.7</td>
<td>4.5</td>
<td>14.3</td>
<td>34.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Corn Stover (ears removed)</td>
<td>40.5</td>
<td>3.4</td>
<td>3.8</td>
<td>19.7</td>
<td>31.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Corn husks</td>
<td>50.9</td>
<td>1.3</td>
<td>2.5</td>
<td>15.3</td>
<td>23.3</td>
<td>0.7</td>
</tr>
<tr>
<td>New corn Product</td>
<td>3.8</td>
<td>4.1</td>
<td>5.2</td>
<td>31.9</td>
<td>47.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Corn leaves</td>
<td>30.0</td>
<td>5.5</td>
<td>6.0</td>
<td>21.4</td>
<td>35.7</td>
<td>1.4</td>
</tr>
</tbody>
</table>

**Fresh Green Roughage:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Water</th>
<th>Ash</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>Nitrogen</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodder Corn all varieties</td>
<td>79.3</td>
<td>1.2</td>
<td>1.8</td>
<td>5.0</td>
<td>12.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Dent varieties</td>
<td>79.0</td>
<td>1.2</td>
<td>1.7</td>
<td>5.6</td>
<td>12.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Dent, kernel glazed</td>
<td>73.4</td>
<td>1.5</td>
<td>2.0</td>
<td>6.7</td>
<td>15.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Flint varieties</td>
<td>79.8</td>
<td>1.1</td>
<td>2.0</td>
<td>4.3</td>
<td>12.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Kernels glazed</td>
<td>77.1</td>
<td>1.1</td>
<td>2.7</td>
<td>4.3</td>
<td>14.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Sweet varieties</td>
<td>79.1</td>
<td>1.3</td>
<td>1.9</td>
<td>4.4</td>
<td>12.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Sweet corn ears removed</td>
<td>80.0</td>
<td>1.2</td>
<td>1.4</td>
<td>4.9</td>
<td>12.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Corn leaves, husks</td>
<td>66.2</td>
<td>2.9</td>
<td>2.1</td>
<td>3.7</td>
<td>19.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Stripped corn stalks</td>
<td>76.1</td>
<td>0.7</td>
<td>0.5</td>
<td>7.3</td>
<td>14.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Teosinte</td>
<td>90.1</td>
<td>1.4</td>
<td>1.4</td>
<td>2.7</td>
<td>4.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

1. Ground or shell after removing the pith
2. Euchloea luxwrians, closely related to Indian corn (Zea mays)
USES FOR FOOD

Human food. Corn in its different forms is one of our important food crops. Of the cereals it ranks next to wheat. For human consumption corn is used in the form of hominy, corn meal, starch, breakfast food and liquors.

In general corn is interchangeable with other cereals. Its fuel or energy value is the highest of the cereals being approximately 1800 calories per pound or about 100 calories above the average.

This is due largely to the fat which is 4.3% while the average for cereals is about 2.5%.

Corns differ slightly in flavor the white being usually milder in flavor. Meal from white corn is generally preferred in the souther states and in Rhode Island and yellow in the northern states as a whole. In the southwest where there are considerable Spanish people the blue, black and red varieties of corn are used largely.

Corn meal is a low priced food stuff and makes an economical dish.

Animal food. Corn is one of the leading animal foods. For fattening purposes it is the superior of other grains.

Its high content of starch and oil suits it to this purpose as well as for a heat producer.

Being low in protein and ash it is not suited to the production of bone and muscle hence it is not adapted to young and growing animals. A

As animal food corn and its products are used in the form of whole or ground grain, gluten feed, corn oil cake, germ oil meal, corn bran, cob meal, whole fodder, silage, bark meal, etc.
Industrial Uses. It is estimated that corn is used in the form of over 100 products.

Many of these are manufactured products such as starch, syrup, sugar, oil, rubber, gun-cotton, etc.

The following outline shows most of the important corn products and their source.

A. Entire plant used as stock food in the form of fodder and silage.

B. Use of parts.

I. Young ear.
   a. Human food; b. Husks for mattresses, mats, etc.

II. Stalk.
   a. Fodder; b. Fertilizer; c. naked stalk for paper.
   d. Pith.
      1. Packing for battleships
      2. Gun cotton
      3. Pyroxlin varnish
   e. Bark (shell after removing pith)
      Animal food (New corn product)

III. Leaves
   a. Cattle and poultry food;
   b. paper; c. Fertilizer.

IV. Ripe ear
   a. Entire ear for animal food;
   b. Cob.
      1. Fuel; 2. Pipes;
   c. Glumes or chaff from ear (corn down) upholstering and padding mattresses.
   d. Kernels (Seeds).
1. Human food as corn flour (Flourine, Maizena, Oswego).
   Corn meal, cracked corn, hominy, corn grits, cerealine,
   samp corn, corn crisp, corn flakes, etc.

2. Starch and sugar.
   a. Dentrine; b. Glucose;
   c. Grape sugar, Caramel;
   d. Commercial starch.

3. Syrup (Karo)

   e. Corn germ.
      Corn oil, paint, lubricating and illuminating oil,
      rubber, salad dressing, preserving, etc.

   f. Hull (corn bran).
      Stock food.
FLAX FAMILY (Linaceae)

Habit of Plant. Annual or perennial herbs or shrubs, with single branching stems from 4 to 50 inches in height.

Root. Plants are tap rooted. Each tap root bears a number of more or less slender lateral branches.

Stem. The stems are single. In some of the perennial wild species (L. compactum)¹ crowns bearing crowded groups of stems are produced by the slender rhizomes. In other cases (L. Kingii) numerous stems ascend from the low woody base which is in reality a very much shortened single stem.

In some species and varieties the stems are branched towards the top only while in others they are branched throughout. The branching is largely paniculate to a greater or less extent. The stems and branches vary in degree of stiffness. Some are more or less angular, others being round. The stems are covered with tough, fibrous bark. They are usually glabrous or nearly so. In Linum arkansanum they may be slightly rought to the touch thru a fine short almost imperceptible down (scabro-puberulent).

The stems are frequently covered with a fine white powder or bloom (glaucous).

Leaves. The leaves are simple; narrow, nearly sessile and usually alternate tho sometimes opposite. (L. catharticum).²

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They vary in shape from linear to linear lanceolate and oblong, and from sharply awn-pointed (acute, mucronate) to blunt, or rounded at the end (obtuse).

The leaf margins are usually entire. In some species (L. rigidum, L. arkansanum) the margins are very finely toothed or ciliated the end of each tooth or cilia containing a gland (glandular serrulate, glandular ciliate). The leaves are without stipules or have stipular glands in their place (L. puberum). The leaves are frequently glaucous.

Inflorescence. The inflorescence may be a few-flowered corymb or the flowers are more or less scattered on the branches.

Flowers. The flowers are perfect, regular, symmetrical and five parted in all respects. Sepals are imbricated, persistent, usually more or less lanceolate or occasionally ovate. The petals are more or less wedge shaped (cuneate) and may be as long as or longer than the sepals. They usually last for only a day or less (ephemeral). They are twisted in the bud (convolute).

In color they may be of some shade of yellow or blue, orange with rose-tinted base, red or white.

Stamens. There are 5 stamens with their filaments united at the base (monadelphous). The outer whorl of stamens is wanting or staminodial.

Pistil. The pistil consists of a five-celled ovary each cell (loculus) bearing two ovules. There are 5 styles, which may be free, united to the stigmas or united part way from the base.

Fruit and Seed. The flax fruit is a five-celled capsule
with 2 seeds in each cell, which is partially or completely divided into 2 cells by a false partition (septum) between the 2 seeds making the capsule 10-celled.

**GEOGRAPHICAL DISTRIBUTION.**

(See "" of genus Linum).

**PHYLOGENY OF FAMILY**

(See "" of genus Linum).

**GENERAL ECONOMIC IMPORTANCE**

(See "" of Linum usitatissimum).

**GENERA OF LINACEAE**

This family contains only 1 genus, Linum. The name Linum is the Latin for flax. The word linen means made from flax or of flax. It is from lin, flax, plus the en suffix. It is from these and other similar foreign names that we get our common words linen, lint, linseed and line.

The genus Linum is said to contain 135 or more species. In many instances the distinctions between these species is so slight that they are scarcely recognized and they are only of botanical interest.

A number of species have been used somewhat for ornamental purposes especially in Europe and Asia. Two of these species have yellow flowers, Linum trigynum, which originated in India and L. campanulatum which comes from southern Europe and from Egypt. A third variety L. grandiflorum has red flowers. Some species are very rare, and not very widely known. Such is L. catharticum, the leaves of which have a bitter taste and
are sometime employed as a purgative. Some writers state that L. usitatissimum is the only industrial species and the only one ready cultivated.

The species have been divided into 2 groups, - those having yellow flowers and those having blue, white, pink or flesh color-ed flowers. L. usitatissimum comes in the latter group.

L. crepitans has been recognized by some writers as a cultivated species. It grows less tall than L. usitatissimum, has much thicker stems which have a tendency to branch, producing more abundant flowers and therefore more seed.

Three species L. usitatissimum, L. vulgare and L. crepitans were reported as being cultivated in Russia in several varieties of both of the above kinds, but the difference in these varieties was so slight and they so easily blend that even those qualified often failed to perceive it.

One European authority says that the tall, slender plants without branches with little seed and the short stalks with a number of branches and considerable seed, may all be obtained from one sort of seed and that no field has ever been seen growing only the 1 type. This suggests that these types are all 1 species and are not really capable of further specific or even varietal classification as has been attempted in some cases.

**GEOGRAPHICAL DISTRIBUTION OF GENUS LINUM**

Whatever its origin this genus has had a wide distribution over the world. Its ancient use is evident when we learn
that the Egyptian mummies are found wrapped in linen and the flax plant is carved on their tombs. Its antiquity is further established by a reference to linen in Genesis, Chapter 41, verse 42.

The introduction of flax into Europe dates from very early times. It is thought that it was introduced into the United States as a cultivated plant at least, by the Pilgrims.

Bessey has reported 135 species of which 22 are said to be native to America. Most of these are annuals, some are perennial.

In Europe there is cultivated somewhat sparingly a form of flax in which the seed balls burst open and scatter the seeds.

Experiments with perennial flax (L. perenne L.) have not proven it to be of commercial importance. It has been found that L. lewissii, one of the varieties occurring widely throughout western United States has been used by the Indians for making cord, fish nets, basket frames and other similar purposes. It is known as Rocky Mountain flax.

PHYLOGENY OF GENUS LINUM

It is not definitely known where flax originated but the most ancient species is thought to be L. angustifolium, a form found growing wild from the Canary Islands to Palestine and Caucasus. This is the species said to have been grown by the Swiss lake dwellers and the ancient inhabitants of Italy.

L. usitatissimum, common flax, is said to be the ancient
flax of Mesopotamia, Assyria and Egypt. It has been suggested that these 2 principal forms of flax exist in cultivation and have probably been wild in their modern areas for the last 5000 years at least. Their transitions and varieties are so numerous that they may be considered as one species comprising 2 or 3 hereditary varieties, which are again divided into sub-varieties. 1

An able Russian flax grower contended that white blossom fiber flax is not stable and that on his farm it passes gradually into blue flower flax within 3 or 4 seasons. 2 He also contended that the shorter, much branched seed flax quickly develops into long fiber flax when properly handled under a new environment and vice versa. As a result of these and other observations he concludes that there are no truly fixed varieties of flax.

Bolley concludes, however, as a result of his observations that there are several well marked varieties of cultivated flax. 3 Of these he finds at least 2 species, L. usitatissimum including all of the small seeded varieties and L. humille Hill, including the large seeded varieties. He is also inclined to believe that at least 2 more species should be separated, viz., the common white flower and the common white seeded, but since botanists have not yet recognized these he does not separate them.

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Bolley gives the following classification:

**L. usitatissimum**

1. Common blue flowered fiber flax (Dalganets)
2. " " " seed " (Rogotch)
3. Dehiscent ball seed flax (Kudratch)
5. White flowered white seeded.

**Linum humille** (Big seeded Sicilian type)

1. Sicilian, big seeded, blue flowered seed flax, sometimes grown as a winter variety (Sicilisky)
2. Big seeded, white flowered, white seeded flax.
3. Indian seed flax, Egyptian seed flax and Argentine seed flax; large seeded varieties of a character almost midway between the Sicilian big seeded flax and the common Russian seed flax.

There seems to be many intermediate grades or strains between the 2 species classified above and within the varieties named. This is likely due partly to intermingling and mixing thru careless handling of seed and possibly to cross breeding.

Whether or not these species and varieties have found their way to any extent in our flax sections, certain it is that with possibly rare exceptions, all cultivated flax strains or varieties in this country are still treated as belonging to one species L. usitatissimum.

**COMMON FLAX 9L. usitatissimum**

Habit. Common flax is an annual upright herb which under

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cultivation grows to a height of 1 to 4 feet.

Root. Common flax is a rather dainty surface feeder with a small root system consisting of a somewhat slender tap root sparingly supplied with slender branches in the first 12 to 18 inches of soil. The tap root runs downward vertically to a depth of 3-4 feet in some cases. No net work of roots is formed near the surface of the soil neither do the roots occupy the soil so completely as do the roots of most plants. In spite of their limited number and extent the flax roots have the ability to subdue raw land especially native sod. They seem to be able to reduce the soil to a good state of tilty and for this reason flax is frequently planted on new land.

Stem. The stem is single, erect, branching in the upper part, rarely to the base. As it matures it becomes rigid at the same time retaining considerable elasticity due to the bast fibers.

In the stem three tissues areas are recognizable, the pith, the wood and the bark. Besides the customary epidermis, parenchyma and cambium layer the flax bark contains the bast or flax fiber cells. These bast fibers give flax straw its great financial value since they make up the part which is made into linen. The bast cells lie between the tender thin walled cells of the parenchyma and cambium and by "retting" the stems it is possible to separate them from the adjoining tissue.

Leaves The leaves are narrow entire and blunt at the apex.
Inflorescence. Is loosely cymose.

Flowers. The flowers of common flax vary in color from white to a deep blue. The same plant bears flowers of the same color. Yellow flowered varieties are not found in this species. The petals are large and conspicuous, wedge shaped (cuneate) about twice as long as the sepals. They are convolute in the bud. They are glabrous with somewhat irregular margins.

Pollination. Studies of flax varieties indicate that there is quite close pollination. Individual flowers produce seed freely whether associated with other flowers or not although the structure of the flowers is such that they might allow cross pollination. Examination of flax flowers at the proper time shows anthers in close proximity to the stigmas which are profusely covered with pollen.

Artificial crossing is done with comparative ease simply by removing the anthers before they are ripe (emasculating) protecting the stigmas and applying the foreign pollen at the receptive stage. In emasculating the petals and parts of the sepals may also be removed.

Bolley suggests¹ that perhaps cases where flax is said to be "running out" may be traced to careless seed handling and mixing whereby the common type seeds characteristic of a particular region soon predominates over a poorly cared for, imported strains. At the same time it is possible that cross pollination may in part account for this deterioration since if crossing can take place with comparative ease in nature it

¹. M. D. Bul. 71. p 211.
would account for the disappearance of the imported strains when it is largely surrounded by a variety common to the entire region.

**Fruit.** The flax fruit is a round capsule known commercially as the seed ball. The seed ball is composed of 5 fused carpels. The balls are divided into 5 true chambers (loculi) by means of 5 true partitions (septi) extending from the wall (pericarp) to the axis. Each loculi contains two seeds and is divided more or less incompletely into 2 loculi by means of false septi. The seed balls are 1/4 inch or more in diameter. When fully ripe the balls are easily separated into parts at the points where the carpels are joined.

**Seed.** The seeds vary in length from 1/7 to 1/5 inch. They are lenticular, compressed, slightly longer than wide. They have a very smooth, polished surface and vary in color, from yellow to dark brown, light brown being the standard color.

The Minnesota station found that as far as oil content, general chemical composition, germinating powers and oil properties are concerned no appreciable difference existed between light brown and dark brown seeds.¹

A mucilagenous material which quickly becomes sticky (viscid) in hot water is found filling the epidermal cells. It is this substance which gives flax its medicinal value.

The embryo of the seed consists of 2 cotyledons and a small radicule and plumule. Surrounding the embryo there is a thin layer of endosperm which in the mature seed contains no starch.

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Germination of Seed. The average vitality of flax seed has been found to be about 35%. In Canada it was found that the decrease in vitality during 5 years was as follows: 81, 82, 75, 49, and 26%.

GEOGRAPHICAL DISTRIBUTION OF COMMON FLAX

Flax is now widely distributed over the world. It is produced commercially to a greater or less extent in Great Britain, especially Ireland, Sweden, Denmark, Holland, Belgium, France, Russia, Austria, Germany, Spain, Portugal and India. In the latter country it is raised more for seed than fiber. It has found its way into Algeria, Natal and Japal and Australia. In Argentina it is grown extensively for oil production. The U. S is one of the largest seed producing countries but produces a very small amount of fiber. The following table shows the production by continents for 1909. 1

<table>
<thead>
<tr>
<th></th>
<th>Seed Bushels</th>
<th>Fiber Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>21,876,000</td>
<td></td>
</tr>
<tr>
<td>South America</td>
<td>41,813,000</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>23,334,000</td>
<td>1,283,122,000</td>
</tr>
<tr>
<td>Asia</td>
<td>13,289,000</td>
<td>96,402,000</td>
</tr>
<tr>
<td>Africa</td>
<td>8,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100,320,000</strong></td>
<td><strong>1,334,524,000</strong></td>
</tr>
</tbody>
</table>

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The large flax seed producing states in 1912 were North Dakota, Montana, South Dakota and Minnesota. Michigan is probably our largest fiber producing state altho it is not given at all as a seed producing state.

**Composition.** Flax seed contains 20-26% protein and 30-39% oil. The average composition of flax seed and old and new process linseed meal follows:

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Flax Seed</th>
<th>Old Process Linseed Meal</th>
<th>New Process Linseed Meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>9.1</td>
<td>9.2</td>
<td>10.1</td>
</tr>
<tr>
<td>Ash</td>
<td>4.3</td>
<td>5.7</td>
<td>5.3</td>
</tr>
<tr>
<td>Protein (N x 6.25)</td>
<td>22.6</td>
<td>32.9</td>
<td>33.2</td>
</tr>
<tr>
<td>Crude Fiber</td>
<td>7.1</td>
<td>3.9</td>
<td>9.5</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>23.2</td>
<td>35.4</td>
<td>33.4</td>
</tr>
<tr>
<td>Fat</td>
<td>33.7</td>
<td>7.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Use of Flax.** Flax seed is used to a limited extent as animal food. For such purpose it should be ground. The stems of straw (halm or haalm) has a limited value for animal food. The greatest value of flax comes from the use of the seeds in making linseed oil. The manufacture of linseed oil is carried

on in manufacturing plants having investments of upwards of a million or more dollars.

The oil is pressed out of the crushed, cooked seeds and is refined into the market oil. The residue from the process is the oil cake. It is sold either as oil cake or ground and placed on the market as oil meal and used for stock food.

By proper processes the fiber of the stem is removed, cleaned and woven into cloth. Our finest linens are made from foreign grown flax, the best of which are grown in Belgium in a region thru which flows the River Lys. The creamy Flemish flax from which the finest linen fabrics are made is grown in this section.

Flax fiber is also used for making shoe thread, carpet yarns, fishing lines, seine-twines, and to a limited extent for binding twine. It is used to some extent for upholstering, for insulating cold storage plants, refrigerator cars and ice boxes.

American grown flax are not used for the production of the highest grade of products made from the fiber.
"POTATO FIELD IN BLOOM"

ON

THE SWEET RANCH,

CARBONDALE, COLORADO
Solanaceae (Potato Family).

Representatives of this family are herbs (*S. tuberosum*, common potato, *Nicotiana* spp., tobacco, etc.), shrubs (*Lycium* spp.), vines (*S. dulcamara*, bittersweet), or some tropical species (*Datura* spp.) trees. The leaves are alternate, rarely opposite, exstipulate (without stipules) entire, dentate, lobed or dissected. The inflorescence is most commonly cymose, sometimes imperfectly racemose, umbellate or paniculate. The flowers are regular or nearly so, perfect, and varying in color. Calyx inferior, with usually 5 united lobes. Corolla sympetalous, mostly 5-lobed, the lobes induplicate-valvate or plicate in the bud; the corolla varies considerably in shape: rotate (*Lycopersicon*), bell-shaped (*Physalis*), funnel-form (*Lycium vulgare*), salverform or tubular (*Petunia* spp.). There are as many stamens as corolla lobes, alternate with them, and inserted on the tube; in most genera the stamens are all equal and bear perfect anthers but in *Petunia*, for example, there are four perfect stamens, the fifth being very much reduced or entirely absent; anthers 2-celled, dehiscence at the apex or along the sides. The single ovary is usually 2-celled (rarely 3-5 cells, as in *Lycopersicon* spp.), the numerous ovules on an axile placenta; style slender, simple; stigma terminal. The fruit is either a berry (*Solanum, Lycopersicon, Physalis*) or a capsule (*Datura, Nicotinia, Petunia,*) bearing numerous seeds; the seeds
have a fleshy endosperm.

The Solanaceae is a large family, chiefly tropical, having about 1600 species in 70 genera. A number of these are important medicinal and food plants. Here are included such economic forms as: Red or Cayenne pepper (Capsicum anuum), tobacco (Nicotiana tabacum), common Irish potato (Solanum tuberosum), egg-plant (Solanum melongena), tomatoes (Lycopersicon spp.), belladonna (Atropa belladonna) furnishing the atropine of commerce, thorn apple (Datura metel), an ornamental cultivated plant, petunia (Petunia spp.), etc.

KEY TO IMPORTANT GENERA

a. Fruit a berry

b. Anthers opening by a terminal pore or slit
   ....Solanum (potato and egg plant)

bb. Anthers opening longitudinally

   c. Flowers white..............Capsicum (pepper)

   cc. Flowers yellow.............Lycopersicon (tomatoes)

aa. Fruit a capsule

d. Capsule generally prickly
   ....Datura (Thorn apple, Jimson weed)

dd. Capsule not prickly

   e. Flowers paniculate or racemose; stamens nearly uniform in length
      .......Nicotiana (tobacco)

   ee. Flowers solitary; stamens very unequal
      .......Petunia (petunia)

SOLANUM

Members of this genus are either erect herbs (as S. nigrum, the black nightshade, S. tuberosum, common potato, etc.), shrubs or climbing herbs (S. dulcamara,
bittersweet). In most species the stems and leaves bear a stellate (star-shaped) pubescence. Leaves alternate, extipulate (without stipules), lobed or pinnately dissected. The inflorescence is cymose (S. dulcamara, bittersweet), umbellate (S. nigrum, black nightshade), racemose (S. carolinense, horse nettle), or rarely paniculate. The flowers are perfect and regular; white (S. tuberosum varieties) (S. nigrum), blue (S. elaeagnifolium, silver-leaved nightshade, S. tuberosum varieties), yellow (S. rostratum, sand bur) or purple (S. dulcamara). Calyx bell-shaped or rotate generally 5-parted or 5-cleft. Corolla rotate or rarely broadly bell-shaped, the tube very short, the limb plaited, 5-angled or 5-lobed. Stamens 5, inserted on the throat of the corolla, filaments short, the anthers converging around the style, usually dehiscent by a terminal pore or sometimes by a short intorse terminal slit, or sometimes longitudinally. Ovary superior, usually 2-celled; style slender, simple; stigma terminal. The fruit is a berry, the calyx persistent at the base or in some species (S. rostratum) enclosing the berry; fruit with many seeds.

There are about 900 species of Solanum, widely distributed, but most abundant in tropical America.

KEY TO IMPORTANT SPECIES

A. Not tuber-bearing

B. Plant not prickly or spiny

C. Erect herbs or shrubs
D. Fruit ovoid or egg-shaped, yellow with purple or violet streaks or splashes, often 4-6 inches long
   ...S. muricatum (Pepino, Melon Pear)

DD. Fruit a small, spherical berry, not over 1 inch in diameter

E. Peduncles 1-3 flowered; ripe berries green
   ...S. triflorum (Wild Tomato, Cut-leaved Nightshade)

EE. Peduncles bearing small cymes, 3-10 flowered; ripe berries black
    ...S. nigrum (Black or Common Nightshade)

CC. Climbing vines
    S. dulcamara (Blue Bindweed, Bittersweet)

BB. Plants prickly or spiny

F. Berry not enclosed by the calyx

G. Flowers light blue or white; fruit a small, spherical berry
    ...S. carolinense (Horse-Nettle)

GG. Flowers purplish; fruit large
    ...S. melongens (Egg plant)

FF. Berry enclosed by calyx
    ...S. rostratum (Sand Bur, Buffalo Bur)

AA. Tuber-bearing

B. Corolla rotate

C. Sepals mucronate

D. Points long and tapering

E. Leaves oval...
   ...(S. tuberosum, S. spont. de Heller (S. Papa d'Amarilla.

EE. Leaves elongated......S. Immite

DD. Points long, not tapering much; leaves ovals....................S. chiloense

DDD. Points medium length; leaves indulate
       ........S. edinense

1. Key from The Botany of Solanum tuberosum, F. Berthault.
DDDD. Points short

E. Leaves oval

F. Anthers straight, smooth, somewhat elongated....
   :S. Utile
   :S. stoloniferum
   :S. boreale
   :S. collinum

FF. Anthers swollen, roughened. stigmas bifid....S. maglia

EE. Leaves almost glabrous; leaflets elongated, sessile....
   .......S. candolleanum

CC. Sepals not mucronate

D. Sepals ending in short point

E. Leaves with numerous leaflets

F. Leaflets oval, slightly hairy

G. Flowers white, S. sabini

GG. Flowers violet....
   .......S. cayenxi....

FF. Leaflets very hairy
   S. verrucosum

FFF. Leaflets smooth....
   :S. fraxinifolium
   :S. suaveolens
   :S. colombianum

EE. Leaves simple or with few leaflets
   .......S. caripense

DD. Sepals rounded on the end

H. Leaflets numerous

I. Slightly hairy....
   .......S. fernandezianum

II. Hairy :S. caldasii
   :S. etuberosum Lindl.

HH. Leaflets simple or with few leaflets
   :S. montanum
   :S. nava
   :S. muricatum
   :S. boliviense
BB. Cololla star-shaped

C. Calyx mucronate; leaves soft hairy.....

...S. polyadenium

CC. Calyx not mucronate

D. Leaves compound

E. Flowers more than 10 mm. across

F. Stigmas ovoid; berries heart-shaped......

:S. commersonii
:S. ohrondii
:S. cardiophyllum
:S. lanceolatum
:S. Jamesii

FF. Stigmas bifid. S. ochranton

FFF. Berries shaped like tenpins

:S. juglandifolium
:S. oxycarpum

EE. Flowers about 5 mm. across....

...S. appendiculatum

DD. Leaves simple.......S. bulbocastanum
THE POTATO
(Solanum tuberosum)

This species (Solanum tuberosum) includes all the varieties having any value worth mentioning for food, and which are cultivated except in an experimental way. The varieties of this species are commonly called the Irish or common potato but are also called white, English, or round potato.

Habit. The potato is a branched, more or less spreading herb, growing to a height of two to five feet or more. It has annual aerial stems but is practically perennial by means of its biennial tubers or underground stems.

Roots. Upon the whole, the development of the root system is less potential (pronounced) than in most other crops. The roots are fibrous and fine. They penetrate the soil to a depth of 2 to 4 feet and frequently extend horizontally 2 feet from the plant.

Stem. Potato stems are of two general kinds, the underground stems (stolons) the ends of which develop into the tubers, and the ordinary aerial or foliage stem. The latter will be discussed at this time, the discussion of the tuber (stem) being left until later.

Stem (aerial). The aerial (or foliage) stem of the potato is herbaceous and generally erect when young but usually becomes spreading later. It is smooth and generally solid. At first it has no ribs but as it develops it becomes more or less quadangular. The internodes according to the variety, the vigor of the plant
and the size of the seed tuber vary from 3/4 to 2-3/4 inches in length.

Morphologically the anatomically no difference has been found between the stems of the different species and varieties. Domestication and culture, soil and climatic changes, and fertilizers do not appear to have affected the stems in either of these respects. This does not apply, however, to the underground stems (the tubers) as will be seen later.

All the stems with their branches are not green in all varieties and types, some being more or less red or violet. The stems are frequently referred to as the halm or haulm.

**Leaves** Potato leaves are compound pinnate, with more or less petioled leaflets, the petiole bearing a number of supplementary leaflets which vary in number and importance with the age of the plant. The rachis is deciduous on the stem. The leaflets are oval, acuminate, base heart shape or oblique in shape. The leaves as well as the stems are characterized by a narcotic smell. They are practically of no economic use, altho they may be eaten by cattle to some extent, and in some cases, like spinach, by man.

At the beginning of their development the leaves are often simple but they increase in complexity with age. The single terminal leaflet which frequently appears alone is soon followed by two lateral leaflets, and others follow, the leaf soon becoming distinctly
pinnatifid. It is said that this feature of the leaf development has been frequently overlooked, owing to the fact that the simple character is of slight duration.

Considerable differences have been found to exist in the appearance of the leaves of the different agricultural varieties.

In general, four main groups have been differentiated, and are given by Berthault¹ as follows:

1. Short leaves with large toothed (serrate) leaflets;

2. Leaves smooth, and larger with longer petioles bearing fewer leaflets, resulting in a less crowded appearance;

3. Leaflets reduced in size and regularly crumpled;

4. Leaflets large, round and very much crumpled.

Many types intermediate between these have also been found, in many cases the individuals uniformly grading from one type to another. This variation in leaf characters is found with different densities of foliage, character of stems, types of branches, and tuber characters. In some cases rather close association of these characters has been observed, while in other cases no such relationship appears to exist.

Plants with a dense foliage and crumpled dark green leaves were found to be early and the tubers to have,

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1. The Botany of Solanum tuberosum, F. Berthault (French)
usually, small parenchymatous cells averaging more than
100 to the square millimeter (mm.). However, an exception
is noted where low cellular density (large cells)
occurs in a variety having the general characters of
this group.

Plants with less dense foliage and large smooth
leaves were found to be medium early (medium prococity)
and to make up the varieties with large tubers of low
cellular density; no exceptions have been noted to this
relationship. The group of plants with small regular
crempled leaflets contain those varieties which are
late, of good starch content, the tubers having large
cells (low density). A fourth group of plants with
crumped leaves and often large stems which are colored
contains varieties with small parenchymalous cells and
others with large (llose) cells. The varieties of this
group are less homogeneous (alike) in foliage, at the
same time being variable in cell character.

In general, there appears to be a somewhat close
relationship between leaf morphology (form) and ap-
pearance, and the anatomy (structure) of the tuber. The
drawings and descriptions of the first potatoes intro-
duced into Europe, made by Clusius about 1588 and Ger-
arde about 1597, are said to show that these first intro-
ductions had a dense foliage with numerous leaflets and
frequent supplementary leaflets and that in this respect
they are medium between the two extreme types discussed
above. The drawings of Clusius appear to show plants with
less crumpled leaves than the drawings of Gerarde, indicating that each of these men recognized a different foliage type. Many variations from these early types have occurred.

Seed propagation from types with leaves similar to those of Clusius and Gerarde have resulted in foliage types of such leaf characters as to authorize the conclusion that 2 close species or groups exist among present cultivated varieties, one of which corresponds to the plants described by one of these early writers, the other type corresponding to the description of the writer. A third group which is less homogeneous than the others is supposed to be a mixing of these two groups. This view is of course based upon the assumption that our present varieties are descended from the types described by Clusius and Gerarde, which it seems is likely open to question.

It is found, however, that the cultivated types of both Europe and the United States conform in general appearance to those early described types which leaves no concrete examples for substantiating the claim that other types are the foundation of present varieties. The evidence does not, however, seem to be of sufficient weight to justify an absolute and final conclusion.

The variations obtained might be due to the segregation of hybrid characters according to Mendel's law. A question which has not yet been studied. However, work by R. N. Salaman with two generations of apple hybrids

has, according to Berthault, thrown no light on the segregation of foliage characters in seedlings of apples. The potato foliage characters considered have been found to fluctuate between two extremes and the variations, more or less distinct, appear to be of recent acquisition.

However, these leaf characters on account of their lack of constancy and stability are considered of little value in classification of species. They are not ever recognized as varietal characteristics, even tho they are useful as a basis for agricultural classification due to the fact that they indicate special qualities of the individuals studied.

Flower. The flowers of the potato occur in a cyme, which is borne on a peduncle varying in length from 2 3/4 to 4 inches. The peduncle length depends upon the age of the plant and inflorescence; the increase in length continues thruout the blossoming season. The pedicles vary from 5/32 to 1/4 of an inch in length. Each one bears a flower. All the cultivated potatoes (S. tuberosum) are characterized by pointed calyx lobes (sepals) each being terminated by a spine. ¹ These spines usually vary in length from 5/32 to 1/4 of an inch, tho they sometimes reach a length of 3/8 of an inch. Their length is not a variety character but it varies with the date the flowers are formed, the vigor of the plant, and the humidity of the air.

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¹. One exception has been observed in the case of a yellow flowered plant which was also abnormal in petal and stamen characters.
There seems to be no knowledge of any changes having occurred in calyx characters from the earliest date that records are available. This same constancy applies in most cases to the other floral parts.

The corolla is tubular, with 5 lobes. It is white, yellow, purple or blue in color and 1 to 1 1/2 inches in diameter. The corolla is not divided into a star in all cultivated varieties.

It has been found that the corolla characters are not always hereditary in progeny from seed, seedlings from white flowered varieties often producing individuals with colored flowers, and vice versa.

There is a single whorl of 5 stamens which alternate with the corolla lobes and are attached to the tube. The stamens are straight with erect yellow anthers which are longer than the filaments and open only at the top.

Two kinds of pollen grains have been observed. Those of most varieties are variable in size, irregular in shape, roughened with an impotent (weak) appearance. Those of the other type are smooth, spherical and potent. The latter kind were found only on varieties which bear fruit and they seem to be necessary to bring about fertilization.

Some varieties have been found to produce both kinds of pollen grains but these plants have not been found to produce fertile (fecund) flowers. Hence while the presence of round pollen grains seems to be necessary to the production of fruit, their presence by no means assures
Fig. 37. Potato flower X 2.

Fig. 38. Potato anther X 10

Fig. 39. Transverse section of potato

1. Eyes
2. Skin or periderm
3. Cortex
4. Vascular ring
5. External medulla
6. Internal medulla.
that the ovary will be formed or fruit produced. The ovary consists of 2 carpels with numerous ovules in each.

**Opening of Flower and Pollination.** The anthers are ripe at the same time that the stigmas are receptive.

The flowers have been found to open between 5 and 6 o'clock a.m. (in Illinois) and slightly close about dusk.¹ The pollen is usually shed on the second day of blooming and at this time the pistil is most receptive.

The anthers open at the top, cup-like and in some cases split for a short distance. The pollen is considered to be carried by the wind. The flowers produce no nectar and are not visited by insects to any extent, altho several species have been reported around the flowers. East concludes from observations of his own (and of others) that self-fertilization is natural to the species.¹ The flowers wither about the fourth day in the profuse seeding varieties.

Considerable variation has been found in the blooming of different varieties under different conditions and different degrees of "breeding." In the varieties which produced flowers without setting fruit, East¹ found anthers containing no pollen, others with shriveled grains containing no protoplasm, while others produced viable pollen, though never in large quantities.

Some writers report that fragrance is correlated with pollen yield, but East says¹ he found no noticeable fragrance in American varieties. It is commonly thought

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that potatoes do not fruit as freely now as formerly, due to the supposedly correct believe that large production of tubers has caused a degeneracy in seeding power. While many of the best varieties seldom bloom and more rarely set seed, still at the same time some of the best varieties have been found to bloom freely, and under proper conditions to set seed. Fraser (N. Y.) says as a result of working with 300 varieties, many which were grown for several years, that it is seldom that a variety will not bloom at some time of its life and, furthermore, he found that many of the heaviest yielding varieties bloomed as freely as those of less value.

At the Wyoming Station the 10 heaviest yielders bloomed in different parts of the state in 1895 and 1896. On the other hand, the Rev. J. R. Lawrence (Mass.) found in 300 varieties some that never bloomed.

This variation in blooming was observed as early as 1722-1726, when varieties were found to produce flowers in Carolina and the Bahama Islands, while in Virginia and to the north no flowers were produced. Many varieties which did not produce seed in Connecticut, seed quite freely in Maine, Minnesota, and Connecticut. Hence there appears to be no real correlation between blooming and seeding power, at least between varieties.

The above instances show definitely in no case, however, that profuse seed producing plants are the high tuber yielders as compared with the low or non-seed producing plants of the same variety grown at the same time
under identical conditions. Possibly within these narrow limits there is some correlation between seed and tuber production.

In many varieties the flowers do not open. In the Pearl variety Fitch finds\(^1\) that tuber productiveness "is universally proportionate to the sexual development of the plant; that the most degenerate tuber is grown by the plant which carries fully developed flowers and virile pollen; while those plants on which only female portions of the flowers appear to be fully developed produce tubers intermediate in form and yield, and that the best tubers and the largest yield are produced by the type of plant who buds do not even swell." Furthermore, these buds do not show any other color than green and they soon blast (wither) and break off.

Artificial Pollination (Crossing). This Process is comparatively simple. The corolla and stamens are cut away before the blossom is fully developed. The remaining part is protected with a small bag or wrapped loosely in paper.

When the stigmas receptive the covering is removed and pollen is dusted on from the male parent with a small brush (camel's-hair). If two days after pollination the pistil has not fallen, the process is repeated.

The covering is replaced and left until the fruit begins to form, when it should be removed allowing the fruit access to air and light. The fruits should be

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gathered when ripe and dry. The viability of the seed is usually better if they are squeezed out of the fruits and dried in place of allowing them to remain in the berries all winter where there is an opportunity to decay.

It is found better to mature no more than two fruits on a plant but "several flowers should be pollinated in order to stimulate growth in the peduncle of the cyme."

**Fruit.** The fruit is a round (globular) or short oval berry with two locules containing numerous seeds attached to the thick axil placenta and embedded in a green acid pulp. They vary in size from 3/4 to 1 1/2 inches in diameter. The fruit is called by various names such as "potato ball," "potato apple", or "apple," and is commonly referred to as the "seed ball."

In color the seed balls are green or green tinged with violet, brown or purplish.

Single fruits contain from none to as high as 200 to 300 seeds. As the type of plant (of the Pearl) deviates from the type which is the most productive of desirable tubers, that is has medium long stems which with their branches are neither erect nor prostrate, the tendency to bear fruit is increased until finally a type is reached which results in many large seed-balls, bearing many virile (potent) seeds. This degenerate type has erect branches, with usually a more or less stiff upright center stalk. Frequently seed-balls are produced which contain no seeds. Fitch found no seeds in 650 seed balls of Early Rose.¹ One seed ball from a Pearl crossed by a Rural con-

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tained no seed, while six seed-balls of the reciprocal
cross all bore abundant seeds.

Removal of the early tubers induces fruit bearing,
while removal of the flowers is said to encourage tuber
development.

Seed. The seeds are small kidney-shaped, embedded
in the green very acrid pulp of the fruit. They measure
about 1/16 (1\(\frac{1}{8}\) mm) to 1/12 inch (2 mm.) by 1/32 (3/10 mm.)
to 1/16 of an inch in size.

Germination of seed. Potatoes are seldom propagated
by seed excepting for the production of new varieties. As
a result, many who are familiar with tuber propagation
methods know little or nothing about the seed.

Germination of seed begins in about 5 to 7 days
after planting, being complete in about 11 to 16 days.
The radicle or primary root appears first, soon becoming
curved, and is followed by the axis of the hypocotyl
which is 1.25 to 1.75 mm. in diameter, from 7 to 8 days
after the beginning of germination.

The hypocotyl is largest at the point where the root
is joined and gradually decreases in size up to the point
of attachment of the cotyledons. The root is not over .3 mm
in diameter where it joins the hypocotyl. The development
of the hypocotyl and the primary root is limited,
progressing only until the permanent roots are formed. In
about 21 to 27 days the very slender stem develops above
the two cotyledons and ends in two leaves which are soon
followed first by pairs and then additional leaves. The
cotyledon leaves are smooth, oval, and more or less elongated, while the first foliage ones are provided with unbranched hairs.

Development of the seedling. From the 37th to 56th day after seeding the stolons arise, the first pair coming from the axils of the cotyledon leaves. These slender cylindrical stems possess small rudimentary leaves arranged alternately and spirally. They trail along on the ground finally penetrating the soil. When these tips strike the ground they begin to swell and form tubers. This has been found in many cases to vary from 48 to 52 days after seeding. Hence the first tubers of the plant, grown from seed, are developed at the tips of slender stolons coming from the axils of the cotyledon leaves. Roots soon arise from these stolons thru which the greater part of nourishment reaches the plant. Secondary stolons appear in the axils of the first foliage leaves. These stolons later constitute the principal connection between the roots and the aerial part of the plant.

Rarely at the time or before the stolons appear, but usually some time after the stolons appear or about the time the tubers begin to form the store starch, the red and violet coloring matter (anthocyan) appears on the stems of some plants of certain varieties. These stems retain their color, which is not changed by development. If the coloring does not appear at this time it is never present. Of 15 varieties experimented with from seed (in
France) 6 showed no anthocyan, while in all the stems from the seed ball of one variety it was present.

While the presence of these pigments seems to be somewhat of a variety character at the same time, all stems of varieties where it occurs are not as a rule pigmented. One of the seed balls of 1 variety produced no pigmented stems, while 26.6% of the stems produced by the other 2 seed balls were pigmented, the balance being green. In the remaining varieties all seeds balls produced some pigmented stems the percentage ranging from 3.5 to 73.8. However, in none of the cases have any of the plants produced had both green and pigmented stems, all stems of the same plant being either green or colored.

From this it appears that pigmentation is more of an individual plant or seed character than either a variety or seed ball character. In other words, in some varieties a plant may produce seed balls all the seeds of which may produce either green or pigmented plants or some seeds may produce one and some the other. However, the individual seeds always produce plants, all the stems of which are either green or pigmented, both the characters never being manifested in the stems of the same plant. About the third month after planting, varying from 92 to 103 days for different varieties, the first compound leaves were formed. This development occurs gradually, the first leaves being tri-foliate, the next five-foliate, and finally appear leaves with 7 to 9 leaf-
lets. The terminal leaflet of all these young leaves is larger than the lateral leaflets.

In comparison with the cultivated varieties of \textit{S. tuberosum}, it was found that 3 wild species, as a general rule, took a longer time to develop in all instances from the time germination began to the time the first compound leaves appeared. In some cases, especially in beginning of germination of \textit{S. commersonii} the time was 11 times as long, ranging from that to 2 days less.

\textbf{Tubers from seedlings.} It is usually that that tubers were produced on seedlings will be small the first year, larger the next year, and so on. However, Frazier reports a tuber weighing over 7 ounces the first year, and says that the Burbank potato was full sizes the first year from seed. It is reported from Svolof (Sweden) that the tubers usually attain normal size and type after about the third year.\footnote{1}

East says\footnote{2} that he has "seldom seen a marketable tuber produced on even a 2 year seedling and thinks that such results must be unusual." The Minnesota Station reports that frequently the tubers do not reach full size the second year.\footnote{3}

The vines often develop to full size the first year, most of the growth, however, being vegetative with very

\begin{footnotes}
\end{footnotes}
little matter stored in the tubers. In some cases they vary from 1 to 50 grams in weight the first year and according to East do not reach full size until the third year. When large tubers are produced they are usually small in number. As a rule, the tubers produced the first year do not have a shape typical of the variety (strain) being usually round in shape.

While a number of breeders have expressed a preference in selection for vines having the largest number of tubers, it is thought by East that the plant as a whole would perhaps be a better unit of selection.

It has been found that from an anatomical and morphological viewpoint no differences exist between cultivated varieties in the development of the potato from seed. Furthermore, the wild species, related to the cultivated varieties which have been studied, have not shown any appreciable difference in these respects from those of the agricultural varieties.

Tuberization. It has been noted previously that the tubers developed on a plant grown from seed come at the tips of stolons arising on the stem above ground. However, when the tuber, as a cutting, is used in propagation, the young tubers form at the buds of long, thin rhizomes (underground stems), which arise underneath the ground, from the main axis or stem. The length of the stolon seems to be constant and a strong variety characteristic. In cultivated varieties it should not exceed 3 or 4 inches. In. S. commersonii it is reported to some-
times reach a length of 10 feet. The tubers or swollen stems bear a number of buds and it is these buds which send out sprouts when the tuber is planted.

Altho as a rule the tubers are formed beneath the ground as noted above, in abnormal cases or when disturbed by diseases the stems above ground may produce tubers (tuberize).

For example, when the disease Rhizoctonia, which shuts off the downward movement of elaborated foods from the leaves to the underground tuber-forming stems, is active, normal tuber formation under ground is interfered with and the stems above ground will have a tendency to swell, and to produce small tubers. This phenomenon is often indicative of Rhizoctonia or other disturbances of the underground parts.

Tuberization, Fungus theory of. In general, it is found that darkness and low temperature favor the development of potato tubers. Tuberization is also facilitated somewhat by checking the growth of shoots or of the fruit.

There is some basis for the theory that the formation of the tubers is associated with the presence of certain fungi. Certain it is that tuber production is encouraged in certain orchids when the stem or root is infected with the proper fungus. The fungus appears to check the growth of the terminal bud and to cause the development of hypertrophied cells.

It was found in France, when the potato was first introduced, that when tubers were planted a crop was pro-
duced but when seed was sown no tubers were obtained. From this it was inferred that when tubers were planted they infected the new ones, while the seed being free from the fungi did not furnish a supply to infect the stolons so that tubers could form. However, no difficulty is now experienced in securing tubers from seed because it is supposed that the soil has become inoculated with the proper fungi.

If this theory should be correct, and there seems to be some evidence that it is, the potato tuber is in reality a gall produced by a foreign organism. In the potato, tuberization has been induced in concentrated solutions (of sucrose or glycerin, etc.) independent of fungi. Similar results have occurred in the case of orchids, onions, and radishes.

From this it seems that the formation of tubers may result when the osmotic pressure in the cultural medium is high. However, this alone does not appear to be the only determiner since different results followed the use of glucose and glycerine solutions of equal pressure. It certainly seems that plenty of sugar must be present for starch formation and perhaps also for tubers to form.

From the fact that a more concentrated cell sap is usually present in fungi than in other plants it does not seem unreasonable to suppose that the function of fungi in tuberization consists in raising the concentration -----

of the media which they enter. It has actually been found that cultures of Fusarium in macerated potato tuber preparations increase the concentration. In this connection it is suggested that low temperatures and dryness of soil may induce tuberization through increase the concentration of cell sap.

Certain it is there are places where there is no apparent reason why tuberization should not occur normally, but as a matter of fact very poor results are obtained. Possibly some soil condition which is connected with one or both of the above possibilities has something to do with the failure to get tubers to "set".

HISTORY

From history it seems "that the potato was cultivated and utilized by the Chilean and Peruvian people before the arrival of the Spaniards. In 1533 Pizarre found the Chilians using the tubers of a plant as their principal food. There is no evidence that he or his party introduced them into Europe.

Wild plants have been found on the Peruvian coast on the (Sleule) Mountains of Chili and Buenos Ayres, in Central America, Mexico and southwestern United States. However, without a doubt, those which were introduced into Europe in 2 different ways were from cultivated plants and not from wild tuberous American species.

There is little doubt that South America, in the neighborhood of Quito, is the place from which the potato
was first introduced into Spain early in the 16th Century. In Chili they were known as papas and in Spain, batatas. From Spain they were taken into Italy by the barefooted Carmelites, where they were known as taratouffli, the same name as the truffle. From thence they were carried to Mons in Hainout, Belgium, by an attendant of the Pope's legate in that country.

From this man they were obtained by Phillippe de Sivry, the Governor of Mons. The Governor is said to have sent to Clusius at Vienna, Austria, 2 tubers and a fruit early in 1538. The next year he sent him a colored drawing of a flowering branch. This drawing has been preserved in the Museum Plantin Moretus d'Anvers and is said to show a complete resemblance to the potato varieties cultivated at this time. Clusius described and illustrated this potato in a publication in 1591.

From Austria the potato is supposed to have gone to Germany, from there to Switzerland, and thence to France. These 2 tubers and the seeds of the seed ball are claimed by him to have produced all the potatoes which at the end of the 16th Century were cultivated in these few countries.

In 1596, John Gerarde, an English botanist, raised at Holborn, a plant which he called Popus orbiculatus. The next year he published a descriptive catalog of his botanical collection. On the frontispiece he placed a likeness of himself holding a flowering branch of this Popus orbiculatus, which from the picture and description
was undoubtedly the potato.

Sanders says¹ that in Gerarde's Herbal of General History of Plants published in 1597 a figure of the potato bears the name Potato of Virginia, from whence Gerarde says he obtained the "rootes" (tubers). It seems that this name was retained by the plant until 1640 or longer in order to distinguish it from the battatas or sweet potato (Convolvulus battatas).

Gerarde obtained his potatoes from the colonists sent out in 1584 by Queen Elizabeth, under Sir Walter Raleigh's direction, to colonize Virginia, and who returned to England in 1586. It is reported that "the potato was first planted by Sir Walter Raleigh on his estate of Youghal, near York, and that they were soon after carried into Lancashire."¹ At this time they were spoken of as delicacies for the confectioner, and not as common food and even as late as 1715 they are mentioned "as inferior to skirrets and radishes."

A record of December 15, 1693, shows that Sir Robert Southwell had introduced into Ireland some potato tubers which he obtained from Sir Walter Raleigh. They "were used for food in Ireland long before they were even known or cultivated in England."

Potatoes were so rare in the time of James the First that they cost two shillings a pound and in 1619 they are mentioned among the articles provided for the royal household.

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¹ The Book of the Potato, Sanders, p. 2.
In 1635 they had become sufficiently well known that the Royal Society recognized their worth and encouraged their cultivation, with the view of preventing famine. However, it was not until about the middle of the 17th Century that they were grown to any extent in England where since about 1806 their use has greatly increased.

The earliest record of potatoes having been grown for market in England is 1307 when a farmer in Essex grew 300 acres and marketed 3000 tons. Their cultivation in the Islands of the English Channel for the English markets is said to have begun between 1570 and 1580.

It has been commonly supposed that the potato was introduced into Scotland in 1725. However, the "Scottish Field" states that as early as 1701 the Duchess of Buccleugh paid 2 s. 6 d. for a peck, and in 1683 Sir George Mackenzie's gardener is said to have published details of its cultivation and treatment generally.¹

In 1836 their cultivation was very general in England and many parts of France and Germany and was increasing rapidly in Russia.

The heat limited their cultivation in Spain and the East and West Indies, while in temperate parts of North and South America and Australia they were grown by the colonists. In China, at this time their cultivation was limited, due to the slowness of the people to take up new things.

From this it seems that 2 distinct potatoes were introduced into Europe, at different times, the one

¹. The Book of the Potato, Sanders, p. S.
described by Gerarde as having yellow tubers and pale blue flowers, and the one described by Clusius as having red tubers and purple flowers. It is probable that all European and probably American varieties of potatoes are descendants of those two varieties described by Gerarde and Clusius about the year 1600.

PHYSIOLOGY

Up to 1901 it was generally thought that the ancestral form of the potato was a wild type of South America, Mexico and southwestern United States, the agricultural varieties of which are classified as Solanum tuberosum Linn.

From his investigations, in 1886, of tuber-bearing Solanums, particularly S. maglia, De Candolle concluded that it (S. maglia) was a small species of S. tuberosum. Somewhat later, in 1904, T. Labergerie, agriculturist at Ververoes (Vienna) obtained by bud mutations a series of plants of all degrees of resemblance to agricultural varieties. Between this time and 1903, Heckel and Flan- chon obtained, from S. commersonii, mutations which appeared like cultivated types. From 1904 to 1909 the above three men are said to have obtained mutations from S. maglia and from a wild plant collected by J. G. Prin- gle September 15, 1902, at El Salto, State of Hidalgo, Mexico.

From these reports it seems that there are indications of a triple origin of our cultivated potato, namely
from S. maglia, S. commersonii, and from a wild species of Mexico the specific name of which is not mentioned. F. Berthault of France investigated this matter thoroly by making a study of all the different forms of wild Solanums which he was able to find in European gardens and secure elsewhere. His work included also a study of the plants obtained by Heckel, LaLergerie, and Planchon from the three wild Solanums from which they have reported mutations. These included in all 35 species. After careful consideration of the available evidence and being fully aware that there is some evidence which at first appears to point to a different conclusion, this investigator, in a recent monograph on the potato, has come to the conclusion that all the cultivated potatoes appear to be different from all the wild Solanums. Further, he concludes that none one of the known wild species of Solanum is the ancestor of our cultivated varieties, but that the prototype was a Solanum tuberosum, the wild form of which is very rare or has disappeared entirely.

CLOSELY RELATED SPECIES

After a careful study of all possible available types and species of Solanum and a perusal of the available literature and records F. Berthault has come to the conclusion that S. tuberosum is characterized and differentiated from all other wild tuberous solanums by its floral characters, notably by its rotate corolla, and
its calyx, always mucronate (sharp pointed). All agricultural varieties of the cultivated plant (potato) have been found to correspond to these characters to the exclusion of all wild forms.

Only 2 plants have been found whose closeness of relationship with S. tuberosum has been in doubt after careful consideration of the types. One of these is a specimen which has all of the characters of the cultivated potato and which is thought to possibly be the wild mother plant of the cultivated potato (S. tuberosum). However, Berthaulds was not willing to unqualifiedly accept it as such on account of the possibility of error and the fact that it might be a type produced (by retrogressive variation. D.W.F.) from a plant which has escaped from cultivation and has later been mistaken for a true wild type. Regardless of this uncertainty regarding its phylogeny, this plant does not differ in any essential point from S. tuberosum and is, therefore, annexed to this species.

The other plant of doubtful identity is S. chiloense. In floral structure it is similar to the cultivated potato. The mucronate and pointed calyx alone is smaller, altho the segments are larger than those of the flowers of some related species (masilia).

As regards the bluish corolla, the stamens and style, the flowers are like the flowers of the cultivated types. The leaves are slightly more pointed than
those of the cultivated varieties. In fact, it was found that the specimen from the herbarium of de Candalle was very close to the cultivated type. Hence the same question is raised as in the other case, that since this specimen is not found in herbaria it is not known but what the plant escaped from cultivation.

The next type in closeness of relationship is probably the species called *S. sabini*. The corolla is rotate (wheel shaped), while the style projects above the stamens. This species seems to be connected directly with *S. chiloense* and not to *S. tuberosum*.

Without attempting further discussion of the closely related species, the reader is referred to the key to the species on another page which shows briefly and clearly the relationship of the species of *Solanum*.

**GEOGRAPHICAL DISTRIBUTION**

Potatoes are one of the most important human food products. While they have been known and cultivated in the eastern hemisphere for a comparatively short time (since 1536), they are now widely distributed and raised in large amounts.

The following table shows the production of potatoes in the countries of the world in 1911.
<table>
<thead>
<tr>
<th>Country</th>
<th>Bushels</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>292,737,000</td>
</tr>
<tr>
<td>Canada</td>
<td>66,023,000</td>
</tr>
<tr>
<td>Mexico</td>
<td>924,000</td>
</tr>
<tr>
<td>New Foundland</td>
<td>1,523,000</td>
</tr>
<tr>
<td>Total North America</td>
<td>361,217,000</td>
</tr>
<tr>
<td>Argentina</td>
<td>13,923,000</td>
</tr>
<tr>
<td>Chile</td>
<td>7,440,000</td>
</tr>
<tr>
<td>Total South America</td>
<td>25,353,000</td>
</tr>
<tr>
<td>Total Europe</td>
<td>4,231,543,000</td>
</tr>
<tr>
<td>Total Asia</td>
<td>57,650,000</td>
</tr>
<tr>
<td>Total Africa</td>
<td>1,687,000</td>
</tr>
<tr>
<td>Total Australia</td>
<td>11,139,000</td>
</tr>
<tr>
<td>World Total</td>
<td>4,748,711,000</td>
</tr>
</tbody>
</table>

The ten largest potato producing countries of the world in 1911 are with yields as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>Bushels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>1,263,024,000</td>
</tr>
<tr>
<td>Austria-Hungary</td>
<td>620,263,000</td>
</tr>
<tr>
<td>France</td>
<td>423,573,000</td>
</tr>
<tr>
<td>United States</td>
<td>292,737,000</td>
</tr>
<tr>
<td>Ireland</td>
<td>137,941,000</td>
</tr>
<tr>
<td>Belgium</td>
<td>104,713,000</td>
</tr>
<tr>
<td>Netherlands</td>
<td>105,463,000</td>
</tr>
<tr>
<td>England</td>
<td>99,853,000</td>
</tr>
<tr>
<td>Spain</td>
<td>93,089,000</td>
</tr>
<tr>
<td>Italy</td>
<td>62,140,000</td>
</tr>
</tbody>
</table>

The ten leading potato producing states in the United States in 1912 with yields as follows:

<table>
<thead>
<tr>
<th>State</th>
<th>State</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>Maine</td>
<td>33,160,000</td>
</tr>
<tr>
<td>Michigan</td>
<td>Ohio</td>
<td>36,750,000</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Iowa</td>
<td>34,920,000</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Illinois</td>
<td>33,075,000</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Washington</td>
<td>23,335,000</td>
</tr>
</tbody>
</table>

Colorado was in 1912 the 16th state in yield with 3,075,000 bushels.

VARIETIES

There are at the present time over 1000 named varieties of potatoes in the United States. Many of these variety names are found to belong to different groups of potatoes which are identical in all respects. In some cases varieties have been stolen and placed on the market under new names.

Usually the new varieties are the seedlings of already established varieties. Occasionally one is found which is equal to or better than its parent. More often, however, they are placed on the market considerably lacking in real merit and much inferior to the standard claimed for them. The fault seems to be largely with the American public, which is always looking for something new and extremely profitable in agriculture. Experience shows that as a rule, progress in potato improvement, as in other crops, is slow and by degrees.
East reports having seen 20 named varieties of Carman No. 3 (short-oval-falt with white skin) which were absolutely indistinguishable to the eye. New varieties are continually being added to the already cumbersome list.

TUBER MORPHOLOGY

The potato tuber is a swollen stem varying in shape, size, color weight, starch content and productiveness, etc., with the variety, environment and other causes not fully understood.

The tuber is made up of a number of zones or layers which are commonly grouped as follows:

1. Periderm or skin.
2. Cortex
3. Vascular ring
4. External medulla
5. Internal medulla

According to Coudon and Boussard these zones (excepting vascular ring) are proportioned as follows:

Skin (av. of 2 varieties) .................. 8.79%
Cortex " " .................. 36.19%
External medulla (av. of 5 varieties) ... 34.17%
Internal medulla " " 1.496%

These zones, for consideration here, are classified as follows:

1. Illinois Bulletin 127 (1903) p. 538.
2. Cornell Bul. 239 (1905) p. 509
Figure 40

"Off Type" Seed Potatoes
1. Periderm or skin
2. Vascular ring
3. Parenchyma
   a. Cortex
      1. External; 2. Internal
d. Medulla
   1. External; 2. Internal

Periderm or skin. The stolon which develops into the tuber possesses the true stem structure having the thin epidermis, the outer parenchyma tissue or cortex, the fibrovascular bundles and the internal parenchyma or medulla.

As the tuber develops the cortex becomes relatively reduced, the vascular bundles separated and the medulla larger. As these changes are going on the outer layers of cells of the cortex undergo changes. The cells become corky and flattened and so arranged that the vertical walls form straight lines and do not overlap. The cells become suberized (water proof) thru the formation within the cell walls of suberin, a substance of the nature of wax. The original true epidermis gradually dies and disappears entirely as the tubers develop. These outer corky layers of cells constitute the periderm or skin of the potato. The outermost layers of periderm split off (exfoliate) giving some varieties a characteristic rough appearance.

The cells of the different layers of periderm vary in size and shape in different varieties. According to Berthault, the number of layers is usually 7 or 8, but varies from 5 to as many as 13 and even 17.
In thickness the variation has been found in many varieties to be from 30 to 252 microns (0.0032 to 0.01 of an inch). The thickness has been found to vary only slightly in large and small tubers developed side by side, and very little in adult potatoes.

In the same tuber the thickness was about the same at the base, middle, and seed end of the tuber, the thickness generally increasing a little from the base (stolon end) to the apex (seed end).

The skin is not continuous but contains air openings (lenticels) here and there through which gases (air, etc.) pass between the tuber and the outside. At the eyes, the periderm (skin) becomes thicker.

The periderm appears to serve protective purposes entirely. It seems to be generally thought by investigators that it is an effective barrier to the penetration of parasitic diseases particularly Phylophthora infestans. This belief is substantiated by experiments which showed that during the period of infection the periderm attains a thickness sufficient to protect the underlying tissue from the Phylophthora which gains entrance through the scar made by the broken stolon. Varieties with thin and thick skin were found to become infected equally easy.

The thickness of the periderm is not found to be constant from year to year; neither is it transmitted from the seed tubers to the resulting tuber crop (the filial tubers).
Physical condition of soil, and moisture conditions seem to be the most important determiners of the thickness of the skin, although how, does not seem to be clear. Fertilizers did not produce any effect on it. Since the skin is variable in the different varieties its relative importance does not serve to characterize the varieties.

Some claim is made that thick-skinned varieties are of better quality than thin-skinned ones, but such has not always been the case.

A netted or rough skin develops on tubers of some varieties as they mature in storage, which suggests that a rough or netted skin in these cases denotes maturity. Possibly this is sometimes the source of the common idea that a rough skinned potato is of good quality.

The size and type of netting is found to vary with the variety and the conditions under which grown. Smoother skins are usually found on potatoes grown on sandy soils, than on those grown on heavy soils.

It has been found that the thicker and rougher skinned varieties stand up better in shipping and are preferable for this purpose even tho they may have no greater merit in other ways.

Gilmore found that a netted skin indicated a degree of maturity "and, as a rule good quality," while on the other hand a smooth skin indicated a degree of immaturity, "hence poor quality and tendency to undersirable flavor." ¹

Scabby potatoes were often "mealy and of good color but undesirable for market conditions."

¹. Cornell Bulletin 230 (1905) p. 509
Potatoes grown so shallow that they were exposed were of inferior color and usually elastic and tough in texture, remaining soggy and heavy after boiling.

Vascular ring. The vascular ring consists of a discontinuous circle of vascular bundles which is located between the cortex and the medulla. At the eyes the vascular tissue approaches the surface of the tuber maintaining, however, its proper relationship with the other tissue, i.e., remaining within the cortex and outside of the medulla. The cortical layer gradually becomes thinner as the vascular bundles approach the eyes. The vascular tissue is poor in starch. It is easily recognized as a very narrow darkened ring near the edge of the exposed surface of a cut.

Parenchyma. Practically the entire mass of tuber tissue inside of the periderm (skin) excepting the vascular tissue is parenchymous tissue, or parenchyma, and will be referred to as such in this discussion. The parenchyma is divided into two principal parts, the cortex and the medulla.

Cortex. Inside of the periderm is a layer of (parenchymous) tissue \(1/8-1/2\) of an inch thick which constitutes the cortex or cortical layer. It is separated from the layer inside of it (the medulla) by the vascular ring. The outer cortex has been found to be made up of smaller cells than the inner cortex, among the
larger cells of which are isolated remnants of vascular bundles. The cells of the cortex are considerably smaller than those of the medulla and the density of the cortex is higher. This increased density is due partly to the smaller cells and also to the presence of fibro-vascular bundles and cellular contents other than starch. However, it is thought by Gilmore to be due to a still greater extent to the thickness and opacity of the cell walls. The cortex is darker in color than the medulla, probably due to its increased density.

Where the cortex is very thick and dense it is said to indicate poor quality, which may have been caused by the potatoes growing near the surface of the ground, where the temperature and moisture were variable. A thinner more translucent cortex is said to indicate higher quality, the result of favorable conditions of development.

The periderm, or skin, and the outer layers of cortex are removed when potatoes are peeled.

Medulla. The medulla consists of all of the tuber inside of the vascular ring. It is divided into two parts, the external and the internal medulla. When a thin slice of potato is held up to the light these two areas are easily distinguished, the external medulla appearing darker and denser, while the internal medulla appears lighter in color due to its being more translucent, the result of being less dense or solid. This condition is caused by a greater percentage of water and considerably less starch and other solid matter, and pro-
bably thinner cell walls.

**Outer Medulla.** The outer medulla varies consider-
ably in thickness. It is more or less permeated by the
radiating areas of the internal medulla. The outer med-
ulla is denser and darker in color than the inner zone
and is considerably higher in starch, slightly lower in
protein and lower in water.

**Inner Medulla.** The internal medulla occupies the
center of the tuber and is usually more or less star-
shaped. Many of the radiating areas of internal medulla
penetrate deeply the outer medulla, some of them extend-
ing to the eyes. In some tubers these two zones are more
or less intermixed with no definite zone boundaries. As
a rule in long potatoes the central area is very much
elongated with lateral radiations, while in many round
potatoes it is typically star-shaped. The greater the
size of the internal medulla and the more its ramifica-
tions into the outer area the poorer the quality of the
tuber, since it means a larger area poor in starch and
in mealiness, on cooking. This area is more translucent
than the other areas due to a high percentage of water
and a very low proportion of starch. The smaller this
area the higher the potato quality.

**Shape.** The common tuber shapes are round, oblong,
and elongated. One dominant form is found in each variety
but never one exclusive form. New varieties based on
tuber form are produced by a selection of tubers and are
maintained only by continued selection. No relationship
is found to exist between strict botanical characters of the potato and the form of the tubers, which is not a stable character but is an agricultural character of great value.

In tuber propagation there appear among the normal shaped tubers a number of aberrant (diverging) forms which are usually in the minority. In production from seed, variations in shape are produced, which resemble those from tuber propagation and do not differ materially in number produced. The dominant form here is almost invariable that of the parent. Tuber propagation, from these individuals from seed, behave the same as those from cuttings.

**Shape and Quality.** In general it seems that the round flat (Irish Cobbler), short oval-flat types (German's productions) are of better quality than the round ones, altho some of the round types (Norton Beauty) and oblong round varieties (Early Ohio) have been found to be of excellent quality.¹

This conclusion seems to be logical since the percentage of cortical layer (the outer, more valuable layer) would be greater in proportion in the flat types than the round ones. Furthermore, the fact that the small round types and the long slender types (Lady Finger) are used for salad suggests at least a possibility of an inferior table quality.

The tendency of a tuber to become drawn out or

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1. Illinois Bulletin 127 (1908) p. 430
pointed at one or both ends indicates a declination of vigor and is the first manifestation of degeneracy. To overcome this tendency is one of the big problems of the potato raiser and breeder.

Color. The common tuber colors which have been observed are yellow, red, violet of different shades, and variegated. Bluish forms are also known. Color variation has been found in a number of cases.

In propagation by cuttings yellow and streaked tubers have appeared from colored ones (red and violet). Yellow tubers have given red and violet ones, a white tuber gave two red and two white tubers, and one with a bluish color gave a series white in color. The Pearl with a brownish white or a well russeted skin is from the Blue Victor which is a purple color often streaked with white. When the white streaks cover an eye the tubers from the eye usually come true (white) in following generations. The People's variety also from the Blue Victor is a deeper brown color than the Pearl. In each of the three sorts there occur occasionally, tubers with spots or more rarely whole tubers which are identical in color with the other two sorts.

The degenerate forms (bastards) found in the three sorts are very similar, although each has a shade indicative of the true color, being a lighter pink in the Blue Victor, whiter and more waxy in the Pearls, and deeper grown in the People's.

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1. Colorado Bulletin 176 (1910) p. 3
The color in general maintained by asexual reproduction, varies, occasionally. Seed propagation produces a greater amount of variation in color. However, the color of the parent is dominant in the seedlings and propagation from the seedlings by cuttings gave results the same on the average as were obtained from continued tuber-propagation.

At the present time, white fleshed tubers are the only ones accepted in American markets. It is thought that possibly yellow flesh is correlated with a strong flavor and a poor standard at least according to American standards.\(^1\) At any rate, a number of yellow fleshed varieties from France were, after boiling, found to be gummy and hard. They were considered by the French to be of prime quality. In this country these varieties are considered of good quality for the making of salads and for frying.

East found\(^2\) that hybrids from the same cross, varying in color from white to light brown, pink, and red, showed no greater variation in quality than did those of a single color; consequently he concludes that color is not correlated to quality. The purple type was the only one in which varieties were not of good quality but this may be accounted for by the fact that none of the purple tubers available were of a size that indicated maturity; hence the poor quality.

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1. Illinois Bulletin 127 (1908) p. 430
2. " " p. 429.
**Eyes.** The buds of the potato tuber usually occur in groups each group lying in more or less of a depression, which together with its buds is called the "eye." The depression is the axil of a scaly leaf which was in evidence when the tuber was young but later disappears. The "eye brow" (eye yoke)\(^1\) is the highest line above the depression, or the line which separates the leaf from the stalk. In reality the eye is a lateral branch with undeveloped internodes, the whole tuber being generally a much branched stem and not a simple shoot.

Of the several buds in the "eye" the central one is commonly the largest and strongest, the side ones being usually comparatively small and less vigorous. Fitch has noted that the "eye brow" differs noticeably in vigorous and in degenerate tubers. In the latter it is stronger and has a tendency to be longer, with the ends running away from the eye.\(^2\)

Careful study shows that the buds or eyes are arranged alternately and at the same time spirally on the tuber, as they are on a normal stem. Beginning at one end of a tuber and proceeding toward the other end at the same time turning the tuber usually enables one to follow clearly the spiral arrangement.

The so-called "seed end," "rose" end, or crown of the tuber is opposite the point of attachment to the

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1. Colorado Bulletin 176 (1910) p. 15
stem. The "stem" end is at the "base" or the heel of the tuber. The eyes are more numerous at the seed end as well as more vigorous. Ordinarily the terminal bud is the strongest and under proper conditions will be the only one to develop. The sprout produced by the terminal eye is spoken of as the "master sprout."

In the nature tuber the remnant of the rhizome (underground stem) whose tip thorough enlarging gave rise to the potato, may be seen at the stem end.

The eyes vary in different varieties, from very deep to level with the surface, resulting in smooth potatoes. The deep eyes varieties examined and reported from France have a yellow or red skin. Deep eyes tend to hold moisture; as a result decay is invited and hastened when the potatoes are stored. Smooth varieties occasionally give rise to deep eyed tubers, altho as a rule eye depth is maintained by tuber propagation. It is likely that the deeper eyed plants give rise also to smooth tubers and that in the case of seed propagation the same results follow as in the case of form and color.

In general it is found that variation resulting from seed propagation as far as tuber characters are concerned is not exceedingly great as is generally believed. On the other hand, relatively slight variations from the types of the parent varieties occur capable of perpetuation in large proportions.

A number of writers have found that coarseness of the tubers accompanies deep eyes. The robustness

1. Illinois Bulletin 127 (1903) p. 430
of the tuber and the vitality of the sprout is found to vary as the size and depth of the eyes which is worth considering; otherwise types might be bred so "high" with respect to vitality as to cause serious weaknesses in sprout vitality.

The number of eyes varies considerably within the same variety, in one case, Rural New Yorker \# 2\textsuperscript{1}, ranging from 7 to 28, and in Early Ohios \textsuperscript{1} from 7 to 22.

The number of eyes affects the quality since the poorer cultural zone of the potato (internal medulla) extends a branch to each eye, thereby increasing the percentage of internal medulla at the expense of the two outer, more valuable layers.

In comparing the two varieties mentioned above (one being tested one year and the other the next year) it was found, that in the case of the Rural New Yorker, \# 2 more potatoes had 12 eyes than any other number and the average dry matter was 20.74\%, while in the case of the Early Ohio the number of eyes of greatest frequency (the mode) was 15 and the average dry matter was only 16.15\%.

Germination or sprouting of tuber. Potatoes undergo some changes in storage. Not only do they lose water and decrease in weight, but they increase in sugar. When sprouting commences the potato becomes sweeter, due to the conversion of starch into sugar by the enzyme, diastase. The most vigorous buds are the terminal ones.

\footnote{1. Illinois Bulletin 127 (1908) p. 431.}
The tip of the main sprout grows upward. The underground stems bear tubers at their ends. These will not tuberize if brought to the light but will develop into ordinary green-leafed shoots.

**COMPOSITION: PHYSICAL**

In all varieties the cells of the cortex are much smaller than those of the medulla. However, at the same depth it is reported that the cellular density is uniform; that is the cells are the same size at a given depth regardless of the part (zone) of the tuber in which they are found.

The number of cells in a one millimeter section has been found in a large number of varieties to vary from 47 to 146 in the cortex and from 40 to 131 in the medulla.

A study of the figures for the different varieties shows that the size of the cortex and medulla (parenchymous) cells for the principal varieties is quite variable between varieties but is somewhat more stable between individuals in a given variety. In France the variations from year to year in the same variety are found to be slight not fluctuating more than 20 cells to a square mm.; on the other hand, the fluctuation between different varieties often reaches as much as 100 cells per square mm.

In general, varieties are characterized by their cellular density and can be grouped accordingly. The groups are not, however, clear cut. The potatoes which
were examined in France by Berthault were placed in
three groups according to the size of their cells.
It was found that the group having from 90 to 140
parenchyma cells to the square mm. contained those
varieties considered good for table use. The tubers
have a fine flavor with the nitrogen-ash content
relatively high, and the planting giving a medium high
yield. Those in the group with 40-70 cells per square mm.,
contained plants of high yield, tubers rich in starch,
and of poor flavor. They are very rarely used for
human food being destined for animal food and the
starch industry. The intermediate group contains those
having 70 to 90 cells per square mm. Varieties in this
group are used commonly in the starch industry and for
cattle food as well as for human food.

These studies show that the good table potatoes
in France have a fine flavor, a firm flesh, and a
smaller yield, and that the parenchyma cells are small,
while on the other hand the large celled varieties,
also of high yield, are used only in the industries
and as cattle food. Some exceptions have been noticed
particularly one variety (Gelbe) which has a high cellul-
lar density but is little used on the table.

Cellular density is thus seen to be an important
factor to consider in the breeding of potatoes for
table use or for the industries.

Even with the same amount of starch in two varie-
ties it is found that the large celled one is the more
valuable to the starch industry due to the fact that in
the small celled varieties a larger number of the cells
remain intact and do not give up their starch in the
starch removing process, while with the large celled var-
ieties fewer starch cells escape because of their being
broken and releasing their starch.

In France it was found that rich, compact (heavy)
soils produced tubers with a lower cellular density, while
the lighter soils produced tubers with smaller cells and
higher density.

The effect of fertilizers was contradictory and sug-
gests that the nature (physical) of the soil is the prin-
cipal factor in modifying cellular density.

Gilmore says that "The structural characteristic of
the tuber is influenced by the conditions of the soil and
of the soil and atmospheric climate in which the potatoes
grow."¹

In general, it may be said that it does not appear
that anatomical characters of the tuber can serve as a
basis for botanical classification. They have not proven
to be hereditary. Thickness of periderm, cellular den-
sity of parenchyma, and size of starch grains are all
valuable. It might be claimed that this variation is
due to the fact that these varieties are hybrids and that
they are exhibiting character segregation in the (filial)
offspring. However, this has not been proven or seriously
considered.

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COMPOSITION: CHEMICAL

Quite a number of analyses have been made of potatoes in this country and in Europe.

Gilmore gives the results of a number of these in the following table:

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Analyses</th>
<th>No. of Varieties</th>
<th>Protein</th>
<th>Starch</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornell</td>
<td>43</td>
<td>4</td>
<td>1.899</td>
<td>17.356</td>
<td>Very good</td>
</tr>
<tr>
<td>Maine</td>
<td>16</td>
<td>4</td>
<td>2.17</td>
<td>18.037</td>
<td></td>
</tr>
<tr>
<td>U. S. all sources</td>
<td>136</td>
<td></td>
<td>2.2</td>
<td>18.4</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coudon and Boussard</td>
<td>7</td>
<td>7</td>
<td>2.676</td>
<td>11.798</td>
<td>Very good</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>8</td>
<td>2.411</td>
<td>13.218</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>7</td>
<td>2.365</td>
<td>14.118</td>
<td>Passable</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>12</td>
<td>2.09</td>
<td>16.047</td>
<td>Poor</td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morgen</td>
<td></td>
<td></td>
<td>2.025</td>
<td>20.013</td>
<td></td>
</tr>
<tr>
<td>König</td>
<td></td>
<td></td>
<td>1.95</td>
<td>20.69</td>
<td></td>
</tr>
<tr>
<td>W. Wolff</td>
<td></td>
<td></td>
<td>2.1</td>
<td>20.7</td>
<td></td>
</tr>
<tr>
<td>Maercker</td>
<td></td>
<td></td>
<td></td>
<td>19.31</td>
<td></td>
</tr>
</tbody>
</table>

Henry gives the following composition of the potato:

Water 79.1%, ash 0.9%, crude protein 2.1%, fiber 0.4%, nitrogen-free extract 17.4%, fat 0.1%.

In analyzing the different zones, Coudon and Boussard obtained in 1897 the following results, calculated to the fresh basis:

1. Cornell Bul. 230 (1905) p. 504
2. Feeds and Feeding, Henry (1909) p. 571
3. Ill. Bul. 127 (1908) p. 419
<table>
<thead>
<tr>
<th>Variety</th>
<th>Zone</th>
<th>Water</th>
<th>Starch</th>
<th>Total nitrogenous matter*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleugeante</td>
<td>Cortical</td>
<td>72.74</td>
<td>21.14</td>
<td>1.91</td>
</tr>
<tr>
<td></td>
<td>Out. med.</td>
<td>74.33</td>
<td>19.78</td>
<td>1.88</td>
</tr>
<tr>
<td></td>
<td>In. med.</td>
<td>81.72</td>
<td>12.30</td>
<td>2.14</td>
</tr>
<tr>
<td>Czarine</td>
<td>Cortical</td>
<td>72.92</td>
<td>22.45</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td>Out. med.</td>
<td>78.87</td>
<td>15.64</td>
<td>2.17</td>
</tr>
<tr>
<td></td>
<td>In. med.</td>
<td>84.48</td>
<td>10.50</td>
<td>2.17</td>
</tr>
<tr>
<td>Saucisse</td>
<td>Cortical</td>
<td>78.72</td>
<td>14.38</td>
<td>2.22</td>
</tr>
<tr>
<td></td>
<td>Out. med.</td>
<td>79.12</td>
<td>13.47</td>
<td>2.39</td>
</tr>
<tr>
<td></td>
<td>In. med.</td>
<td>80.73</td>
<td>12.31</td>
<td>2.62</td>
</tr>
</tbody>
</table>

* Probably total N. x 6.25

In these cases the water and nitrogen increase from the outer to the inner zones, while the starch content decreases. The portion of proteid nitrogen to total nitrogen decreases in the inner zones being 68.7% in the cortex, 56.0% in the outer medulla, and 47.3% in the inner medulla.

With five varieties the results of these French investigators were as follows:

<table>
<thead>
<tr>
<th>Zone</th>
<th>Starch Percent</th>
<th>Protein percent</th>
<th>Water percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical layer and skin</td>
<td>15.784</td>
<td>2.173</td>
<td>76.57</td>
</tr>
<tr>
<td>External medullary area</td>
<td>17.324</td>
<td>2.291</td>
<td>78.43</td>
</tr>
<tr>
<td>Internal medullary area</td>
<td>12.75</td>
<td>2.457</td>
<td>81.13</td>
</tr>
</tbody>
</table>

Frisby and Bryant give the composition of the different parts of the American variety, White Star, as follows:

Concerning nitrogen and starch these results are directly opposite to Coudon's and Bousard's. It is suggested that the discrepancy may be due to the different methods of determination.

Snyder gives the following analyses of potatoes:

<table>
<thead>
<tr>
<th>Zone</th>
<th>Water %</th>
<th>Proteid N.</th>
<th>Total N.</th>
<th>Free Extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical layer</td>
<td>83.2</td>
<td>.24</td>
<td>.36</td>
<td>12.6</td>
</tr>
<tr>
<td>Outer and inner med.</td>
<td>81.1</td>
<td>.18</td>
<td>.32</td>
<td>1.57</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Snyder gives the following analyses of potatoes:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
</tr>
<tr>
<td>%</td>
</tr>
<tr>
<td><strong>Skin</strong></td>
</tr>
<tr>
<td><strong>Cortex</strong></td>
</tr>
<tr>
<td><strong>Medulla</strong></td>
</tr>
<tr>
<td><strong>Av. of 86 Amer. analyses</strong></td>
</tr>
<tr>
<td><strong>Av. of 118 European Analyses</strong></td>
</tr>
</tbody>
</table>

East obtained the following results on the composition of the potato:

2. Illinois Bul. 127, (1908) p. 422
<table>
<thead>
<tr>
<th>Variety</th>
<th>Zone</th>
<th>matter percent</th>
<th>Total N French basis percent</th>
<th>Total N Dry basis percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural New</td>
<td>Cortical</td>
<td>20.95</td>
<td>0.46</td>
<td>2.20</td>
</tr>
<tr>
<td></td>
<td>Outer Med.</td>
<td>18.46</td>
<td>0.47</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>Inner Med.</td>
<td>14.04</td>
<td>0.45</td>
<td>3.23</td>
</tr>
<tr>
<td>Carman No 3</td>
<td>Cortical</td>
<td>22.20</td>
<td>0.49</td>
<td>2.23</td>
</tr>
<tr>
<td></td>
<td>Outer Med.</td>
<td>19.41</td>
<td>0.51</td>
<td>2.63</td>
</tr>
<tr>
<td></td>
<td>Inner Med.</td>
<td>14.92</td>
<td>0.52</td>
<td>3.49</td>
</tr>
</tbody>
</table>

This table shows that the dry matter decreases from the outside to the inside zone. The nitrogen content shows an increase, on dry basis, from the outside to the center, although on a fresh basis there seems to be no regularity of percentage, probably due to variability in water content.

Ash determinations varied little from 0.9 on fresh basis. The carbohydrates were found to be higher in the cortex and quite low in the inner medulla. East found that the inner cells of the cortex contained a much larger amount of starch than those of the external medulla which in turn contained considerably more than the cells of the internal medulla. The outer cells of the cortex which are removed with the skin (in peeling) were comparatively low in starch.

The starch grains of the cortex and external medulla were found generally to average larger in size than those of the external medulla. The amount of starch as well as the size of the grains seem to decrease as the skin, vascular ring or internal medulla are approached.

Waterstadt and Willner\textsuperscript{1} found in 1901 that the cortex is higher in dry matter and starch, and lower in nitrogen than the medulla when computed on a fresh basis. However, when figured on a dry basis, the starch variations were slight no equaling 1 percent. The total nitrogen variations are similar to those obtained by Coudon and Boussard.

The following results are given by a number of Germans:\textsuperscript{2}

<table>
<thead>
<tr>
<th>Name of Authority</th>
<th>Moisture</th>
<th>Protein</th>
<th>Carbo-Nx 62.5</th>
<th>Fat hydrates</th>
<th>Fiber</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Konig</td>
<td>75.48</td>
<td>1.95</td>
<td>.15</td>
<td>20.69</td>
<td>.75</td>
<td>.93</td>
</tr>
<tr>
<td>Lintner</td>
<td>76.0</td>
<td>2.1</td>
<td>.2</td>
<td>19.7</td>
<td>.6</td>
<td>1.2</td>
</tr>
<tr>
<td>E. Wolff</td>
<td>75.0</td>
<td>2.1</td>
<td>.2</td>
<td>20.7</td>
<td>1.1</td>
<td></td>
</tr>
</tbody>
</table>

STARCH AND SUGAR

Potato starch grains are egg-shaped or nearly spherical with eccentric markings and with the hilum (summit of the grain) near the small end. In a modified light under certain conditions of observation a black cross is visible upon the granule.

French investigations showed the large grains to be about 80 times heavier than the small grains. Some varieties of potatoes are found to be abundantly supplied with large starch grains with infrequent small ones while in other varieties the reverse is the case.

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1. Illinois Bul. 127 (1908) p. 420
No correlation has been found between the size of the starch grains and the size of the tuber or its total starch content. In general, the early varieties have been found to contain large starch grains while the late varieties contained a larger proportion of small grains.

The formation of starch grains is very slow. At first many small grains are found many of which later increase in size. This increase in size begins much sooner in the early varieties than in the late varieties. It has been found that most all of the old varieties were small celled tubers slightly rich in starch (fecule) and of good table quality, while most of the industrial varieties which are rich in starch, low in cellular density and late maturing appear to be of recent origin, the result of 150 years of selection.

No relationship has been found between the intensity of leaf color or the amount of chlorophyll present and the amount of starch stored in the tubers. The quantity of foliage and the length of the life of the plant (duration of the vegetation) indicate to some extent the relative quantity of starch which the tubers produce.

1 In Sweden it was found that under certain conditions the yields were greater than under others, while the starch content was lower. The tubers having the

low starch content were the larger, indicating that
their internal development was not so far advanced.

In addition to the starch, potatoes contain
noticeable amounts of sugar which may occur as straight
sugar, reducing sugar, or dextrin all of which are sol-
uble in water. The average quantity is likely not far
from 0.35%. This sugar is lost in starch making, but
is utilized in the manufacture of alcohol.\(^1\) German var-
ieties are reported to contain from .4% to as high as
3.4% with an average of 1.9%. It is believed that the
maximum and average are both more than is usually found.\(^1\)

In Wisconsin\(^2\) it was found that the amount of sugar
varied according to the variety, the length of time the
potatoes had been in storage and the temperature. The
limits of variation were from a trace of sugar (less than
0.05%) to 1.42%. The average sugar content of 9 varieties
as they were received for the test was 0.41%, the limits
being 0.10 and 0.88%.

It has been found that as respiration of potatoes
in storage decreased with a lowering of the temperature,
the sugar content increased.

The supposition that sweetness in potatoes indicated
that they had been frozen was found to be incorrect.
Potatoes rapidly frozen contained no sugar in excess of
that already present.

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1. Farmers Bulletin 268, p. 22
3. Ibid. p. 28
In Wisconsin it was found that potatoes stored at 1°-5°C contained more sugar (0.85-1.42%) and were inferior to those stored at 8°-11°C, which contained 0.16-0.65% sugar. These potatoes in turn were inferior to those stored at 20°C and which contained from a trace to 0.65% sugar.

With a temperature of 8°-11°C the sugar content remains about constant. It is supposed that at this temperature respiration (which consumes sugar) about balances sugar formation.

From these investigations it is concluded that "potatoes for culinary purposes should be stored in a dry cellar at 8°-10°C." "Potatoes high in sugar will be improved in quality (sugar reduced) if stored, not to exceed 20 days, at 20°C. It has been found that potatoes are sweetish (sweet to the taste) when they contain about 0.5% or more of sugar. However, the Red Alcohol were sweetish when they contained only 0.1%, and Rural New Yorker with 1.01%.

No relationship seems to exist between the degree of mealiness and the presence of sugar as determined by analysis. However, quite a marked correlation was shown between sweetness and degree of mealiness. This was marked enough to permit the conclusion that "a sweetish potato is never mealy."¹

"The amount of acid present in potatoes has no direct effect upon their quality."²

---

2. Ibid, p. 18.
MEALINESS

In estimating the quality of potatoes in the United States, mealiness is the most important consideration. Different investigators have concluded that mealiness depends quite largely upon the relative amount of starch in the cells. This is thought to be due to the expansion and coalescing (combining) of the starch when boiled in water.

If there is sufficient starch, as is usually the case in the cortex, this expansion is thought to rupture the cells freeing their contents and producing mealiness. On the other hand, a deficiency of starch, as is usually the case in the cells of the internal medulla, is supposed to produce swelling, insufficient to rupture the cells, hence sogginess results and the tuber retains its form.

East seems to think that mealiness is caused by the presence of abundant starch which upon cooking swells, filling the cells and rupturing them. Gilmore is also inclined to this opinion, altho he states, that while the starch grains expand greatly, "yet the volume of potato substance is not materially increased because in expanding the starch grains incorporate the water which was originally in the tuber in a free state. In other words, the mass acts somewhat as a sponge.

On the other hand, Coudon and Boussard showed that the starch content of potatoes was no guide to their mealiness, in particular, as is seen in the following table:
<table>
<thead>
<tr>
<th>Mealiness of Potatoes</th>
<th>Percentage starch Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Mealy</td>
<td>19.327</td>
<td>13.520</td>
</tr>
<tr>
<td>Slightly mealy</td>
<td>17.454</td>
<td>11.999</td>
</tr>
<tr>
<td>Not mealy</td>
<td>17.126</td>
<td>10.653</td>
</tr>
</tbody>
</table>

Harcourt's figures show similar results:

<table>
<thead>
<tr>
<th>Mealiness 4 = perfect</th>
<th>Percentage starch Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 - 40</td>
<td>20.74</td>
<td>13.02</td>
</tr>
<tr>
<td>20 - 30</td>
<td>18.41</td>
<td>10.38</td>
</tr>
<tr>
<td>10 - 20</td>
<td>15.29</td>
<td>9.57</td>
</tr>
<tr>
<td>0 - 10</td>
<td>13.65</td>
<td>12.78</td>
</tr>
</tbody>
</table>

In Wisconsin the following results were obtained by Butler, et al:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Quality 100 points perfect</th>
<th>percent starch</th>
<th>Mealiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Ohio</td>
<td>90</td>
<td>15.70</td>
<td>Mealy</td>
</tr>
<tr>
<td>Rural New Yorker</td>
<td>90</td>
<td>15.35</td>
<td>&quot;</td>
</tr>
<tr>
<td>Rusty Rose</td>
<td>85</td>
<td>17.85</td>
<td>&quot;</td>
</tr>
<tr>
<td>Early Rose</td>
<td>80</td>
<td>16.60</td>
<td>&quot;</td>
</tr>
<tr>
<td>McCormick</td>
<td>75</td>
<td>14.13</td>
<td>Slightly</td>
</tr>
<tr>
<td>Blue Victor</td>
<td>65</td>
<td>14.61</td>
<td>Mealy</td>
</tr>
<tr>
<td>Red Alcohol</td>
<td>50</td>
<td>16.19</td>
<td>Slightly</td>
</tr>
</tbody>
</table>

These men conclude that mealiness is modified by water content, and that the percentage of starch in a potato is not indicative of mealiness.

Evidence is presented on both sides of this question. At present, it seems to be stronger in support of the conclusion that the starch content of potatoes has little or no direct influence on their mealiness.

The conclusions of the Wisconsin investigators agree with those of Coudon and Boussard; viz., that mealiness is due to a separation of the cells, and not to cellular disintegration. The former state that this can be readily determined by direct experimentation.

QUALITY OF POTATOES

The standards for table quality in potatoes vary somewhat in different countries. The more noticeable differences seem to be between France and the United States.

East found that most of the potatoes imported from France, which he examined had a yellow flesh, a strong flavor, and were firm and soggy after boiling. In France, potatoes are commonly cooked by frying in deep fat. For this purpose it seems from reports and examinations by investigators that a potato yellowish in color and which holds its form, and is as a result more or less soggy after boiling, is preferred. These characteristics are usually found in potatoes which are low in starch and high in protein. In the United States, on the other hand, where probably nine-tenths of the potatoes eaten are boiled, a white, floury
starchy potato which is mealy and dry when cooked is demanded for table use.

In Germany table potato standards are more like they are in the United States; hence the results of investigations there are more applicable to this country than are those of France.

In regard to chemical composition, Coudon and Boussard consider three things: (1) aqueousness; (2) richness in nitrogenous matter, principally albuminoids; (3) relative poorness in starch. ¹ From their investigations in France in 1897 with 34 varieties of potatoes they concluded that their culinary value is dependent upon the chemical composition, and that it varies directly as the nitrogen content and inversely as the starch content, that is culinary value equals $\frac{\text{nitrogen}}{\text{starch}}$.

This conclusion is supported by examining the table on another page, where it is seen that the potatoes which are graded as very good in quality are the highest in protein (2.676%) and lowest in starch (11.793%), while those classed as poor in quality are lowest in protein (2.09%) and highest in starch (16.047%).

From their cooking tests, these same investigators considered that the varieties highest in table quality are those which "are more resistant to boiling, or retain their form and remain solid or soggy after cooking, while

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those varieties considered poorest from a culinary standpoint broke down and became mealy after a short period of boiling.\(^1\) Continuing, they say, "The resistance to boiling in water......without breaking down in structure does not depend (hold), as one might believe, on a high content of peptic bodies, more than on a paucity (smallness) of starch. This resistance seems due, more or less, in a large measure to the proportion of albuminoids which they contain compared with their starch content.

Among the varieties studied in 1895 all those in which the proportion of albuminoids to 100 parts starch fell above 8.6 resisted boiling in water completely, while those falling below that average varied considerably. Breaking down was complete in those varieties in which the proportion was below 6.6\(^2\).

Butler, et al., of Wisconsin,\(^3\) conclude from their investigations that "the ratio of Coudon and Boussard albuminoid nitrogen, does not appear to be a very reliable indicator of the degree of mealiness of potatoes. Furthermore, they believe that "the ratio, total nitrogen, starch is no criterion of quality."

East says that "variation in nitrogen content does not have a noticeable effect on quality, altho there is a slight indication that extremely high nitrogen might make the flavor more pronounced."\(^4\)

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1. Cornell Bul. 230 (1905) p. 505
2. Ibid, p. 508
He found that in the variety tested 18% dry matter, or probably 15% starch is the lower limit below which tubers cannot go and be of good quality. This would possibly vary in different varieties. When the dry matter was above this lower limit the quality was not found to be directly affected. Some potatoes with dry matter as high as 19% were found to be excellent.

East concludes from general experience "that potatoes with a starch content above a certain limit would easily fall to pieces or if the cell walls were strong enough to hold together under such pressure, they must necessarily be coarse and woody." In general, it is considered that for table use in this country potatoes must contain about 17% or more of starch.

In Maine, 16 analyses of four varieties made in 1908 show a range in starch from 15.96 to 20.38%, 3 of these being between 18 and 19% with an average for all of 13.037%.

In comparing these figures with those of German analyses, Wiley says that while the American potatoes are lower in starch, they are "much superior in palatability for domestic consumption." In Germany with certain varieties those tubers having very high starch content were found to be coarse in quality. European potatoes have been bred for high starch content for starch and alcohol making, with little regard for table

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1. Illinois Bul. 127 (1908) p. 426
2. Bureau of Chemistry Bul. 53, p. 23
quality and it appears that when the starch content exceeds a certain percentage it is at the detriment of American table quality. Walterstradt and Willner found in Germany that potatoes of better table quality are considerably lower in starch than the others. On account of the similarity of quality standards in Germany and America their results are more applicable to our conditions than are results in France. They found also that the proportionate area in sections of good eating potatoes was 100 cortex to 121.4 medulla, and in coarse varieties 100 to 140.4 showing that the table varieties contained a higher proportion of cortex.

In France high cellular density (small cells) (90-140 per sq. mm.) was found in varieties considered good for table use, the tubers having a fine flavor and a relatively high nitrogen and ash content. On the other hand, potatoes having a low cellular density (40-70 per sq. mm.) were rarely used for human food being used for animal feeding and starch making. They had high starch content and poor flavor.

Gilmore concludes after two years' work that, "It seems that the culinary and dietetic quality of potatoes is not dependent upon chemical composition so much as it is upon the anatomical (and perhaps physiological) characteristics of the tuber and the arrangement and distribution of starch and water areas in its substance."

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1. Illinois Bul. 127 (1908) p. 422.
He says further as a result of his investigations that "the quality of mealiness of a potato when boiled and to a considerable extent, the flavor is influenced in the main by the following considerations:

1. The daily range of soil and atmospheric temperature during the growing period.

2. The degree of ripeness of the tuber when the plant dies.

3. They physical condition and type of the soil.

As a result of experimentation with 15 American varieties East says, "It is quite evident then that potatoes having as far as possible a homogeneous flesh and containing as large an amount as possible of cortical and outer medullary layers in proportion to inner medullary layer, should be of the finest quality."

**Degree of Maturity and quality.** Analyses in the United States have shown that the "greater part of the total nitrogen is developed early in the growth of the tuber, while the starch is stored up later."\(^2\) It was also found that "the starch grains of immature tubers are small in size and few in number." In the cortex and outer medulla of mature tubers the starch grains averaged 75 mm., while in the immature tubers of less than an ounce in weight the starch grains averaged only 25 mm. in size.

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2. Ibid, p. 435
The composition of a number of tubers of different degrees of maturity was obtained as follows:

<table>
<thead>
<tr>
<th>Degree of Maturity</th>
<th>Dry matter percent</th>
<th>Protein fresh basis percent</th>
<th>Protein dry basis percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very immature</td>
<td>8.01</td>
<td>1.22</td>
<td>15.23</td>
</tr>
<tr>
<td>Immature</td>
<td>11.15</td>
<td>1.66</td>
<td>14.93</td>
</tr>
<tr>
<td>Fairly mature</td>
<td>16.70</td>
<td>2.15</td>
<td>12.85</td>
</tr>
<tr>
<td>Mature</td>
<td>21.20</td>
<td>1.94</td>
<td>9.16</td>
</tr>
</tbody>
</table>

From the figures in this table East concluded that "These tubers, as might be expected from their composition, increased in desirability for table use with maturity to such an extent that we may conclude that all immature potatoes should be rejected for cooking." He says, furthermore, that "Any and all conditions of environment" (such as distance apart and time of planting, depth and frequency of cultivation) "that lead to the normal development of healthy, mature potatoes may be considered as contributing toward their table quality."

Gilmore found that potatoes which come from plants which die normally at the end of a shortened season and consequently did not have time to mature normally were of poorer quality than potatoes of good size taken from green and growing plants. He says that the reasons are not clearly understood but "it is supposed that the cessa-

tion or retarding of growth of the tubers, as the plant
dies slowly, causes abnormal development in both compo-
sition and cellular structure, while tubers taken from
the growing plants are suddenly interrupted in the midst
of normal growth and development.\(^1\)

He found "that immature potatoes are relatively
richer in protein and poorer in starch than normally
developed and ripened tubers," as shown by the following
\(^1\) table of 1903 and 1904 results:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Date Plowed</th>
<th>Date Dug</th>
<th>Dry matter</th>
<th>Ash</th>
<th>Protein</th>
<th>Starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Mountain</td>
<td>May 7</td>
<td>Oct. 20</td>
<td>22.9</td>
<td>4.5</td>
<td>9.77</td>
<td>77.38</td>
</tr>
<tr>
<td></td>
<td>July 6</td>
<td>Oct. 20</td>
<td>18.1</td>
<td>5.56</td>
<td>11.36</td>
<td>72.43</td>
</tr>
<tr>
<td>Doe's Pride</td>
<td>May 7</td>
<td></td>
<td>21.75</td>
<td>5.39</td>
<td>10.35</td>
<td>74.28</td>
</tr>
<tr>
<td></td>
<td>July 6</td>
<td></td>
<td>19.06</td>
<td>5.10</td>
<td>12.11</td>
<td>71.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variety</th>
<th>Date Plowed</th>
<th>Date Dug</th>
<th>Dry matter</th>
<th>Ash</th>
<th>Protein</th>
<th>Starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doe's Pride</td>
<td>May 21</td>
<td>Sept. 28</td>
<td>21.64</td>
<td>13.11</td>
<td>72.38</td>
<td></td>
</tr>
<tr>
<td></td>
<td>July 12</td>
<td></td>
<td>18.55</td>
<td>16.80</td>
<td>65.79</td>
<td></td>
</tr>
</tbody>
</table>

The late planted potatoes not only gave a much lower
yield per acre, but, for both years, were of poor quality,
when mealiness in boiling and physical aspects, were
considered. In the case of the late planted potatoes the
cortex was poorly defined and the external medulla was not

\(1\). Cornell Bul. 230 (1905) p. 522.
uniform "being permeated by water areas and branches of the (large) internal medullary area." In texture, the tubers were leathery and watery, lacking that snappiness in cutting so characteristic of tubers of good quality. "After boiling," they "retained their form and were soggy." "The flavor and color also were not attractive and the liquor in which they were boiled had a pronounced taste and odor."

In specific gravity the late planted tubers averaged 1.07 and 1.08 for the two years and was slightly less than that of normal tubers.

Gilmore says that from his experiments he is led to the belief that "starch elaboration and cellular formation had not advanced to normal" in these potatoes. Normal dying of the plants at the end of the year did not insure ripeness of the potatoes. East and Gilmore seem to agree that "maturity is essential to high quality in potatoes."

DEGENERACY OF THE POTATO

The "running out" of potatoes is a common observation. New varieties are put on the market, are very productive for a varying number of years, then they usually begin to "run out" or degenerate.

In Colorado varieties in the mountain districts do not tend to run out or only very slowly, the tendency apparently being easily overcome by seed selection, while
in the Greeley district, on the plains, at an altitude of 4648 feet, the sexual tendencies and consequent degeneracy seem to overcome other influences such as selection, and the usual life of a variety is about 3 or 4 years.

At Svalof (Sweden) the opinion is held that in a variety of potatoes "there is no period of old age." On the other hand, they say that the degeneracy is believed to be the result of "factors which hinder the normal development of the plants and tubers or invite disease." It is claimed by the Swedish investigators that more vigorous seed tubers are produced in cool, moist conditions than in hot, dry regions. This view is also held by Fitch who worked in Colorado. The cause of this increased vigor is another question. It may be due to a well developed vascular system in the tuber or an abundance of diastase at the sprouting season.

Seed from sections with an environment unfavorable to the production of vigorous tubers may when planted again under these conditions year after year gradually weaken, resulting in a depreciation in yield and quality. While on the other hand, seed from a favorable environment will usually give a maximum yield and quality one or possibly more years, when planted under unfavorable conditions. In this connection the evidence available at Svalof (Sweden) in 1912 is said to show that where suitable

Figure 41

"True to Type" Seed Potatoes
sorts are used and where suitable tubers of these sorts are utilized for seeding purposes each year, the standard of a variety may be maintained indefinitely under all favorable conditions of soil and climate. 1 Hence it seems that the inherent tendency to degenerate is perhaps no stronger in potatoes than in other crops but that they are more widely and strongly influenced by environmental conditions than are most other crops.

It is likely that unfavorable natural environment is usually assisted in causing and hastening degeneracy by the use of small, poorly developed, unsound and diseased tubers for seed. Such practices can never result in anything but declining yield and quality. At the same time it is undoubtedly true that varieties vary considerably in their ability to hold up under certain adverse conditions, "even with careful selection and as a result some degenerate or "run out" quickly, while other strains or varieties apparently hold their own at least for a number of years.

It is reported that at Svalof the variety Dala, introduced about 150 years ago in the province of Delarne is still one of the best sorts grown there.

USE OF POTATOES

Potatoes are used for human and stock food and for industrial purposes. It is estimated 2 that in Germany

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2. U S Dept of Agr. Bul. 47, p. 11
"40% of the potatoes are fed to stock, 28% are used for table purposes, 12% for seed, 6% for alcohol, 4% for starch and related products, and 10% decay."

In Sweden they are raised for five distinct purposes: viz—cooking, the production of commercial starch, cattle feeding, and the manufacture of spirits.¹ The same is true of the United States, although their use for some purposes is less than in other countries.

Human food. Next to the cereals, potatoes are the most important food of northern nations. In Germany, it is found² that the consumption is in inverse ratio to the wealth and status of the people, being for the well-to-do people 3.6 bushels per annum, the peasantry 8.3 bushels, the laborers in western Germany 12.3 bushels, and for the poorer laborers in the eastern Provinces 17 bushels per year. The average consumption per annum for Germany is 7.3 bushels per capita.

Fraser³ gives the average consumption in the United States in 1902 as 3.5 bushels per capita, and Orton⁴ in 1913 gives it 2.6 bushels. In 1902 the consumption north of Mason and Dixon's line was about 4½ bushels per capita exclusive of those used for seed or starch, making the amount south of the line less than 1½ bushels per capita.

2. U S Dept. of Agr. Bul. 47, p. 11
3. The Potato, Fraser, p. 156.
4. U S Dept of Agr Bul 47, p. 3
Besides the ordinary ways of preparing of potatoes from the raw tubers, for human food, they are preserved by dessicating and canning to some extent. Most of the protein of the potato is albumin, which is soluble in water.

Snyder\(^1\) says that "When potatoes are peeled, cut in small pieces, and soaked in water for several hours before boiling, 80% of the total nitrogenous material is extracted, while when they are placed directly in boiling water the losses of nitrogenous material are reduced to about 7% and when the skins are not removed to 1%.

Ninety-two percent of the starch and 72% of the protein have been found to be digested.

Stock food. When plentiful and low in price, potatoes are profitable food for all classes of stock. However, they are not adapted to young animals under two years, owing to their deficiency in protein and ash, excepting in small amounts for balancing the ration.

Fjord found that 400# of potatoes to 100# of mixed grain and 445# cooked to 100# of corn were their relative values for pig feeding.\(^2\) Heavy feeding of potatoes has been found to induce scouring.

Per 1000# of live weight as high as 60# of raw potatoes for fattening steers, 25# for milch cows and yearling ewes and wether sheep, 40# for fattening sheep and 12# for horses have been fed with other feeds with good results.

1. Human Foods, Snyder, p. 38.
It is said that 40% of the entire German Production of potatoes are fed to stock, mostly swine. Their value for direct feeding is estimated to be 25 cents per bushel. Dried, they have been fed in Germany to cattle and horses with good results.

Indirect uses. Aside from their use as human and stock food, potatoes are used in considerable quantities for making starch, alcohol, syrup, dextrin, etc.

Potatoes have been used in foreign countries successfully for the making of cheap alcohol. For this purpose about 1.3 gallons of denatured alcohol, "180° proof"\(^1\) can be made from 100 pounds of potatoes.\(^2\) The average price for distilling potatoes in Germany for the years 1906-1910 was 18.3 cents per bushel.\(^3\) Was it not for the fact that the mash left after distilling has considerable feeding value, it is very unlikely that many potatoes would be raised for this purpose. With corn at 40 cents a bushel Wiley states\(^4\) that potatoes are worth about 15 cents per bushel for the manufacture of alcohol.

1. Contains 90% of alcohol by volume
3. Ibid, p. 11
CHENOPODIACEAE (Goosefoot family)

DESCRIPTION

Members of this family are annual or perennial herbs or shrubs (Atriplex, salt bush). The stems are terete (pencil shaped) or angled, erect or decumbent. The leaves are usually alternate, rarely opposite (Salicornia, glass wort), extipulate (without stipules), simple, entire, toothed or lobed. The inflorescence varies, the flowers occurring in panicled spikes (Beta, beet), or in globular, axillary sessile heads (Blitum capitatum, strawberry blite) or sometimes solitary in the axils (Salsola, Russian thistle). The flowers are usually small, greenish, bractless (Sarcobatus, greasewood) or bracteolate (Beta). They are perfect (Beta), pistillate (Kochia), polygamous-bearing both perfect and imperfect flowers (Kochia), monoecious (Sarcobatus) or dioecious (Atriplex spp.). They are usually regular. There are no petals. The calyx is 3-5 lobed or parted, rarely of one sepal (Monolepsis) or entirely wanting in the pistillate flowers of some genera (Atriplex). The calyx is persistent in fruit. There are usually as many stamens as the lobes of the perianth, rarely fewer (Chenopodium spp.); the filaments are commonly slender and bear longitudinally-dehiscent, 2-celled anthers. The ovary is superior, free from the calyx and 1-celled; the styles are terminal, short or elongated, 1-3 in number, and bear capitate stigmas. There is a single, amphitropous, erect ovule. The mature fruit is a utricle (1 seeded fruit with a loose pericarp) with membranous, leathery or thin pericarp. The seeds may possess an abundance of endosperm
(Beta, Furotia, etc) or none (Sarcobatus, Salsola); the embryo is spirally coiled (Salsola), annular (Beta) or conduplicate (Salicornia).

**DISTRIBUTION AND IMPORTANCE**

As a family the Chenopodiaceae is widely distributed geographically. They are for the most part saline plants found near the ocean or deserts and steppes; in the alkaline swamps and meadows of the Western United States members of the family are well represented. There are about 75 genera and 550 species.

From an economic standpoint the family is of considerable importance. The principal cultivated forms are the beet (Beta vulgaris) and spinach (Spinacea oleracea). A large number of representatives are weeds. Chief of these are Chenopodium spp. (Goosefoot, pigweed, lamb's quarters), Blitum (Strawberry blite), Atriplex spp. (Orache), *Kochia scoparia*, *Salsola tragus* (Russian thistle).
KEY TO PRINCIPAL GENERA

A. Embryo spirally coiled; endosperm little or none.
   Shrubs..............................................Sarcobatus (greasewood)
   Herbs..............................................Salsola (Russian thistle)

AA. Embryo not spirally coiled, partly or completely annular
    (in form of ring) or conduplicate (folded lengthwise; endo-
    sperm abundant.

B. Flowers perfect (polygamous in Kochia)
   
   C. Calyx with 5 lobes, about the base of which is
      developed a wing..................Kochia

   CC Calyx wingless, persistent.

   D. Lobes of the calyx becoming fleshy and
      bright red.....Blitum (strawberry blite)
   DD Lobes of calyx not becoming fleshy and
      never red in color.

   F. Developing large fleshy tap-roots
      .........................Beta (beet)
   FF. Tap roots not fleshy...Chenopodium
      (Goosefoot,lamb's quarters, pig weed)

BB. Flowers monoecious or dioecious
   
   F. Bractlets silky-hairy.......Eurotia (winter sage)
   FF. Bractlets not silky-hairy

   G. Pistillate flowers without a calyx
      .........................Atriplex (Orach)
   GG Pistillate flowers with a calyx.
      .........................Spinacia, (Spinach)
BEET (Beta vulgaris L.)

The above is the only species of the genus Beta of any economic importance. It is a complex species, however, separated into a number of rather distinct groups which are the result of cultural processes. These groups are as follows:

1. Sugar beet
2. Mangel-wurzels or mangels
3. Common garden beet
4. Leaf beets
   a. Chard or Swiss chard
   b. Ornamental or foliage beets

These groups are considered to have been derived from an original perennial form growing along the coast of southern Europe.

SUGAR BEET (Beta vulgaris L.)

Habit. The sugar beet is a biennial, storing up food in the crown (fleshy stem) and tap root the first year, from which aerial seed bearing shoots are produced the second year.

Roots. The "beet" itself is, for the most part, an enlarged tap root. The "crown" of the beet is developed from hypocotyl. The root part of the beet may be distinguished from the hypocotyl portion (stem) by the two opposite, longitudinal rows of secondary roots.

The true root system of the beet consists only of the lateral roots and the part of the beet which bears them. The tap root extends almost straight downward, the lower portion becoming small and thread-like and commonly reaching a depth
of 4 feet and often 6 or 7 feet. The lateral roots and rootlets are very abundant. They are often arranged spirally. The first 6 to 3 inches, however, are almost free of side roots. The upper laterals are the largest of the branch roots and extend farthest in the soil, spreading almost horizontally 2 to 3 feet. The lower laterals are more vertical and those near the very tip are almost parallel with the tap root. The shape of the tap root varies widely with the variety, and with the physical and chemical conditions of the soil.

Stems. The upper part (crown) of the sugar beet is hypocotyl, i.e., stem. This is a very much shortened fleshy stem with the leaves crowded at the apex. The second year the very short stem sends up, from terminal and axillary buds, stout, angular, branching stems to a height of 3 or 4 feet and occasionally 5 feet; these stems give rise to the flowering branches.

Leaves. During the first season a cluster of large leaves is developed from the crown of the beet. The oldest leaves are on the outside; the youngest toward the center. Each leaf has a long petiole which broadens out at the base; the blade is large and roughly triangular in shape at base and longer than broad. The veins are prominent.

The leaves produced on the stems of the beets the second year decrease in size rapidly as they approach the top of the stems. They are narrower and more pointed than those of the first year.

The leaves of the beet are the only place where sugar (saccharose) is generated. The protoplasm of the leaf with
the chlorophyll is the real sugar factory altho it is not
definitely known whether sugar is formed immediately or whether
some intermediate product is formed first. The sugar which is
formed is transported to the root where it is stored.

The amount of sugar elaborated depends upon the anatomical
structure of the leaf, the intensity of the light or the
amount of light available to the leaf, and according to Brock
the temperature.

According to Mayer and Strahmer the rays of yellow light:
play the leading part in the generation of organic substance.

The influence of light depends upon the (1) quantity of
foliage; (2) the position of the leaves (3) their age; (4)
the period of exposure. In general beets high in sugar con-
tent have abundant foliage. The sugar content is proportional
to the size and development of the leaf surface, leaves ly-
ing flat produce more sugar than upright ones, since the sun
light strikes them more nearly at right angles.

Brock found that taking the total leaf surface of a
beet of normal development at about 2000 square centimeters,
the highest amount of work in a day for the leaf substance of
a beet is 1.7 grams of dry substance.

It is found that the more continuously the sky is
cloudy and the lower the temperature the less is the increase
of sugar. With approximately uniform light during the day
the greatest increase of sugar has been found to occur before
noon.

The amount of sugar elaborated increases or decreases
during the day according to the changes in light. Even in the autumn days tests show that with sufficient temperature and intensity of light, the remaining sound leaves of the beet function to a normal capacity, the amount of dry matter produced being equal to that of the earlier months. This is confirmed by Girard who states that the cane sugar content in the leaf surfaces in the early evening is always dependent upon the amount of light which the plants have received during the day.

It is thought probable that the autumn grown leaves have little to do in the production of sugar on account of their small surface area. The reason why, as the season advances, a continually diminishing leaf surface suffices to assimilate the food taken up, is said to be due to the fact that the number of leaves increase in the same ratio as the surfaces of the individual leaves decrease.

Westermeier found in a test with three beets that the number of leaves remaining on Oct. 17 averaged 28, while the total number of producing leaves in the course of vegetation was 53.

The surface of a single full grown leaf averages 105 – 120 square centimeters.

The total surface of the leaves of a beet measured by Gohren in July was 6,981 sq. cm. and in September 14,044 sq. cm. on which the sun can exert the influence that is necessary for the production of sugar or organic substance generally.

The work per day is very great. According to Pognaul
a bunch of beet leaves weighing 500 grams contained approximately 0.4% on 2 grams of sugar, about half of which descends into the root during the night. Hence in 100 days 100 grams of sugar, that is, 14.16% of the final weight of about 700 grams is carried into the root.

The work of the light in the leaves depends also upon the presence of certain mineral substances and hence upon the fertility of the soil.

Potash among the nutrient substances is the one primarily concerned in the production of sugar. According to Noble's physiological experiments it was found that with a supply of all other needful nutritive substances without potash, a plant was unable to form starch or sugar. The presence of potash therefore is of fundamental importance for the process of assimilation in the beet leaf.

(The condensation of formaldehyde into glucose proceeds very readily in the presence of strong hoses. The function of potash in the process of assimilation would therefore be, according to Nuttelstadt, that the potash acting as a transferrer of energy performs the condensation of formaldehyde into sugar and starch).

Phosphoric acid has also been found necessary for the proper development and functions of the leaf and beet.

Inflorescence. The inflorescences are loosely spicate and terminal. The flowers are arranged along an axis, singly or in dense, sessile clusters, each of which is subtended by a small bract.
**Flowers.** Beet flowers are perfect. The perianth consists of 5 greenish parts united below to the base of the ovary. There are 5 stamens opposite to and partially attached to the perianth ring. The anthers are two celled, opening vertically to shed the pollen, which is very abundant.

The pollen grains are spherical. They vary in diameter from 13.3 to 25.8 micro-millimeters, averaging about 30 micro-millimeters.

They have a smooth surface which contains about 35 pores which have a special function when the grains germinate.

The pistil is three-carpellate with usually three short awl-shaped stigmas united at the base.

The ovary is half-inferior, that is partially imbedded in the flesh of the receptacle. It is one celled and one-seeded.

**Pollination.** Protrandry (maturation of stamens before pistils of same flower) occurs in the beet, consequently self-fertilization seldom, if ever, occurs. Wind and insects are the chief agents in the distribution of pollen. The flowers are very fragrant and this character is most prominent when the flowers are receptive and pollination is going on.

At pollination time the stigmas become sticky. The anthers begin to loose their moisture and the resulting contraction and diminution of the cavities forces out the pollen grains throwing them a considerable distance.

**Fruit and seed.** The ripened ovary of each flower is imbedded in the receptacle and base of perianth. The fruit is hard and nutlike containing a single dark, smooth seed about the size of a turnip seed. The "seed ball" is a term
Fig. 42. Sugar beet. X ½

Fig. 43. Cross section of sugar beet. X 3/4

Fig. 44. Sugar beet seed ball and seed X 8

Fig. 45. Longitudinal section of sugar beet. X ½
applied to beet seed. The "seed ball" usually contains a number of germs; however, in some cases a single germ is produced. The multiple germ beet seed arises when the flowers are in clusters; in this case the parts of the several flowers stick together forming a several-seeded mass, the "seed ball". If the flowers stand by itself on the stem, a single-germ beet seed is produced. In the single-germ beet seed, the 5 parts of the perianth which persist form the 5-pointed star of the seed.\(^1\) The single flowers are usually located at points on the stem where a branch arises. According to this a highly branched inflorescence will produce a greater proportion of single flowers.

Tests of the comparative yields of beets from single germ seed and multiple germ seeds have not been made. Of course, the advantage of single germ seed is in the elimination, to a large extent, of "thinning". Townsend and Rittue say that there is some indication that plants grown from single germ seeds produce a greater number of single flowers than plants from multiple germ seeds. It must be borne in mind that the so-called "beet seed" is in reality a fruit; a multiple germ seed consists of several 1-seeded fruits, a single germ seed of one 1-seeded fruit.

The true seed is kidney shaped, and about the size of a turnip seed, measuring about 3 mm. by 1.5 mm.

The testa or covering is smooth and brown. It is composed of several layers, the principal ones being the inner and outer.

The endosperm found at the center of the seed is white and consists of geometrical shaped starch cells measuring about .004 mm.

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Surrounding the endosperm is the annular embryo, consisting of the radicle and two cotyledons.

The center of the seed is made up of perisperm which is white and floury. Around this is the annular embryo consisting of a radicle, and two cotyledons surrounded by usually a single layer of endosperm.

Germination and the seedling. The primary root is the first to appear. Soon the cotyledons follow, pushing their way above ground (epigean). The seedling consists of a very short hypocotyl which scarcely appears above ground, two rather fleshy glabrous, short-petioled, one-nerved cotyledons and a tapering primary root, giving off a few red, fibrous laterals.

Types of sugar-beets. There are two well-known and common types of sugar beets: Kleinwanzlebener and Vilmorin. The Vilmorin beet is of French origin, and as compared with the Kleinwanzlebener, a German beet, is more circular in cross-section, smaller, has a lighter skin and a much smaller top of leaves. The percentage of sugar in the two types are about the same. The tonnage of the Vilmorin, of course, is lower.

HISTORY

The generic name of the beet Beta, is of Celtic origin. Deep red and white beets were known at least 3000 years B.C.

Theophrastus (372-288 B.C.) a Greek Philosopher, have described these two varieties. The red beet, only, was mentioned as early as 1590 by Oliver de Serres, who on boiling them recognized the sugar like nature of the juice.

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The red variety is said to have been introduced into England in 1548 and the white variety in 1570.

Abbe Rosier (an Englishman) says, that four varieties the small and large red, the yellow and the white were known in 1782.

A variety known as "disette" is still grown in France for feeding purposes, and was believed to have originated in Germany. It was brought into notice by Vilmorin who died in 1804. Perkins introduced it into England in 1786.

The French claim that the beet came to them across the Alps from Italy.

About the middle of the 18th century Marggraf, a member of the Berlin Academy of Science separated sugar from the beet.

He published his results in a pamphlet in 1747 and began advocating beet raising and sugar making.

However it was not until a half century later when Karl Franz Archard, director of the Academy of Sciences of Berlin and a former pupil of Marggraf modified and cheapened the sugar process that the world became interested in the possibilities of the beet for sugar making.

Investigations were begun in France by Vilmorin in 1775 and in Russia in 1800. Later in 1799 Conrad Adam experimented in Vienna.

F C Archard experimented on his farm in 1786 with at least 22 varieties.

As a result he published a book on the manufacture of beet sugar.

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1. U S Dept Agr. Spec Rept 28 p 7
2. U S Dept Agr Spec Rept 28, p 7
Other men who fostered the development of the beet in one way or another were Lampodius, professor of Chemistry and Metallurgy at the School of Mines at Freyburg, Baron de Koppy (in 1805) by erecting a factory, on his estate near Stiehlen, lower Silesia with an annual capacity of 525 tons of roots.

It is claimed by some that the beet came to Germany from Holland. In some countries especially France, interest in the sugar beet was stimulated by governmental aid and by prizes offered by many scientific and industrial societies.

Napoleon on Jan. 15, 1812 issued a decree providing for a School for manufactur of Beet - Root Sugar and the Creation of Four Imperial Factories and encouraging the culture of beets.

It was not until the 18th century that this root received a standard name (probably sugar-beet) and at that time it was used almost entirely for stock feeding.

However, as early as 1812 beet sugar was sold in commercial quantities about 13 tons being placed on the market at that time.

Since that the beet sugar industry has had a steady growth. In 1910-1911 the United States produced 456,000 tons of beet sugar; Ontario, Canada 9,200 tons and Europe 7,525,000 tons in the following countries principally Austria, Hungary, Belgium, France, Germany, Italy, Netherlands, Russia, Spain and Sweden, making a total world production of 3,040,000 tons of beet sugar.

It is not known when the beet was introduced into the United States but the first work seems to have been done with the sugar beet in 1830 by two men of Philadelphia. This work however was
a failure due to lack of familiarity with beet culture and sugar extraction.

Eight years later David Lee Child who had spent 1 ½ years in beet sections of Europe did some work at Northampton, Mass. He reports that the cost per acre of beets was $42 with 13-15 tons yielding 6% sugar and 2 ¼% molasses, the sugar costing 11c per pound. From that time interest in the sugar beet was more or less dormant until 1863 which marked the beginning of 6 years of unsuccessful factory work at Chatsworth, Illinois followed by failures with factories at Freeport, Illinois (1870) and at Black Hawk, Wisconsin (1871).

At Fond-du-lac, Wisconsin about this time it seems that a factory had two years successful experience under the management of two Germans, Messrs. Bonesteel and Otto who used $12,000 capital.

These men were induced to abandon their factory even tho they had offers of additional capital, to go to California where they took charge of the Alvarado Sugar Company with $250,000 capital, which built a factory in 1869.

This factory is said¹ to have been in successful operation every year but one since that date, altho its owners experienced some rather serious financial difficulties at different times in its early history. This factory is said to be the pioneer in successful manufacture of beet-sugar. Since this factory was started others have been built and operated, some successfully others unsuccessfully in California until in 1912 there were 11 factories in the state with an out put of 158,904 (Short)

tons of sugar.

In the ten years following the building of the first California factory 1869 one factory was established in each of the states of Maine, Massachusetts, New Jersey and Delaware. However none of them survived the difficulties which they met with.

In 1892 only six factories were in operation, indicating the slow growth of the industry.

The beet sugar industry was taken up actively and successfully in the different states other than California with the building of the first factories as follows: 1 Nebraska 1890; Utah 1891; Wisconsin 1896; New Mexico 1896; New York 1897; Michigan 1898; Minnesota 1898; Oregon 1898. Factories have also been established in Colorado, Washington, Arizona, Idaho, Illinois, Indiana, Kansas, Montana, Nevada and Ohio.

Bounties on all sugar produced were offered by some states as a stimulus to the industry but for various reasons these were discontinued although they were more or less effective in encouraging the industry.

GEOGRAPHICAL DISTRIBUTION

The following tables show the extent of the sugar beet raising and the beet sugar industry in the world and in the states of the United States for the year 1912.
<table>
<thead>
<tr>
<th>States</th>
<th>Number of Factories</th>
<th>Av. Length of campaign</th>
<th>Total Daily slicing capacity</th>
<th>Sugar made</th>
<th>Area harvested</th>
<th>Av. yield</th>
<th>Quantity worked</th>
<th>Sugar beets used</th>
<th>Av. Price per ton</th>
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</thead>
<tbody>
<tr>
<td>California</td>
<td>11</td>
<td>90</td>
<td>13,750</td>
<td>158,904</td>
<td>111,416</td>
<td>9.01</td>
<td>1,004,328</td>
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<td>Colorado</td>
<td>17</td>
<td>91</td>
<td>17,714</td>
<td>216,010</td>
<td>144,999</td>
<td>11.32</td>
<td>1,641,861</td>
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<td>Michigan</td>
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<td>74</td>
<td>14,367</td>
<td>95,049</td>
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<td>87</td>
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<td>1</td>
<td>88</td>
<td>500</td>
<td>80,340</td>
<td>63,706</td>
<td>9.25</td>
<td>589,217</td>
<td>5.81</td>
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<td><strong>Total</strong></td>
<td><strong>73</strong></td>
<td><strong>86</strong></td>
<td><strong>67,208</strong></td>
<td><strong>692,556</strong></td>
<td><strong>555,300</strong></td>
<td><strong>9.41</strong></td>
<td><strong>5,224,377</strong></td>
<td><strong>5.82</strong></td>
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</table>

1. Data from Beet Sugar Factories of the U.S., Truman G. Palmer
Besides the above factories there are 2 in California, one in Washington which were not in operation in 1912.

For the above factories 57,021 farmers raised beets.

The total estimated cost of construction of the buildings and installation of machinery but exclusive of lands, irrigation works and working capital, etc. for these 73 factories is $4,000,000.
PHYLOGENY

It is thought likely that our common sugar beet (Beta vulgaris) originated from a wild sea-beet (Beta vulgaris L. variety maritima Kock) Beta maritima. This form is a perennial found growing wild on the muddy western Mediterranean shores and on the Canary Islands.

It has a tough, moderately thick, fleshy root. It is said that the flower of the present sugar beet has many points in common with this wild beet. The pollen grains of the wild form are smaller and it has more lateral roots than the cultivated beet. Whether our cultivated beet is distinct from this wild type is not definitely known.

The common Mangel Wurzel or field beet belongs to the same species as the sugar beet. It differs from the sugar beet in size, shape and sugar content.

The sugar beet has developed from a root with a low percentage of sugar, 6% or less, to one with 20% or more of sugar in some cases.

In Germany in 1882 the average sugar content was 13.1, ten years later it was 15%.

Prof. Shepard of the South Dakota Station, has, from 1888 to 1913, succeeded in producing from a lot of beets containing from 13 to 17% sugar, a strain which he believes will yield 25% sugar.

The average percentage of sugar in beets used for sugar in the United States in 1912 was 16.31.
SHAPE AND STRUCTURE OF THE BEET

There is a great variation in the shape and size of sugar beets. This is determined by the variety and the environmental conditions under which they are grown. Some importance has been attached to the correlation between sugar content and beet-shape. This relation, however, is of little significance.

There seems to be some justification for thinking that more frequently the best beets are long with a gradual tapering from crown to the tip of the root. Other things being equal they more often contain a greater percentage of sugar, and will yield a larger tonnage than beets that taper very suddenly.

Beets with branched roots are very undesirable. They usually give a small tonnage, are low in sugar and the branches carry dirt and stones which increase the tare, and are often carried into the factory and cause damage to the slicers. The percent of sugar has been found to increase from the crown and the tip of the beet towards the middle, being the highest at a point somewhat above the middle of the beet.

The axis or central core of the beet is less rich in sugar than the zones surrounding it. The percentage increases from the axis to a point somewhat nearer to the epidermis than to the axis, and then decreases gradually to the skin.

Investigations indicate that beets which have the lateral roots arranged spirally are higher in sugar than beets which do not possess this character. It has been found that the pith next to the vascular rings is higher in sugar and that the percentage decreases as the distance from the rings increases. This being the case, other things being equal, beets having
the greatest number of rings will test higher. Since the number of rings does not vary directly with the size of the beets, the percentage of sugar would tend to be higher in the smaller beets because they contain a greater amount of pith near to the vascular rings.

The sides of the beet which are compressed and which bear the lateral roots have been found to be richer in sugar than the other sides. The cells of the compressed sides are narrower than those of the smooth sides of the beet which have a more expanded form.

Uniformity of type in beets is desirable but to attempt to judge sugar content accurately by shape is risky.

Headden shows\(^1\) that nitrates in the soil affect the shape of the beet. When he applied nitrates in excessive amounts to the soil, the beets produced were turnip-like in shape and the crown and leaves were abnormally well developed. Beets with a large crown are undesirable. An excessive production of leaves has resulted in a large stem.

The researches of a number of European investigators have shown that the anatomical structure of the sugar beet is correlated with sugar content. In general, beets with a high percentage of sugar have a finer structure than those with a low percentage. A cross or longitudinal section of a beet shows it to be made up, for the most part, of a ground tissue, penetrated by groups of vessels. In a cross-section, these groups of vessels take a circular form, being separated from each other by parenchyma tissue. At the center of the beet the bundles

---

are close together, forming the so-called "star". The tissue separating the vessels is composed of two kinds of parenchyma cells: small cells surrounding the vessels and large ones further removed. The smaller parenchyma cells are rich in sugar, while the larger ones are principally water storage cells, poor in sugar. Hence, beets having a predominance of small celled parenchyma are richer in sugar than those in which large water storage cells predominate.

It must not be assumed from this that it would be possible to find conspicuous differences in the anatomical structure of beets, varying one or two percent in sugar. Furthermore, a certain microscopical appearance is not to be associated with a given sugar content.

In a longitudinal section of a beet it will be seen that there is a crossing of the vascular bundles in the stem. The oldest part of the beet is the center, new rings of growth being placed upon these, while the new leaves come from the center of the crown. Hence there is a crossing of the older and younger bundles that lead into the leaves.

Many of these connecting strands lead out into the rootlets and from the connection between them and the leaves.

The rings of growth vary in number depending upon the length of the growing season. Ordinarily, 6 to 10 rings complete their growth. The cambium arise in the pericycle each remaining active but for a short period of several weeks.

The following table gives the composition of sugar beets, and products according to Henry.

---

<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Ash</th>
<th>Protein</th>
<th>Crude Fiber</th>
<th>Nitrogen free extract</th>
<th>Ether extract</th>
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</thead>
<tbody>
<tr>
<td>Beet, sugar</td>
<td>86.5</td>
<td>0.9</td>
<td>1.8</td>
<td>0.9</td>
<td>9.8</td>
<td>0.1</td>
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<tr>
<td>Beet, mangel</td>
<td>90.9</td>
<td>1.1</td>
<td>1.4</td>
<td>0.9</td>
<td>5.5</td>
<td>0.2</td>
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<tr>
<td>Beet, common</td>
<td>88.5</td>
<td>1.0</td>
<td>1.5</td>
<td>0.9</td>
<td>8.0</td>
<td>0.1</td>
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<tr>
<td>Beet, pulp</td>
<td>89.8</td>
<td>0.6</td>
<td>0.9</td>
<td>2.4</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>Beet, leaves</td>
<td>88.0</td>
<td>2.4</td>
<td>2.4</td>
<td>2.2</td>
<td>4.4</td>
<td>0.4</td>
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<tr>
<td>Beet, molasses</td>
<td>20.8</td>
<td>10.6</td>
<td>2.2</td>
<td></td>
<td>59.5</td>
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</table>

The following table of analyses of sugar beets is abbreviated from Headden:\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>German beet grms</th>
<th>Michigan beet grams</th>
<th>Ft. Collins beet grams</th>
<th>Montana beet grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave. wt. trimmed</td>
<td>813.0</td>
<td>673.0</td>
<td>479.3</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>74.550</td>
<td>73.000</td>
<td>75.800</td>
<td>74.630</td>
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<tr>
<td>Dry substance</td>
<td>25.450</td>
<td>22.000</td>
<td>24.200</td>
<td>25.370</td>
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<tr>
<td>Sugar</td>
<td>16.600</td>
<td>15.300</td>
<td>13.300</td>
<td>18.240</td>
</tr>
<tr>
<td>Total ash</td>
<td>0.900</td>
<td>0.701</td>
<td>0.320</td>
<td>2.680</td>
</tr>
<tr>
<td>Proteid</td>
<td>0.706</td>
<td>0.769</td>
<td>0.543</td>
<td>0.436</td>
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</table>

The average percentage per year of sugar, in beets in the United States from 1901-1912 varied from 14.6% in 1902 to 16.35 in 1910 while the percentage actually recovered from the beets varied from 10.95% in 1901 to 13.26 in 1912, the losses varying from 3.08% in 1902 to 4.05% in 1911.

Except in extreme cases there seems to be little support for the statement that the greater the weight the less the sugar content of the beet. The composition of the beet is affected by age, disease, fertilizers, insufficient food supply, light, time of topping, rainfall, etc.

PURITY

The term purity refers to the proportion which the sugar bears to other soluble ingredients. This is important because other ingredients prevent a portion of the sugar from crystallizing and therefore diminishes the sugar yield.

The purity is expressed in percentage of sugar compared with that of the table soluble matter. Thus, if the juice of a sugar beet contain 14% of total solid matter in solution and 12% of sugar, the coefficient of purity is 12 divided by 14 or 85.72%.

A purity of 80% is usually considered to be near the minimum permissible in beets intended for sugar making, altho this depends somewhat upon the absolute richness in sugar.

The purity coefficient of beets in the US from 1901-

1912 varied from 82.20 in 1902 to 84.49 in 1912.

USES OF SUGAR BEETS

The principal use of sugar beets is the production of sugar. However, they are used to some extent for cattle feeding and are used occasionally as human food.

**Human Food.** On account of its high sugar content the sugar beet is said to be superior for eating to the ordinary table beet.

It is cooked in the same manner as the table beet but requires a longer time on account of its size.

When cooked it is not quite as attractive in appearance as the red beet on account of the lack of color.

In **Belgium** the desiccation of sliced beets is practiced. From the dried material a meal is made which is said to be free from the distinctive faàvor of the best. This meal is used in making cake, puddings and pastry. It contains about 65% sugar and is sometimes substituted for sugar. This desiccation costs less than the extraction of sugar and all the sugar is retained while in making sugar some is lost in the form of molasses.

The per capita consumption of sugar in the United States was 51.00 pounds in 1884 and 49.95 pounds in 1885 and has increased to 77.54 in 1907.

In 1906–07 the per capita consumption of sugar in Europe was as follows:

---

2. Report of U S Dept of Agr., 36, p. 68
3. Ibid, p. 69
<table>
<thead>
<tr>
<th>Country</th>
<th>Pounds</th>
<th>Country</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>40.92</td>
<td>Portugal &amp; Maderia</td>
<td>15.51</td>
</tr>
<tr>
<td>Austria</td>
<td>24.32</td>
<td>England</td>
<td>93.50</td>
</tr>
<tr>
<td>France</td>
<td>36.05</td>
<td>Bulgaria</td>
<td>7.98</td>
</tr>
<tr>
<td>Russia</td>
<td>20.55</td>
<td>Greece</td>
<td>10.16</td>
</tr>
<tr>
<td>Holland</td>
<td>41.40</td>
<td>Servia</td>
<td>6.92</td>
</tr>
<tr>
<td>Belgium</td>
<td>29.70</td>
<td>Turkey</td>
<td>11.73</td>
</tr>
<tr>
<td>Denmark</td>
<td>73.68</td>
<td>Switzerland</td>
<td>55.22</td>
</tr>
<tr>
<td>Sweden &amp; Norway</td>
<td>47.88</td>
<td>All Europe</td>
<td>31.61</td>
</tr>
<tr>
<td>Italy</td>
<td>7.63</td>
<td>United States</td>
<td>77.54</td>
</tr>
<tr>
<td>Roumania</td>
<td>7.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spain</td>
<td>11.37</td>
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</tr>
</tbody>
</table>

Stock Food. The sugar beet is valuable for stock feeding. If fed too liberally it is said to produce scouring on account of its high sugar content.

Mumford of Michigan obtained better results with sugar beets than with corn silage for fattening lambs, using 4.7# of the former and 4.5# of the latter.

Shaw of Michigan obtained 716# gain on pigs from 1 acre of beets and 792# gain from ½ beets and ½ mangels.\(^1\)

Clark of Montana replaced \(100\#\) of wheat shorts with 396# of sugar beets in feeding pigs.\(^2\)

---

1. Feeds and Feeding, Henry (1910) p. 466.
2. Ibid p. 533
Haecker of Nebraska found that 30# of sugar beets were slightly less valuable than an equal amount of corn silage for dairy cows.¹

Beet tops are valuable for sheep and cattle. They are often sold for cash at from $2.50 to $5.00 per acre, but at this price the seller is considered to be the loser especially if they are removed from the farm and fed since he loses their manual value. The tops can be siloed successfully.

Beet pulp is also a valuable stock food. It may be fed green or dried. In the latter conditions it may be sacked and shipped long distances. Pulp must be fed with a protein feed in order to get a balanced ration.

The molasses is highly carbonaceous and is a valuable stock food when mixed with other feeds.

**Industrial Use.** Of course the principal use of the sugar beet is in the production of sugar.

In making sugar the beets are washed and cut into long strips, "Cassettes". Hot water is forced thru them which removes the juice, leaving the pulp as a by-product.

The juice is purified and boiled down. When of the proper thickness it is placed in vacuum pans and boiled until the sugar crystallizes.

The sugar mass (massouite) is placed in a centrifugal machine lined with fine sieves. The whirling drives the molasses thru the sieves. A stream of water is applied washing

---¹. Ibid  

p. 408.
out all of the molasses. The wet sugar is dried and sacked ready for market.

Sugar Yield of Beets. United States 1912.

<table>
<thead>
<tr>
<th>States</th>
<th>Analysis of beets</th>
<th>Recovery of sucrose</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
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<tr>
<td>California</td>
<td>18.79</td>
<td>83.99</td>
<td>15.83</td>
</tr>
<tr>
<td>Colorado</td>
<td>16.19</td>
<td>34.81</td>
<td>13.16</td>
</tr>
<tr>
<td>Michigan</td>
<td>14.72</td>
<td>83.75</td>
<td>11.33</td>
</tr>
<tr>
<td>Idaho &amp; Utah</td>
<td>16.65</td>
<td>86.83</td>
<td>13.70</td>
</tr>
<tr>
<td>Illinois and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wisconsin</td>
<td>14.43</td>
<td>82.30</td>
<td>10.84</td>
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<tr>
<td>Other States</td>
<td>16.61</td>
<td>84.13</td>
<td>13.64</td>
</tr>
<tr>
<td>United States</td>
<td>16.31</td>
<td>84.49</td>
<td>13.26</td>
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## BEET SUGAR PRODUCTION IN 1912

### North America

<table>
<thead>
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<th>Country</th>
<th>Tons</th>
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<tbody>
<tr>
<td>United States: Contiguous</td>
<td>535,000</td>
</tr>
<tr>
<td>Canada: Ontario</td>
<td>9,900</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>544,900</td>
</tr>
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</table>

### EUROPE

<table>
<thead>
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<th>Country</th>
<th>Tons</th>
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</thead>
<tbody>
<tr>
<td>Austria-Hungary</td>
<td>1,124,900</td>
</tr>
<tr>
<td>Belgium</td>
<td>231,000</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>6,000</td>
</tr>
<tr>
<td>Denmark</td>
<td>51,900</td>
</tr>
<tr>
<td>France</td>
<td>448,000</td>
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<tr>
<td>Germany</td>
<td>1,474,000</td>
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<tr>
<td>Greece</td>
<td>1,000</td>
</tr>
<tr>
<td>Italy</td>
<td>165,000</td>
</tr>
<tr>
<td>Netherlands</td>
<td>270,000</td>
</tr>
<tr>
<td>Roumania</td>
<td>27,000</td>
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<tr>
<td>Russia</td>
<td>1,808,000</td>
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<tr>
<td>Servia</td>
<td>7,300</td>
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<tr>
<td>Spain</td>
<td>35,000</td>
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<tr>
<td>Sweden</td>
<td>121,000</td>
</tr>
<tr>
<td>Switzerland</td>
<td>3,600</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5,824,600</td>
</tr>
<tr>
<td><strong>Total Beet sugar</strong></td>
<td>6,369,500</td>
</tr>
</tbody>
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APPENDIX

LABORATORY DIRECTIONS

Follow these directions closely.

Provide yourself with a note book containing paper about 8 x 10½ inches in size, part of which is ruled for notes and part smooth, hard unruled paper of good quality for drawings, a good pencil eraser and a 4 H drawing pencil.

Make all drawings with the 4 H pencil, and large enough to show plainly all of the important details. Indicate by means of an "X" followed by a figure, the number of times the drawing is larger than the specimen. For example, if the drawing is 5 times as large as the specimen, indicate it thus: X5. Use only one side of the drawing paper.

Number each sheet of drawings consecutively with Plate numbers placed one half inch from the margins of the upper right hand corner of the sheet, thus: Plate 1, Plate 2, etc.

Place your name in the lower left hand corner of each plate 1/4 inch from the bottom, and the date the plate was started, in the lower right hand corner on a line with the name.

Name and number the drawings in succession according to the names and numbers in the directions. Label all parts of the drawings.

All lettering on the drawings must be horizontal and uniform, and may be either written or printed, although the latter is preferred.

Indicate the parts of the drawings to which the labels
refer by means of dotted lines. Place no writing directly on the drawings.

Answer the questions by number, writing the answers on sheets of paper to be inserted in the note book in front of the respective drawings. Begin each answer on a separate line, properly numbered and indented.

Place all general notes taken in class in the back of the note book.

Neatness of work counts as well as accuracy and students will be expected to use every care and precaution to keep their note books in good condition.

All will be expected to attain a certain degree of proficiency in interpreting what they see in the specimens and in making the drawings.
LABORATORY EXERCISES

WHEAT

1. Draw natural size, flat and side views of a spike of common bread wheat; label rachis and spikelets.

2. Draw in detail, enlarged, the imbricated view of a spikelet; label glumes, palets, and sterile flowers which show.

3. Dissect and draw, enlarged, in proper order, the parts of a spikelet. Arrange the drawing of the parts on a slightly convex line. Label glumes, lemmas, grains, palets, sterile flowers, rachilla.

4. Draw, enlarged, a side view of glume. Label beak, shoulder, keel, nerves.

5. Draw, enlarged, dorsal and ventral views of a grain; label embryo, brush, suture, cheek.

6. Is the embryo end of the grain or the opposite end attached to the spikelet?

7. Is the convex side of the grain or the groove side towards the center of the spikelet?

8. From the position of the grain in the spikelet which side would you call dorsal, ventral? Is this the way the terms are used?

9. Cut a grain longitudinally and one traversely. Draw the inside views; label embryo, endosperm, seed covering, suture, cheek, brush. Indicate the location of the plumule and the radicle.

10. About what proportion of the volume of the grain does the embryo occupy?
11. What is the color of the embryo?
12. What is the color of the endosperm?
13. Draw a portion of a spike of Durum wheat showing beards and characteristic shapes of parts.
14. Draw a portion of a side view of a spike of Durum wheat, showing differences in arrangement of and compactness of spikelets from common bread wheat.
15. Draw, enlarged, glume of Durum wheat, showing in particular any characters in which it differs from common wheat.
16. Draw a flat view of a portion of a spike of Turkey Red winter wheat. Label rachis, spikelets and beards.
17. Which glumes are bearded?
18. Where is the beard attached?
19. Draw a portion of a rachis of a wheat spike with spikelets removed to show its structure. Label the point of attachment of the spikelets.
21. Draw, enlarged, an imbricated view of a Polish wheat spikelet. Label the parts.
22. Separate carefully and draw in order, the parts of a spikelet of Polish wheat, using particular care to show the relative size and shape of the parts.
23. In what way do the relative sizes of the parts of a Polish wheat spikelet differ from the relative sizes of the parts of common wheat?
24. Draw a portion of a spike of einkorn.
25. Draw, enlarged, a spikelet of einkorn.

26. Separate and draw the parts of a spikelets of einkorn.
   Note in particular, the palet which divides longitudinally
   at maturity.

27. Draw a portion of a side view of a spike of speltz.

28. Remove a spikelet of speltz and draw the side next to
   the rachis. Label glumes, lemma, sterile flower and
   adherent portion of rachis.

29. Does the portion of the rachis which adheres to the
   speltz spikelet extend above or below the point of
   attachment?

30. Draw a portion of a side view of a spike of emmer.

31. Draw the inside view of a spikelet. Label glumes,
    lemma, sterile flower, adherent portion of rachis.

32. Separate and examine the parts of a spikelet of emmer.
    Do the parts differ in number and arrangement from
    the parts of a spikelet of speltz? If so show
    differences by drawings.

33. In what way do emmer and speltz spikes, spikelets and
    grains differ? How will you tell them apart?

34. Draw the outer end of a spike of club wheat.

35. In what way does club wheat differ from common wheat?

36. Outline a head of Alaska wheat and draw a portion of
    the spike in detail.

37. Place a thin longitudinal section of a wheat grain under
    the compound microscope and draw a portion showing the
    pericarp, testa, nucellus, aleurone layer, embry@, plumule,
    radicle, epithelial layer of the scutellum and the hairs
at the end of the grain. Show also the cells of the endosperm if distinct enough to be differentiated.

38. Draw on the same plate, side and dorsal views, enlarged, of all the distinct types of kernels studied, showing characteristic shapes and relative sizes.

39. Draw a floral diagram of 2 wheat spikelets as attached to the rachis, showing the relative arrangement of their parts.

BARLEY

40. Examine a spike of a six-rowed barley, noting the arrangement of the spikelets, glumes, etc. Draw a portion of the spike showing the 3 rows of grains. Label glumes, lemmas, beards and central and lateral rows of grains.

41. How many rows of spikelets are there on a spike of six-rowed barley?

42. How many fertile glumes in each spikelet?

43. Are there any sterile flowers in a spikelet containing a grain.

44. How do barley spikelets differ from wheat spikelets?

45. What are the fine awl-shaped projections from the bases of the grains?

46. How many are there for each grain?

47. Draw a portion of a side view of a six-rowed spike.


49. Remove the 3 grains of a group. Compare for differences in size and shape. Make drawings showing differences.

50. What are the principal differences between the center and
the lateral grains of a group of barley grains.

51. Draw a portion of a two-rowed barley spike showing the 2 rows of grains. Label glumes, lemmas, grains, sterile flowers and beards.

52. Draw a portion of a two-rowed barley spike showing one row of grains. Label parts.

53. Make diagram of 2 and 6 rowed barley spikes. Label parts.

54. Remove a grain from the center of a spike of 2-rowed barley and compare with the 3 grains of a group from the 6-rowed barley. Make drawings showing comparative size, shape, etc.

55. How do the grains of the 2 types of barley differ?

56. How would you tell the difference between thrashed lots of 2-rowed and 6-rowed barley?

57. Draw, enlarged, the ventral side of a grain. Label lemma, palet, suture, beard and basal bristle. (the basal bristle will be found in the suture at the base of the grain. It is the tip end of the rachilla which connects the grain to the rachis).

58. Examine the basal bristles of a number of grains under the low power microscope. Note any differences in number, size and length of the bristle hairs. Make drawings showing at least 2 kinds of bristles.

59. Wheat becomes of the lemma and palet of barley of this type (common) when they are thrashed?

60. Cut a grain of barley longitudinally and one transversely. Make drawings, enlarged, showing the endosperm, embryo, pericarp, rachilla or basal bristle, palet and lemma.

61. Examine a spike of hooded barley. Note the shape and
and size of the reduced beard. Draw a grain showing the shape of the trifoliate or three-parted beard. Barleys bearing this kind of a beard are called hooded to distinguish them from another type with the beard entirely wanting and which is called beardless barley.

62. **Remove the grain from a hulless barley spikelet.** Note its size, shape, etc. **Compare with a grain of common wheat** and make drawings of ventral and side views showing the differences.

63. **Separate the parts of a spikelet of hulless barley and draw them showing their proper relation.**

64. **Remove the grains from a portion of a spike of nodding 2-rowed barley, and from a portion of a spike of erect 2-rowed barley.** Examine the rachii for relative length of internodes. Draw portions of the rachii showing differences.

65. **Examine grains of 2-rowed and 6-rowed barley and determine which has the thickest hull and the largest percentage of hull.**

66. The hard corneous barley grains are more often higher in protein than the white crumbly grains as seen in cross section. From your examination of these 2 types of barleys, would you expect the 6-rowed or 2-rowed types to be higher in protein?

67. **Does there seem to be any relation between the size of grains and the characters which indicate high protein?** If so what is it?

68. **Examine longitudinal sections of a barley grain under**
the microscope. Draw a portion of the section showing the embryo, endosperm, plumule, radicle, cotyledon, scutellum, aleurone layer, testa and pericarp.

OATS

69. Examine a head of common oats. Draw the head, showing arrangement of branches, spikelets. Label the pedicels, rays, spikelets and rachis.

70. What kind of an inflorescence is an oat head and how does it differ from a spike of wheat?

71. There are 4 general types of oat panicles; open or closed and side or spreading. In the open types the branches of the rachis stand at a considerable angle to the central axis, while in the closed types the branches are nearly parallel to the main stem. In the side oats the branches are attached in groups to opposite sides of the rachis the same as in the spreading types but the outer ends of the branches are all collected together on one side, giving the whole panicle a very much one-sided appearance, hence the name side oats. Side oats are of the closed type, while spreading panicles tend to the open type. Examine samples of the various types, making drawings which show the principal differences between them.

72. Examine an oat spikelet. Spread the glumes at the top and make a drawing showing the grain inside. Label glumes, lemmas, awn, pedicel and sterile flower.

73. Are the empty glumes of the same size? What is their relative position at the point of attachment.

74. Draw the groove side of an oat showing the 2 parts of the hull. What are these parts. Label.
75. Search the groove at the base of the grain for a very small hair-like stem extending about one third of the length of the grain. At its end will often be found a light colored feathery appendage. Include these parts in your drawing above. What is the hair-like stem?

76. What is the appendage at the end of the hair-like stem?

77. If this small appendage is absent what has possibly become of it?

78. Draw the dorsal or awn side of a grain of oats. Label parts.

79. How do awns of oats differ from awns of wheat and barley?

80. Draw in detail an oat spikelet with all of the parts separated showing their relative arrangement. Label glumes,lemma, grains, palets and sterile flower.

81. Find a double oat, cut a cross section and draw, showing the relative arrangement of the parts. Note that the 2 palets of the 2 grains composing the double oat face one another, while the fertile glumes form the outside covering. Label.

82. Remove the kernels from a double oat and note their size in comparison with the kernel from a plump single oat. Draw a kernel from each kind of oats (double and single) showing differences in size and shape.

83. What are pin oats. Find one and draw.

84. Examine grains of wild oats. Note the several ways in which they differ from cultivated oats. Make drawings showing all of the distinguishing characters of wild oats.

85. How do wild oats differ from cultivated oats in color?
In size? In shape?

86. How does the awn of wild oats, differ from the awn of cultivated oats?

87. What differences do you find at the base of the grains?

88. How do wild and cultivated oats differ relatively in weight per volume and percentage of hull to kernel.

**RYE**

89. Examine closely a rye spike. Note arrangement of spikelets and the general shape of the spike in cross section. Draw a portion of the spike showing about 2 spikelets. Label the parts.

90. Examine a spikelet in detail, noting how it differs in number, size and shape of parts from wheat and barley. Draw a single spikelet in detail, enlarged, showing the glumes, lemmas, grains and palets. Do you find any sterile flowers?

91. In what way do the glumes and lemmas of rye differ from those of wheat? Note the barbed keel of the lemma of rye. Draw in detail, enlarged, a lemma and a glume of rye.

92. Draw, enlarged, a grain of rye showing its relative size and shape compared with wheat and barley.

**CORN**

93. Draw a spikelet of pod corn bearing the husk, or glumes.

94. Dissect the spikelet. Homologize the parts with the parts of a spikelet of wheat. Draw and label similar to the wheat spikelet.

95. Draw the embryo side of a kernel of dent corn. Label embryo, crown and tip of kernel.
96. Cut with a knife, cross and longitudinal sections of kernels of dent corn. Draw, showing by proper shading, the starchy and horny portions of the endosperm. Label embryo, starchy endosperm, horny endosperm, pericarp, and dent.

97. Draw the embryo side of a kernel of flint corn. Label

98. Cut cross and longitudinal sections of kernels of flint corn. Draw showing by proper shading, the starchy and horny portions of the endosperm. Label.

99. Repeat 97 on soft corn.

100. Repeat 98 for soft corn.

101. Repeat 97 for pearl and rice pop corn.

102. Repeat 98 for pearl and rice pop corn.

103. Repeat 97 for sweet corn.

104. Repeat 98 for sweet corn.

105. Examine mounted sections of corn under the microscope. Draw portions of the sections showing embryo, plumule, radicle, endosperm, aleurone layer, nucellus, tests pericarp, epithelial layer, scutellum and embryo.

106. Examine sections of grains of different colored corns and determine the areas which contain the coloring material. Write your conclusions in your notebook.

107. If the coloring material is found in the pericarp of kernels that will be the influence on the color of kernels produced, by using pollen from these plants for fertilization?

108. In what areas of the kernel must the coloring material be in order that pollen from the kernels may influence directly the color of the resulting kernels?
FLAX

109. Draw a flax seed ball showing the characteristic lines along which the ripened seed dehisces. Label the lines of dehiscence.

110 The external lines of dehiscence mark the location of what internal structures?

111 Carefully cut transversely a flax capsule. Draw the cross section, showing the loculi or cells containing the seeds, the true and false septa, and the seeds. Label all parts.

112 How many loculi, true and false septa, and seeds does a normal flax capsule contain.

113. Examine a flax flower. Make drawings showing all characteristic parts.

POTATO

114. Examine a potato observing carefully the eyes, eye brows, seed end, base, and the small piece of stem at the base. Draw a potato showing these parts. Label.

115 How many eyes does the potato have?

116 How are they arranged?

117 How are the eyes distributed on the tuber?

118 Cut tubers longitudinally and transversely and examine for the skin cortex, vascular ring, external medulla and internal medulla. Make drawings showing these parts. Label.

119 Cut a potato thru one or more eyes. Trace the course of the vascular ring. What do your observations signify? Draw what you see.
120. Examine and draw a potato flower.
121 Dissect a flower and draw the parts.
122 Examine and draw a potato fruit.
123 Cut a fruit and draw the inside showing the seed present.
124 Secure and draw on or more potato seeds.

SUGAR BEET

125 Examine carefully a sugar beet. Draw the beet about natural size showing the leaf scars, crown, hypocotyl, true root, lateral roots and furrow. Label.
126 Is the furrow straight. If not what is its general course.
127 Cut a beet longitudinally and one transversely. Draw the sections showing the skin, parenchyma, vascular rings, core or axis and the transverse strands of vascular bundles. Label. Indicate on your drawing the supposed high and low sugar areas.
128 What shape is the beet in cross section?
129 Examine and draw several sugar beet seed balls.
130 Separate and draw several seeds.
131 How many seeds can you find in a seed ball?
120. Examine and draw a potato flower.
121 Dissect a flower and draw the parts.
122 Examine and draw a potato fruit.
123 Cut a fruit and draw the inside showing the seed present.
124 Secure and draw on or more potato seeds.

SUGAR BEET

125 Examine carefully a sugar beet. Draw the beet about natural size showing the leaf scars, crown, hypocotyl, true root, lateral roots and furrow. Label.
126 Is the furrow straight. If not what is its general course.
127 Cut a beet longitudinally and one transversely. Draw the sections showing the skin, parenchyma, vascular rings, core or axis and the transverse strands of vascular bundles. Label. Indicate on your drawing the supposed high and low sugar areas.
128 What shape is the beet in cross section?
129 Examine and draw several sugar beet seed balls.
130 Separate and draw several seeds.
131 How many seeds can you find in a seed ball?