PRINCIPLES OF VEGETABLE ANATOMY AND PHYSIOLOGY AS APPLIED TO AGRICULTURE.

THIRD ARTICLE.

THE VEGETABLE CELL.—(*continued*).—THE STARCH GRANULE—CELL CONTENTS—CELL DEVELOPMENT.

Starch may be said to occur in the tissues of all plants, except Fungi, at some stage of their existence. It is one of the nutritive or assimilable products of plants, being stored up in their cells for future nutrition; and it is thus subject to various changes during the life of the plant, often becoming converted either into sugar or cellulose, or some of the numerous unassimilable secretions. "That the latter takes place very frequently is rendered probable by the discovery that caoutchouc and gutta percha can be artificially manufactured from starch," (Lankester), whilst the conversion of starch into gum is a familiar phenomenon. Schleiden states that starch is gradually dissolved in the full grown potato, so that after three months there is scarcely a trace of it to be met with in the vegetable, even where it is in a perfectly sound condition.

The utility of starch as a nutritive substance is seen in the germination of our cereal grains; these consist for the most part of starch and gluten, which form the materials required for the growth of the young plant. These are insoluble in water, but as germination proceeds, they undergo chemical change, the gluten being converted, among other products, into the soluble substance called diastase: this diastase acting upon the starch, converts it into soluble grape sugar, a process which is taken advantage of by the brewer and distiller. The same change may indeed be brought about by the action of dilute sulphuric acid, which is extensively employed on the continent of Europe to convert starch into sugar; but the manufacture is illegal in Britain.

The great abundance of starch in many succulent roots and seeds give to these their nutritive value—so that many agricultural crops depend upon the production of this substance. Our cereal grains, potato, leguminous crops, as well as Indian corn, and the rice and other grains of warmer climes, owe their value in a great measure to this substance; but it is chiefly from other plants that the pure starches known in commerce are obtained. Thus arrow-root is derived from Maranta arrundinacea; many species of Canna supply toules-mois; Sago is obtained from Sagus and Meteroxylon, and Tapico from the Cassava plant. The presence of starch in the bark of birch and pine trees explains to us why these become a source of human food in those inhospitable regions where the low ebb of the conditions necessary for the development of more agreeable edible plants compels man to have recourse to the most unpalatable fare. In the same countries the "Iceland moss" and other Lichens are prized as articles of food, their nutritive value depending upon the presence of lichenin, a form of starch peculiar to them. Inuline, another starchy matter is obtained from the roots of Dahlias, Dandelions and Elecampane.

Although the starch granules are shut up in the cells of the plant, they are easily disengaged for commercial purposes. This is accomplished by bruising and rupturing the tissues, and soaking them in water so as to free the starch granules. Thus potato starch is obtained by rasping down the potatoes into a large vessel. The comminuted tissue is stirred in water, and when left at rest the cellulose immediately falls to the bottom; but the starch still floats in the water, and is thus poured off into another vessel. In this it is allowed to stand for a few hours, when the starch finally settles to the bottom, and is easily collected. Even diseased potatoes which are quite unfit for food, yield starch, as it is the cell wall that first decays, leaving the starch granules comparatively unaffected for a time. Starch may be obtained from wheat flour by putting it in a cloth and kneading it in water; the granules will thus be freed from the tissue of the grain (previously broken up by grinding) and will pass through the cloth into the water. Starch is not soluble in cold water, but being in the form of microscopically minute corpuscles, is readily diffusible thro' it.

While the forms of the starch granule are exceedingly various, they are often so characteristic as to afford the means of determining the plant to which they belong, at least so far as regards its genus or family. This fact, originally noticed by Fritsche, has been subsequently applied to the purposes of commerce with much success. In the determination of the numerous and varied adulterations of flour, bread, and some other common farinaceous articles of food, it has, in Dr. Hassall's hands, proved a valuable instrument; and in the histological examination of drugs I have found the starch granule a useful guide. In some cases the histological characters of commercial substances are so decided as to enable any one acquainted with the use of the microscope to determine at once whether they are pure or adulterated; but the adulteration of flours and starches are often so complicated as to require a very careful previous study of the characters of the numerous kinds of starch which enter into the composition of articles of food. This kind of knowledge is not to be derived from books, but from actual examination of authentic specimens, and in many cases by tracing the development of substances in the living plant. A definite and systematic method of observation must be pursued. Fortunately in the case of Starch, the characters presented in the form and structure of the granules are sufficiently definite to enable an intelligible classification to be formed. In the following attempt to present a tabular view of the characteristics of the different kinds of starch, I have chiefly followed Schleiden. It must be kept in view that the size and form of the granules are in most cases variable, so that whilst the following descriptions give characteristic marks which will be seen in most of the granules, these may be absent in many of them:—

I.—AMORPHOUS STARCH.

1. Sarsaparilla, rhizome of Carex arenaria and seeds of Cardamomum minus.

II.—GRANULES SIMPLE.

(Not united into masses.)

1. *Roundish or oval.*

A. Hilum apparently wanting.

2. Granules small, nearly spherical, very common in parenchymatous cells, along with other cell contents, often associated with, or invested by chlorophyll; in carrots and some other esculent and medicinal roots.
3. Large, irregular, knobby, truncated multiangular. In Saxifraga, granulata, Ranunculus Ficaria.

B. Hilum small, roundish.

a. Perceptibly lamellated.

4. Granules large, rough deformed. Cycadaceæ, (pith).
5. Granules ovate. Potato.
6. Granules Mussellike (Lilium, Fritillaria), or almost triangular (Tulip). Liliaceæ.

b. Obscurely, or not at all lamellated.

7. Rounded off poleydric granules. Zea Mays or Indian Corn.
8. Sharp edged, poleydric, very small granules. Rice.

C. Granules with an elongated central cavity, or hilum.

9. Granules roundish or oval, generally showing a starlike cleft in the inner layers. Pea, Kidney Bean, &c., also Horse Chestnut (pear shaped).

D. Granules perfectly hollow, cup-like.

10. In Iris florentina, &c.

2. *Granules flatly-compressed lenticular.*

11. The *larger* granules without hilum or concentric rings. Wheat.
12. Most of the larger granules with a longitudinal furrow, many of them distinctly ridged (Hassal). Barley.
13. With a radiated torn up cavity or hilum. Rye.

3. *Perfectly flat discs.*

14. In Zingiberaceæ, Lindl.

4. *Elongated Corpuscles* (with elongated central cavity).

15. In milk-sap of European and some tropical Euphorbiaceæ.