THE FIBRO-VASCULAR SYSTEM OF THE QUINCE FRUIT COMPARED WITH THAT OF THE APPLE AND PEAR.

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(Plates lxxi.-lxxiii.).

The quince agrees with the apple and pear in having five carpels, but, in the cavity of each, there are two rows of ovules, instead of merely two ovules in each chamber (Fig. 4). After fertilisation, the ovules become the well-known pips or seeds, while the walls of the ovaries assume a leathery texture, and the whole represents the "core." In the seed-coat of the quince, the cellulose becomes converted into mucilage, which is said to serve the purpose of attaching the seeds to the soil. The flask-like thickened floral axis becomes the succulent portion of the ripening quince.

The vascular system of the quince will now be considered, and it will be found to agree, in the main, with that already described in connection with the apple and pear.

According to De Candolle, in his *Origin of Cultivated Plants,* "the quince is a fruit which has been little modified by cultivation; it is harsh and acid when fresh, as in the time of the ancient Greeks." The reduction of the number of seeds in the fruit of the apple and pear, as compared with that of the quince, may be due to this very fact of cultivation and selection applied to them, having induced a more succulent and more palatable fleshy portion. The more attractive the fruit becomes to animals and birds feeding upon it, the more certainly will the seeds be widely distributed and deposited under conditions favourable to their germination. A fewer number of seeds will thus suffice for the propagation of the species, and even in the apple and pear, not only is there frequently but one mature seed in each carpel, but there are "seedless" apples in which they have become aborted altogether.

In some of the Natural Orders of plants, this reduction in the number of seeds concurrently with the enhanced attractiveness of the fruit, is clearly shown. In the *Ranunculaceæ* or Buttercup Family, there is every gradation from the numerous one-seeded achenes of the Buttercup itself, which are hard and unattractive, through the Columbine with its follicles reduced to five, and finally, the Baneberry, where the carpels are reduced to one, and the attractive fruit contains only a few seeds. Even in the *Rosaceæ*, or Rose Family, to which the apple, pear, and quince belong, there is a similar gradation, from the numerous carpels becoming the fruits or achenes of the wild rose itself, through the apple, pear, and quince, with only five carpels, down to the peach, plum, apricot, and cherry, with only one carpel containing one seed. The lusciousness and attractiveness of these fruits are well-known.

Transverse and Longitudinal Sections of Quince—young and mature.

In the transverse section of a young quince, the core is seen to occupy the greater part of it, and each of the five cavities contains a double row of seeds. The very centre of the core is hollow, *i.e.*, where the five carpels meet, and even with the naked eye, the ten primary fibro-vascular bundles are seen as dark green spots, five being opposite, and five intermediate to each seed-cavity (Fig. 5). In the mature quince, the core is surrounded by a dense layer of stone-cells, so that the primary vascular bundles are obscured (Fig. 2). In the longitudinal median section of a young quince (Fig. 4), the seeds are seen to be arranged in two rows. There is a small cavity between the two carpels, which tapers towards the apex, where the styles are given off, and the top of the floral axis forms its base. The core is surrounded by a comparatively narrow fleshy portion, which, however, increases considerably towards maturity. In the full-grown quince, the "core" is seen to be towards the "eye" end, and occupies but a relatively small proportion of the whole (Fig. 3).

Transverse and Longitudinal Sections of Young Apples and Pears for comparison.

In each case, the core forms the conspicuous portion, which becomes relatively small towards maturity. In the transverse section of the apple(Fig. 7), the ten fibro-vascular bundles are distinctly seen, surrounding the core. They almost adjoin the skin, as the flesh is so little developed at this stage. In the pear(Fig. 9), they are somewhat obscured by the stone-cells; still an inner whorl of five may be seen at the tips of the seed-vessels, and an outer whorl of five between. While the "core" is more or less central in the apple (Fig.6), it is more towards the apex of the fruit in the pear (Fig. 8).

Section of Fruit-stalk.

When a transverse section of the stalk is made just at the base of the fruit, the ten fibro-vascular bundles are distinctly seen, just as in the apple and pear(Fig. 1). They are continued into the fruit, and form a vascular system there, which is practically the same as in other pomes. The continuity between the fruit and the parent stem is thus maintained, and the materials necessary for growth, including water, are supplied, until the fruit drops when fully mature.

Fibro-vascular System as a whole.

The softening of the quince, for purposes of dissection, was not an easy matter, as it was necessary that the reagents used should not injuriously affect the structure of the tissue. The pear was readily softened by macerating in water, the apple by using a dilute solution of potassium hydrate, but neither of these methods was suitable for the quince. After steeping in water for some time and simmering for a few hours over a slow fire, it was rendered soft and spongy, but there was still a toughness about the "flesh," which prevented its separation from the vascular bundles.

If we endeavour to find a reason for this toughness, particularly in the outer layers of the flesh, the minute structure requires to be investigated. The numerous groups of stone-cells, even larger than those in the pear, will not account for it.

If a section is made through the skin of the fruit and the underlying tissue, the following structures occur(Fig. 14). There is the thickened cuticular layer, with the columnar epidermal cells. Beneath that, there are several layers of subepidermal cells, oval or elongated, and expanded transversely. Then at the junction of this layer with the pulp-cells, the vascular bundles constituting the plume-like branches spread out in a dense mass horizontally. If this is taken in conjunction with the naked-eye appearance of the plume-like filaments, as they appear when the skin is removed from a rotting quince (Fig. 12), there are good grounds for believing that the cells there are matted together by the permeating vessels, and that the tissue is tough in consequence.

If we turn to the chemical composition of the ash of the respective fruits, some of the constituents are seen to be in very different proportions, which may throw some light on the difference of texture.

The following analyses are taken from Dr. Griffiths' "Manures for Fruit and other Trees" (1908) :—

Percentage chemical composition of the ash.

	Apple.	*Pear.*	*Quince.*
Potash (K_2O)	56·21	55·00	43·20
Soda (Na_2O)	14·02	8·69	1·68
Lime (CaO)	4·87	7·99	6·32
Magnesia (MgO)	6·53	5·42	10·56
Oxide of Iron (Fe_2O_3)	1·93	1·20	1·54
Chlorine (Cl)	0·68	0·52	0·41
Silica (SiO_2)	2·82	1·52	9·64
Sulphuric acid (SO_3)	3·05	5·73	0·82
Phosphoric acid (P_2O_5)	10·89	13·93	26·33
	101·00	100·00	100·50

This is the composition of the ash of the ripe fruit, for it varies considerably at different stages of growth. Thus, unripe apples contain 0·32% of oxide of iron, and 52% of potash; whereas ripe apples contain 1·93% of oxide of iron, and 56% of potash. In the above analyses, there is considerable excess of silica and phosphoric acid in the quince, and a deficiency of sulphuric acid; but how far these compounds affect the texture of the fruit, it is impossible to say.

The vascular net does not readily separate from the flesh, as in the apple and pear, but is intimately bound up with it. A small portion of the net has been detached (Fig. 11), and the meshes are shown with the delicate veinlets arising from their boundaries. It is situated about one-eighth of an inch beneath the skin, and forms a continuous layer.

There is the same elaborate system of vessels, as in the apple and pear; but the plume-like branchlets towards the circumference are apparently much more numerous, and much more delicate. In a relatively large fruit, such as the quince, and one which has been little modified by cultivation, the green hypodermal cells of the fruit itself (Fig. 14) would contribute a considerable proportion of the starch for storing up, and consequently the means for conveying it, when converted into sugar, would require to be increased.

The vascular net-work is likewise present, and having examined this wonderful structure in the three principal pip-fruits or pomes, we are now in a position to show what part it plays in the economy of the fruit.

This network exists from the earliest stages of the fruit (Fig. 10), and it is similarly developed in connection with the "core" and the "flesh," thus ensuring the harmonious growth of both structures.

As regards the carpels, the primary vascular bundles give off internal branches passing to the dorsal and ventral surface of each. These dorsal and ventral branches spread out over the surface, and unite to form the beautiful network completely enveloping each carpel.

As regards the flesh, which is the bulkiest part of the pome, the primary bundles give off external branches, which form a vascular net at the zone of greatest growth, just beneath the skin. This net must be continually enlarging its meshes, so as to accommodate itself to the ever-increasing area, until the fruit is finally mature. The boundaries of each mesh give rise to plume-like branches, which permeate and bind together the peripheral layers, like a compact turf knit together by the fibrous roots of grasses.

The vascular net, both on the carpels and in the flesh, must be undergoing expansion while growth continues, and the question is, How is this done? It has to be continually readjusted to the increasing size and enlargement of the carpels and the flesh. If we start with the net-work in the fruit just formed, as in Fig. 10, the pressure exerted by the continuous growth of the flesh and conducting tissue combined, will not merely cause the net to stretch, but the conducting tissue will be added to. Just as the cells of the flesh enlarge, so will the conducting tissue which conveys the nutritive material necessary for their expansion, increase, and there will be a mutual accommodation between the growing flesh and the conducting tissue, which conveys the nourishment.

One cannot fail to be struck with the analogy, in a broad sense, between the blood-capillaries in the human body and the vascular or capillary net in the flesh of a pome, both serving to regulate the flow of nutriment, and equalise its distribution.

Professor J. S. Macdonald, in his presidential address before the Section of Physiology at the meeting of the British Association for the Advancement of Science(1911), referred to the blood-capillaries as follows: "They are no more and no less than blood-tissue. In its early days, this blood-tissue, or if you will, this capillary network, is pushed into each portion of the body by pressure due to its growth. In its later stage, the tissues surrounding it, which form the muscular coat of the heart, and the walls of the blood-vessels, are arranged into an external mechanical system providing a new pressure, which still further tends to push the blood-tissue into every available space." Without straining analogy too far, we may say that the capillary net-work in the pome is acted on by pressure, due not only to its own growth, but by the surrounding enlarging tissue; and in this way, it meets the increasing demands made upon it under ordinary conditions, as the fruit grows larger and larger.

Comparison of the Vascular System in Apple, Pear, and Quince.

There is a general resemblance in that of each of the three fruits, but there are differences in detail, largely dependent upon differences in the shape and texture of the respective fruits. There are the same number of primary bundles in each, and the general distribution is the same, but owing to the shape of the fruit in the pear, the vascular bundles run together for a greater distance before spreading out, than in the apple. The nests of strongly-thickened cells or "stone-cells," which occur so plentifully in the pear and form the so-called "grit," also occur in the quince, but not in the apple. The want of this additional skeleton in the apple may be correlated with the fibro-vascular system being generally coarser and tougher in texture.

The vascular system invariably forms a network beneath the skin, with the plume-like branches arising from it; and in the quince, these are particularly noticeable as forming a dense interwoven mass of delicate down-like material.

We can now picture to ourselves, in some measure, the marvellous adjustments necessary to produce the symmetrical, shapely, and healthy pome. The core, at first, is the main portion, in connection with which the vascular system is developed. Then the flesh surrounding it enlarges, and the pressure of growth in both flesh and vessels will cause branches from the main vascular system to permeate it. These branches, at the periphery, must form a regular capillary network, so as to ensure a regular and equable supply of nourishment where the greatest and most rapid growth is taking place. If growth is regular and steady, a shapely fruit is produced; but if it is intermittent, by fits and starts, then the regular formation of the capillary network is interfered with, and at those spots where this occurs, the cells are deprived of their nourishment and die.

There are thus two centres, as it were, to which food-material must be steadily directed, the developing seeds of the core, and the rapidly growing cells of the flesh. There must be an equable distribution of nourishment between them, so that there is proportionate growth in each, otherwise, the balance would be disturbed. The core reaches maturity first, and then the pulp-cells monopolise and store up material for the ripening process to take place.

The fruit becomes soft and succulent, while the sweet taste, the aroma, and the delicate flavour are developed. If there has been harmonious working of the different parts, if the different capillary networks have been completely formed, and if the food has been supplied in due proportion, the result is the symmetrically formed, well flavoured, often highly coloured, nourishing, and usually delicious fruit.

EXPLANATION OF PLATES LXXI.-LXXIII.

Plate lxxi.

Fig. 1.—Transverse section of stalk at base of fruit, showing the ten distinct fibro-vascular bundles (× 30).

Fig. 2.—Transverse median section, showing the five carpels and the "stone cells." In the mature quince, the position of the primary vascular bundles is obscured by the "stone-cells."

Fig. 3.—Longitudinal median section, showing the "core" towards the blossom-end. The primary vascular bundles are seen traversing the flesh from the stalk-end towards the carpels, which are surrounded by a dense layer of stone-cells. The stone-cells are also scattered through the flesh, and there are thin streaks here and there, indicating the vascular bundles.

Plate lxxii.

Fig. 4.—Longitudinal median section of young pear-shaped quince, showing the "core" occupying the greater portion of it, and tiers of seeds in the carpels. There is a cavity between the carpels, tapering towards the styles (× 3).

Fig. 5.—Transverse median section of young quince, showing the ten vascular bundles surrounding the core, which occupies the greater portion of the section, and the cavity is shown in the centre (× 3).

Fig. 6.—Longitudinal median section of young apple, showing "core" and flesh distinct (× 3).

Fig. 7*a*,*b*.—Transverse median sections of very young apples, showing distinct "core," and ten fibro-vascular bundles surrounding it(× 3).

Fig. 8.—Longitudinal section of young pear, showing the elongated fleshy portion below the seed-vessels.

Fig. 9.—Transverse section of young pear, showing the fibro-vascular bundles surrounding the core, five being at the outer tips of the seed-vessels, and five intermediate. The stone-cells are scattered all through the flesh.

Plate lxxiii.

Fig. 10.—Young apple-fruit (Cleopatra), just after the petals have fallen, showing the very delicate vascular network beneath the skin, even at this early stage (× 3).

Fig. 11.—Portion of vascular net of quince, enveloping the flesh beneath the skin, and showing the meshes (× 4).

Fig. 12.—Portion of plume-like branches, taken from a decaying quince in water, and appearing like fine fluffy material when the stem is removed. The innumerable branchlets extending to the skin are shown, and the deeper-lying branches from which they originate (× 3).

Fig. 13.—Surface-view of skin of quince, showing the "window-cells," about the same size as those of the pear. There are actual openings in the skin, round or polygonal (lenticels), and here and there, the stomata still persist (× 100).

Fig. 14.—Cross-section through skin and flesh, showing the thickened outer walls(20μ) of the oblong epidermal cells, and several layers of subepidermal cells. The vascular bundles extend to the subepidermal layer, and groups of "stone-cells" are shown, with the elongated parenchyma-cells radiating from them (× 100).