STUDIES OF PHYSICAL AND MORPHOLOGICAL CHANGES IN BARTLETT PEARS [1]

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Introduction

During the comparatively short period of development and maturity, the pear fruit passes through a series of profound morphological, physical, and chemical changes. While the gross features of most of these alterations are more or less observable, the more detailed changes, such as may have taken place during a brief interval of time, are rather difficult to measure or even to approximate. Yet in all harvesting, transportation, and storage operations with most of the commercial varieties of pears, these changes assume a profound importance, for they have a direct bearing on both the eating and the keeping quality of the fruit. This is of particular significance in view of the fact that the pear is a highly perishable product. Hence of late, because of the rapid expansion of our marketing operations, particularly with fruit from the Pacific Coast, the subject is receiving an ever-increasing emphasis. There is a growing demand for more extensive and more detailed information in this field as a logical addition to some of the groundwork already laid by a number of more or less correlated investigations.

Review of Literature

As a result of the studies of Kulisch (9), Ewert (2), Kelhofer (6), Ritter (15), Rivière and Bailhache (16), and other European investigators, there has accumulated considerable information on the chemical changes in the pear as affected both by seasonal differences and by artificial alterations of a number of environmental factors. In this country, Dunbar and Bigelow (1), Thompson and Whittier (17), and Magness (11) have made valuable contributions on the subject. All of these investigations, however, have been based largely on changes of the cell contents and only indirectly on those of the structural part of the tissues. This is but natural if we remember that our present knowledge of the chemistry of the principal substances of the cell walls is very imperfect. So, too, the culinary properties of the pear fruit being determined primarily by the amount of sugars, acids, and tannin present, these substances have naturally received first consideration. Though most of our present chemical data have been secured from samples taken at considerable intervals of time, still they may

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be used as fairly good indices of the gross seasonal changes of the fruit during the time both of development and of maturity. It is to be questioned, however, whether it would be at all possible to show by means of chemical analyses such small differences in maturity as take place in but a few, say three or four, days.

In contrast to our knowledge of the chemistry of the pear, we know far less of the important morphological and physical changes that are coincident with the development of this fruit. The fundamental work of Kraus, McAlpine, Malfatti, Zschokke, and others is, however, of particular significance in this respect. They have given us a good conception of the gross structure of the pear fruit. Hence their work warrants a detailed review.

Though not considering the pear directly, the analytical researches of Kraus (7) on the morphology of pomaceous fruits convey thorough and definite information on the character and development of the various tissues—vascular, parenchymatous, dermal—forming a pome fruit. Briefly, it is to be regarded as consisting of several drupe-like fruits, borne within, and connected with, a fleshy torus. The three regions—carpellary, pith, and cortical—are clearly distinguishable both as to their ontogenetic development and their morphology. Outside of the seed, development of the structures consists mainly in the expansion of cells already formed, alterations in their chemical content, and the storing of food. It is hinted, however, that further cell division may possibly take place in some such manner as suggested by Farmer (3). The vascular system permeates all parts of the fruit except the pith region, the cortex being particularly well supplied. The ten primary toral bundles divide and anastomose, forming a complete fibral network under the epidermis.

The fibro-vascular system of the pear (pome) as it appears in two varieties, Harrington's Victoria and Achan, has been pictured by McAlpine (13). Excepting the pith region, it forms a complete and elaborate network throughout the fleshy part of the fruit.

Malfatti (12) describes more in detail the anatomy of the pear, particularly that of the epidermal region. As a result of growth, epidermal cells divide into "daughter" cells. Thinness of the walls indicates which are the newest cells. A thick cuticle covers the epidermis. It becomes cracked and torn at points where lenticels are formed. The latter are underlain with cork. So, too, in case of russeting, epidermal cells anywhere may be replaced by cork cells. Below the epidermis is found a subepidermis consisting of 3–4 layers of tangentially stretched plate-like parenchymatous cells. Ordinary isodiametric cells of the cortex adjoin the subepidermis. In addition to protoplasm, they contain small granules of starch, distributed either singly or in groups, and sugar in solution, while subepidermal cells contain beside sugar also chlorophyll, tannin, and chromoplasts. Stone cells, either singly or more frequently in groups, are found imbedded in the cortex. They are roundish-polygonal, very thick, and are layered and dotted with many pore canals. Radially arranged parenchymatous cells adjoin groups of stone cells.

The structural features of the epidermis are described in further detail by Zschokke (19). Increase of the surface of the fruit is accomplished partly by subdivision and partly by expansion of the epidermal cells. Tangential walls of the epidermis become thickened early in the development of the pear. Great differences in amount of cuticle were observed between fruit grown in the sun and that grown in the shade. The "bloom" consists of particles of wax. Stomata are present in all young fruit. As the fruit grows, they disappear or are torn and become lenticels. Morphologically, the subepidermis differs considerably from that of the cortex. The cells are smaller, more tabular, thick-walled, and contain tannin and pigment bodies. Color of fruit depends on the contents of these cells. Within the subepidermis are found scattered stone or grit cells. They are plated on the outside and pointed toward the core. This layer of stone cells is present in all pears. In some it forms almost a "stony shell" all over the fruit.

It is to be noted that none of the above-named investigators take cognizance of such morphological or physical alterations in the pear as may be exhibited comparatively late in the development of the fruit and may therefore be coincident with the time of harvesting and marketing of the crop. No correlation is noted between the morphological features and the condition of maturity of the pear.

A Physical Test for Maturity

In view of the existing situation, the Oregon Agricultural Experiment Station has for the past four seasons endeavored to find a simple but reliable test for maturity of pears. As the work progressed, it was soon evident that such a test, in order to be applicable, must be based largely, if not entirely, upon the physical properties of cells rather than upon their chemical contents. Of the various new testing methods under consideration, a simple one, since then known as the "pressure test," has given strikingly satisfactory results. Work extending through four seasons has shown that it is by far the most practical means of measuring the changes in maturity of pears (10, 14).

This new test is based upon the fact that during the growth and ripening of the pear there is a gradual and consistent alteration in physical resistance to pressure or wounding of the epidermal and cortical regions of the fruit. On the average this amounts to close to one half pound every 24 hours. It points either to rapid changes in size or to some other modifications of the structural parts of the cells. A special apparatus was constructed for the purpose of measuring and expressing in convenient units this change.[2]

[2] For a description of the apparatus and of its use, see Oregon Agricultural Experiment Station Bulletin 186, pp. 7–10.

During the past four shipping seasons several thousand tests have been made by means of this instrument on all leading commercial varieties of pears in Oregon, but particularly on the Bartlett.

Table 1. *Summary of Pressure Tests, Bartlett Pears, Oregon, 1918–1921*

Date	Rogue River Valley		Willamette Valley	
	1918 Ave. of 4 orchards, Lbs.	1919 Ave. of 5 orchards, Lbs.	1920 Ave. of 4 orchards, Lbs.	1921 Ave. of 3 orchards, Lbs.
August 1	34.5			
August 2	32.4	35.7		
August 4		35.1		
August 5–6	31.2	35.1		
August 8–9	30.0	34.0		
August 11		32.1		41.0
August 12	29.2			
August 13		31.7		
August 15	27.8	31.7		
August 16				36.7
August 18		30.5		
August 19–20	25.4		40.8	36.2
August 22	24.4	29.4		
August 23			38.5	33.8
August 25		27.8		
August 26	24.3			32.2
August 27			37.5	
August 29		26.5		
August 30			36.7	31.0
September 2			34.5	30.8
September 6				29.3
September 7			33.2	
September 11			31.6	
September 14			27.2	

Table 1 shows in a condensed numerical form the results of several thousand tests on Bartletts. It is evident that a strict correlation exists between the stage of maturity of a Bartlett pear and the resistance to physical pressure of the outer regions of the fruit. The data for the respective years show a really remarkable consistency in this respect (text fig. 1). It should be particularly noted that the data were collected at extremely short (2- to 4-day) intervals. These results have been put to practical test in a number of commercial orchards. The "pressure apparatus" is now in use in several pear-growing sections in the Pacific northwest. It permits the individual grower, or the growers of a certain district, to measure conveniently and to express in concrete units the exact stage of ripeness of the fruit at the time of harvesting or shipping. One may thus be guided in all harvesting operations and helped to avoid misunderstanding and unnecessary economic loss.

In connection with the above-described investigations, the question naturally arose as to what may be the underlying causes of the gradual change of tissues of the epidermis and the cortex to resistance to pressure of the character above noted. One is led to assume that the factors involved

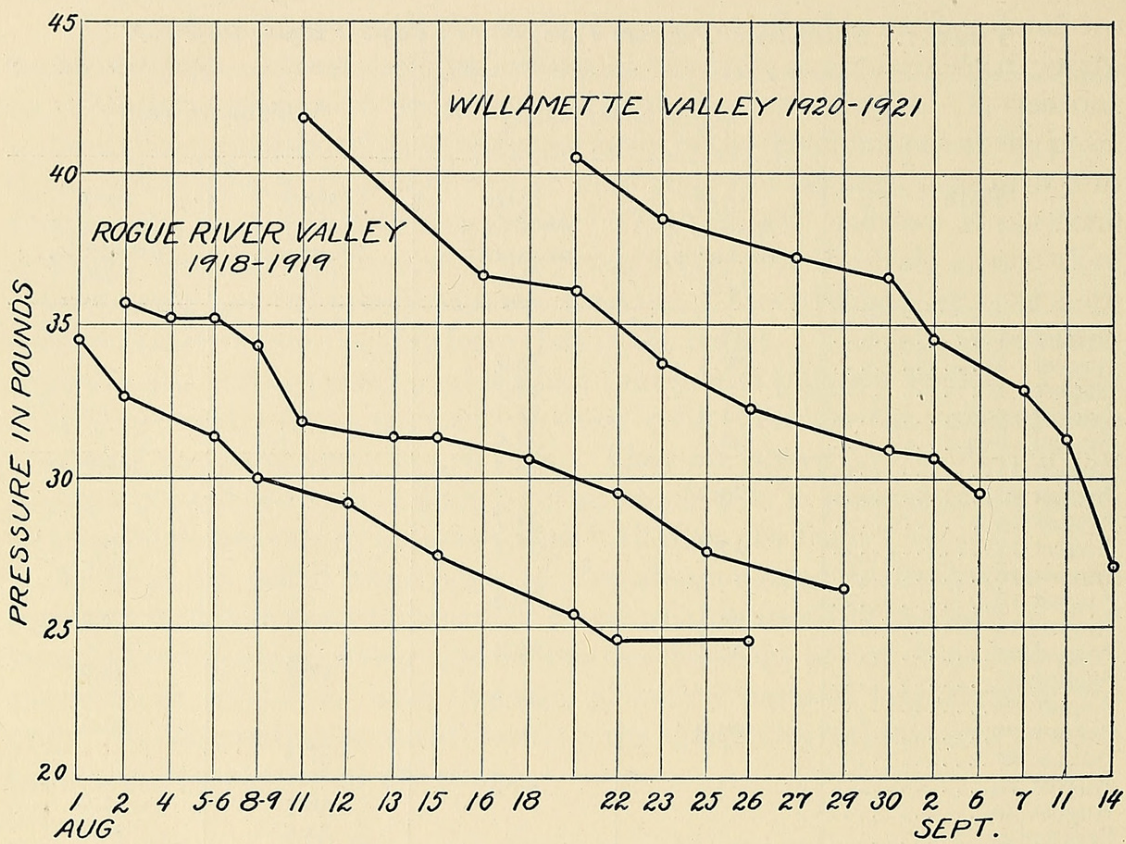

Fig. 1. Graphs showing records of pressure tests on Bartlett pears and length of shipping seasons. Rogue River Valley, Oregon, 1918–1919, and Willamette Valley, Oregon, 1920–1921.

are primarily physical, but in accordance with their physical alterations cells undergo considerable chemical changes. No chemical investigations, however, were attempted at this time. The following is a report on studies of morphological and histological modifications of the Bartlett pear as revealed during the comparatively brief period of harvesting and shipping of the fruit.

Morphological and Histological Investigations

Material and Methods

A concise account may be given here of the nature and extent of injury caused by the physical test, *i.e.*, by the tip of the plunger of the pressure apparatus. The tissues affected form a conical area, with the apex toward the axis of the fruit (Pl. XXIV, figs. 4, 5). The epidermis, subepidermis, and a considerable number of immediately underlying cells of the cortex are not ruptured, excepting in extremely ripe pears, but are torn in a circle, forming a plug which crushes against the cells of the cortex. A decided line of rupture is thus caused from the epidermis down into the flesh around the outer margin of the area of pressure. As the fruit increases in ripeness, much more crushing of cells of the cortex takes place. The cells adjoining the line of cleavage do not appear to have been pressed out of position. Many of them perforce are torn, or else they may be separated from one another along the middle lamellae. It is to be noted that in no fruit used in connection with this study did the area of pressure extend farther than the cortical region. Consequently the present histological study was confined to the cortex and epidermis.

Bartlett pears, obtained from four typical orchards and employed for the pressure tests, were used as material. Radial sections (plugs) from representative specimens of each orchard were cut at the point of the greatest diameter of the fruit at the time of taking of pressure records (fig. 5). They were preserved in 70% alcohol. All material for microscopic observation was imbedded in paraffin. Radial transverse sections were cut 10 and 25 microns thick, stained in Delafield's haematoxylin or safranin, or in both for contrast, and preserved in Canada balsam. In all cases standard histological methods were followed.

Results

Upon examination of a large number of sections, it was soon evident that in order to show the greatest possible differences in all measurements only material collected comparatively early and comparatively late in the season should be taken into account. Hence, "early" refers here to sections obtained from specimens preserved on August 20, and "late" to those preserved on September 17. These dates indicate the greatest extremes of the harvesting season for the Bartlett pear in the Willamette Valley, Oregon, in 1920.

Cuticle. Early in the season the cuticle is quite uniformly distributed over the epidermis, filling the spaces between the unevenly arranged cells. Opposite a comparatively wide space, formed by grouping of cells, the cuticle is slightly depressed or somewhat torn. As the season progresses, narrow cracks appear. The outer surface now becomes more uneven and "netted." This condition increases as the fruit enlarges, some specimens showing a decidedly close-netted checking during or towards the end of the ripening time. Under certain circumstances these may turn into open cracks with slightly raised ridges. There is a general decrease in thickness of the cuticle.

TABLE 2. *Measurements of Thickness of Cuticle*

Date	Aug. 20	Sept. 17	Decrease	Ripe
No. of determinations	35	34		15
Thickness	5.8 μ	4.7 μ	19.0%	4.2 μ

Epidermis. Because of differences in position, size, and form of the cells, only the outermost layer of cells has been designated here as *epidermis.* Great irregularity in form and distribution is exhibited by the cells of this layer. Many of them are tangentially stretched, or become so in due course of time. A considerable number, however, are conic in form, with the apex protruding into the cuticle. Tangential and radial measurements taken early and late may be considered as a fair index of the general change in form and size of the epidermal cells. The outer tangential wall is usually somewhat thickened, and the thickening may extend also to the fore part of the radial wall. No seasoned change in this respect, however, could be detected.

TABLE 3. *Measurement of Cells of Epidermis*

	Ave. Diam., Tangential	Ave. Diam., Radial	Approx. Area Long. Sect.	Increase
No. of determinations	42	42		
August 20	13.5 μ	12.5 μ	170 sq. μ	
September 17	15.5 μ	12.5 μ	194 sq. μ	14.1%

Two or more cells, often called "daughter" or "window" cells, may be grouped together to form a "mother" cell, as shown by McAlpine (13) and other investigators, thus making a comparatively large open space between adjacent groups. Early in the growth of the fruit the "window cells" appear to be more irregular in outline and closer together. The average number of "window cells" per "mother cell" was found to have increased during the season as shown in table 4. Material collected on August 20 showed

TABLE 4. *Average Number of "Window Cells" per "Mother Cell"*

	Date	
	Aug. 20	Sept. 17
No. of determinations	53	53
Number	2.92	4.00

usually two "window cells" in each group, though some groups contained four, and a few one, three, or five cells. On September 17 the average number of "daughter cells" had increased to four, with a few groups containing two, six, and eight. Uneven numbers of cells—three, five, etc.—were now only rarely encountered. This numerical distribution may be considered as a fair proof of the usual subdivision of the original cells during the time of enlargement of the fruit. Quite often single undivided cells were also present.

Subepidermis: First layer. Though the tissue to a depth of five cells or more immediately below the epidermis may be designated as *subepidermis* (fig. 6), the first layer was considered separately. Cells of this layer differ quite conspicuously from those underlying them, being much smaller and more flattened. Stretched tangentially and plate-like in form, they are more evenly arranged and more closely united with each other than are those of the epidermis. There appears to be no thickening of the outer walls. Subepidermal cells of the first layer show a proportionally faster seasonal increase in tangential than in radial diameter. The resultant enlargement in size, as measured in one plane, is close to 40% (table 5). This perhaps is a good indication that subdivision of cells is much less frequent here than in the epidermis.

TABLE 5. *Measurement of Cells of Subepidermis (second layer below epidermis)*

	Ave. Diam., Tangential	Ave. Diam., Radial	Approx. Area Long. Sect.	Increase
No. of determinations....	80	80		
August 20................	18.2 μ	12.2 μ	224 sq. μ	
September 17............	22.2 μ	14.0 μ	312 sq. μ	39.3%

Second to fifteenth layers. As a rule, cells of the subepidermal region, as far as the fifteenth layer, are considerably smaller and more compact than those of the cortex proper (fig. 6). Observation showed, however, rather gradual but quite conspicuous increments in size from the periphery inward. Most probably the enlargement is at the same rate in all diameters. From measurements in 1920 it appears, however, that a relatively greater increase had taken place in the radial diameter, the cells having rounded out and become more nearly isodiametric. No difference in thickness of walls on the peripheral side of the cells could be noted.

TABLE 6. *Measurements of Cells of Subepidermis (3d to 5th layer below epidermis)*

	Ave. Diam., Tangential	Ave. Diam., Radial	Approx. Area Long. Sect.	Increase
No. of determinations....	80	80		
August 20................	26.5 μ	16.8 μ	445 sq. μ	
September 17............	33.5 μ	22.0 μ	737 sq. μ	65.6%

Within the subepidermis are scattered groups of a few to a dozen or more sclerenchymatous or stone cells (fig. 7). Occasionally single isolated cells of this type are found imbedded in this region. Although the sclerenchymatous cells of the subepidermis are conspicuous enough in the Bartlett, Zschokke (19) found them to be so numerous in some late varieties of pears as to form a shell as it were around the fruit. No seasonal change in distribution of stone cells could be detected, though naturally they become somewhat more widely separated due to the expansion of parenchymatous cells surrounding them.

Lenticels. As a result of the expansion of the epidermis, the stomatal openings are pulled apart, resulting in the formation of distinct pores or lenticels. During the fore part of the season (August 20) they are comparatively small in size and conspicuously deep (fig. 8). Cork cells are then distributed largely around the edges of lenticels. As the season progresses, the lenticels gradually become larger and shallower and more cork cells are laid down at the bottom. The fruit developing still further, lenticels eventually become flat, shallow openings surrounded and underlain with cork tissues. Extreme expansion and mass formation of corky tissues may eventually disfigure a lenticel, leaving only a patch of corky tissues with a marginal scar of the epidermal cells surrounding it (fig. 9).

The seasonal changes in relative distribution of lenticels may be of interest. A large number of close determinations showed that the average number of lenticels per square centimeter of surface area of the fruit had decreased between August 20 and September 14 from 44 to 32.

TABLE 7. *Number of Lenticels per Square Centimeter of Surface of Fruit*

	Date	
	August 21	September 14
No. of determinations	13	9
No. of lenticels	44	32

Cortex. The pressure test involves primarily the cortical cells. Hence, from the point of view of physical changes in the pear the cortical region is of far greater importance than any other heretofore considered. Moreover, the tissues of the cortex constitute the main edible part of the fruit. Naturally any alterations that may take place here will at once affect its keeping and eating qualities. The cells of this part of the pear are extremely thin-walled, more or less nearly isodiametric in form, and quite variable in size (fig. 10). While arranged rather compactly early in the season, they become separated at maturity of the fruit, giving rise to the large intercellular spaces. During the enlargement of the pear, cortical cells undergo a rapid increase in size.

TABLE 8. *Measurements of Cells of Cortex (approximately 3–6 mm. below epidermis)*

	Ave. Diam., Tangential	Ave. Diam., Radial	Approx. Area Long. Sect.	Increase
No. of determinations	80	80		
August 20	90.5 μ	130.8 μ	1188 sq. μ	
September 17	128.8 μ	178.8 μ	2301 sq. μ	93.7%

Groups of stone cells of considerable size are found scattered throughout this region. They are surrounded by radially arranged, distinctly elongated paranchymatous cells (fig. 11). There is considerable variation in the number and distribution of these groups in the various specimens. As the cells of the cortex enlarge, the groups of stone cells in a given area become fewer.

The wound caused by the pressure test being of such a character as to tear the cells across their walls instead of separating them from one another along the middle lamellae, any change in the walls becomes of prime importance in these considerations. Measurements showed a general decrease of close to 15% in thickness of walls of the cortical cells during the harvesting season. It is certain, however, that, in addition to changes in thickness,

TABLE 9. *Measurements of Cell Walls of Cortex (approximately 3–6 mm. below epidermis)*

	Date		
	Aug. 2	Aug. 30	Decrease
No. of determinations	45	45	
Thickness	1.15 μ	0.98 μ	14.8%

other physical and chemical modifications of the cell walls take place at this time. Most probably changes in the pectic compounds are of prime importance in this respect. Since no tests were made, one can only conjecture what some of these differences may be.

Vascular bundles. The vascular system being made up of more lignified cells than any other tissues considered here (7, 13), one would expect it to undergo the least change during the time in question. No study was made of seasonal modifications in vascular bundles.

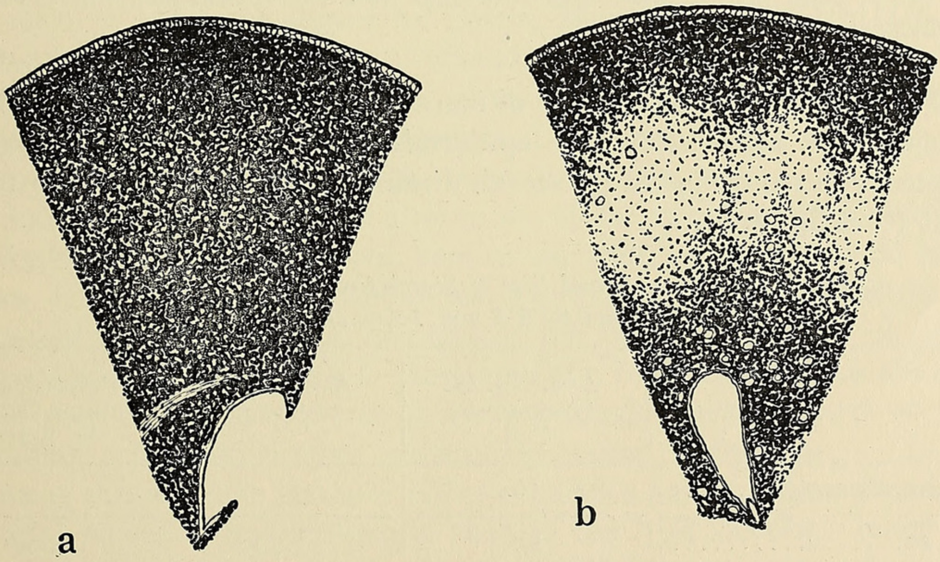

FIG. 2. Radial sections from the cortex stained with potassium iodid to show distribution of starch: *a*, 32 lbs. pressure; *b*, 34 lbs. pressure. Camera lucida drawings. × 25.

Cell contents: Starch. Of the various substances found within the cell, solids only are of importance in this study, since they only would have any bearing upon a physical test of this nature. Besides protoplasm and some minor substances, starch is the usual important solid in the cells of the cortical region of the pear. During the early part of the development of the fruit there is an abundance of starch in all tissues excepting the conducting vessels (text fig. 2, *a*). As the fruit matures starch disappears rapidly, the disappearance beginning with the region near the primary vascular bundles and thence continuing through the cortex to the periphery of the fruit. The final traces of starch are usually visible in the subepidermal region (text fig. 2, *b*). On August 20, starch grains, 6–11 microns in diameter and spherical or nearly so in form, were found either singly or in aggregate groups of several grains in almost all cells (text fig. 3, *a*).

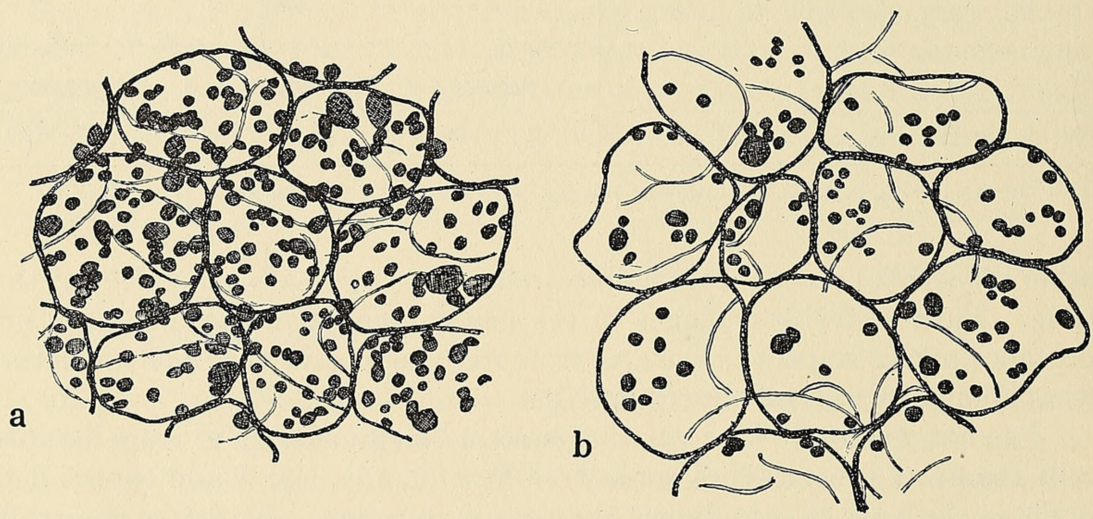

FIG. 3. Cells of Bartlett pears showing relative amounts and distribution of starch: *a*, Aug. 20; *b*, Sept. 17. Camera lucida drawings from one optical plane, more than one cell in thickness. × 200.

Actual counts and measurements of starch grains as found early and late in the season, 6–8 mm. below the epidermis, showed that the approximate calculated volume occupied by starch diminished from 5.49 percent to 1.17 percent (text fig. 3, *b*).

TABLE 10. *Number and Size of Starch Grains in Cells of Cortex (approximately 6–8 mm. below epidermis)*

	Ave. No. of Grains per Cell	Ave. Diam. of Grains	Percentage of Volume Occupied by Starch
No. of determinations........	10	31	
August 20....................	54	8.7 μ	5.49
September 17................	36	7.8 μ	1.17

It should be pointed out here that, when potassium iodid is used as an indicator of the amount of starch present, the sections will invariably stain solid blue as a result of the intensity of the color and the translucency of the cell walls, although only a small percentage of the volume (5 percent or less) is occupied by starch (text fig. 3, *a*).

Discussion of Results

From the foregoing data it may be concluded that a series of morphological and histological changes of the dermal and cortical regions of the pear may be largely responsible for the marked physical changes of these tissues in respect to resistance to pressure. Naturally the cells of the cortex are of the greatest importance here, since by far the predominating percentage of the tissues involved were those of the cortical region. While the average seasonal decrease in resistance to a certain physical pressure (14) amounted to approximately 30 percent, the cortical cells had increased in size during this period by 94 percent. At the same time, the walls of these cells showed a reduction of 14.8 percent in thickness. Consequently an assumption may be made of a probable correlation between the physical and the morphological changes in the cortex. One can only conjecture, however, as to the exact numerical relations here. So, too, it is possible that, as a result of a gradual hydrolysis of starch into sugars, a greater turgidity is attained by the cells of the cortex during the latter part of the season, resulting in a lowering of physical resistance. Such a mechanical explanation is offered by Hawkins and Sando (4) for the greater resistance to wounding of the epidermis of cherries and of various other small fruits. In the cases of these fruits, however, changes in turgidity, caused by lowering of temperature, are assumed to be due to probable differences in the coefficient of expansion of the cell walls and the cell contents. The point is very suggestive, since it has been shown by Lewis, Murneek, and Cate (10) that a marked increase in resistance to wounding of Bartlett pears was obtained when the fruit was kept for 24 hours at room temperature (summer). Naturally there was a considerable loss of moisture during this time, with a consequent profound effect on the turgidity of the cells.

Undoubtedly the chemical alterations of the various constituents of the cell walls should be considered here as an additional factor. It is a well known fact that the hemicelluloses, pentosans, and particularly pectic compounds, undergo radical changes at the time of maturity of the fruit. By careful chemical analyses, Magness (11), for instance, has shown that as the pear ripens on the tree there is a conspicuous decrease of alcohol-insoluble, acid-hydrolyzable substances other than starch. In many instances the decrease in these polysaccharides amounted to 50 percent of the total present, thus indicating that as the fruit develops much of this material, other than starch, is hydrolyzed. Magness points to the reduction of pectose and related material, which is thought to be largely responsible for the thickening and cementing together of the cell walls, as a possible cause of the lowering of resistance to pressure of the pear.

There is a prevalent opinion that as the fruit ripens a gradual dissolving of the middle lamellae takes place (18, and others). Sections through the wounded areas of even comparatively ripe pears showed, however, that the cells had very rarely separated along the middle lamellae, but that the characteristic tearing was across the cell walls. This fact, of course, does not diminish the importance of the possible changes of pectic substances in the middle lamellae and the cell walls proper. Hornby (5), for instance, found an increased pectin content in those parts of the potato and other tubers that were most exposed to light. The writer's own experience indicates that the pigmented part of the pear, the side of the fruit most exposed to light, has a greater resistance to wounding than the green portion.

Of minor consequence here is the reduction of the starch content from 5.5 percent to approximately 1 percent of the total volume of the cell. This, too, may play a part in the relative resistance to physical changes of these cells. Again, because of expansion of the cortex and subepidermis, greater separation of the groups of stone cells may be effected, thus lowering to some extent the combined resistance to pressure of the tissues as a whole.

Apart from the cortex, the seasonal differences in size and distribution of the epidermal cells are of interest. Cells of the subepidermis show a relative increase of approximately 65 percent in size. Close to the outside this increase of course was much lower, amounting to 40 and 14 percent respectively for the first layer of subepidermis and epidermis. A decrease in thickness of the cuticle of 19 percent may also be noted. Undoubtedly all these factors contribute to the measurable physical changes of the tissues of this region. So, too, one may expect changes in the cell walls here quite similar to those suggested for the cortex proper.

In conclusion, it may be said that the lowering of resistance to physical pressure of the cortex and epidermis of the Bartlett pear may be due in a large measure to the morphological and histological changes of the tissues involved. In order of decreasing importance the factors under consideration could possibly be arranged as follows:

a. Cortex: Increase in size of cells and decrease in thickness of cell walls.

b. Subepidermis: Increase in size of cells and possible decrease in thickness of cell walls.

c. Epidermis: Increase in size of cells and decrease in thickness of cuticle.

d. Decrease in amount of solids (starch) in the cells.

e. A wider separation of the groups of stone cells in both subepidermis and cortex.

Summary

1. Changes in maturity of the pear fruit have been commonly expressed in terms of chemical differences of the cell contents.

2. A physical test has been perfected which shows that alterations in the structural part of the fruit are evidently more uniformly consistent than the chemical changes.

3. The results of several thousand tests with Bartlett pears showed a close correlation between physical resistance to a definite pressure or wounding of the epidermis and cortex, and the maturity of the fruit. When measured and expressed in convenient units, the average seasonal decrement in this respect was found to be approximately 10 lbs., or close to $\frac{1}{2}$ lb. for every 24 hours.

4. Though chemical modifications of the cell walls may be responsible to a large extent for these differences, the following seasonal morphological and histological changes were observed in the Bartlett pear:

a. There was an average increase of 93.7 percent in size and an average decrease of 14.8 percent in thickness of walls of cells of the cortex.

b. Cells of the lower portion of the subepidermis increased in size (area of a longitudinal section) by 65.6 percent, while those of the first layer beneath the epidermis increased by 39.3 percent.

c. Though comparatively slight, still there was a seasonal enlargement in size of epidermal cells amounting to close to 14 percent. The cuticle covering these cells decreased in thickness at the same time by 19 percent.

d. The average increase in number of "window cells" per "mother cell" was from 2.92 to 4.00.

e. Lenticels decreased during this period from 44 to 32 per square centimeter of surface area of the pear. A conspicuous alteration in form and structure of lenticels was noted.

f. The volume occupied by starch in an average cortex cell decreased from 5.49 percent to 1.17 percent.

5. A partial explanation of the significance of these morphological changes and their possible correlation with the physical resistance to pressure of the tissues involved is offered.

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DESCRIPTION OF PLATE XXIV

FIG. 4. Bartlett pear, showing position of pressure punctures. × 2/3.

FIG. 5. Section of Bartlett pear. Note character and depth of pressure punctures and section (plug) used for histological work. Natural size.

FIG. 6. The rather thick subepidermis of a Bartlett pear. × 30.

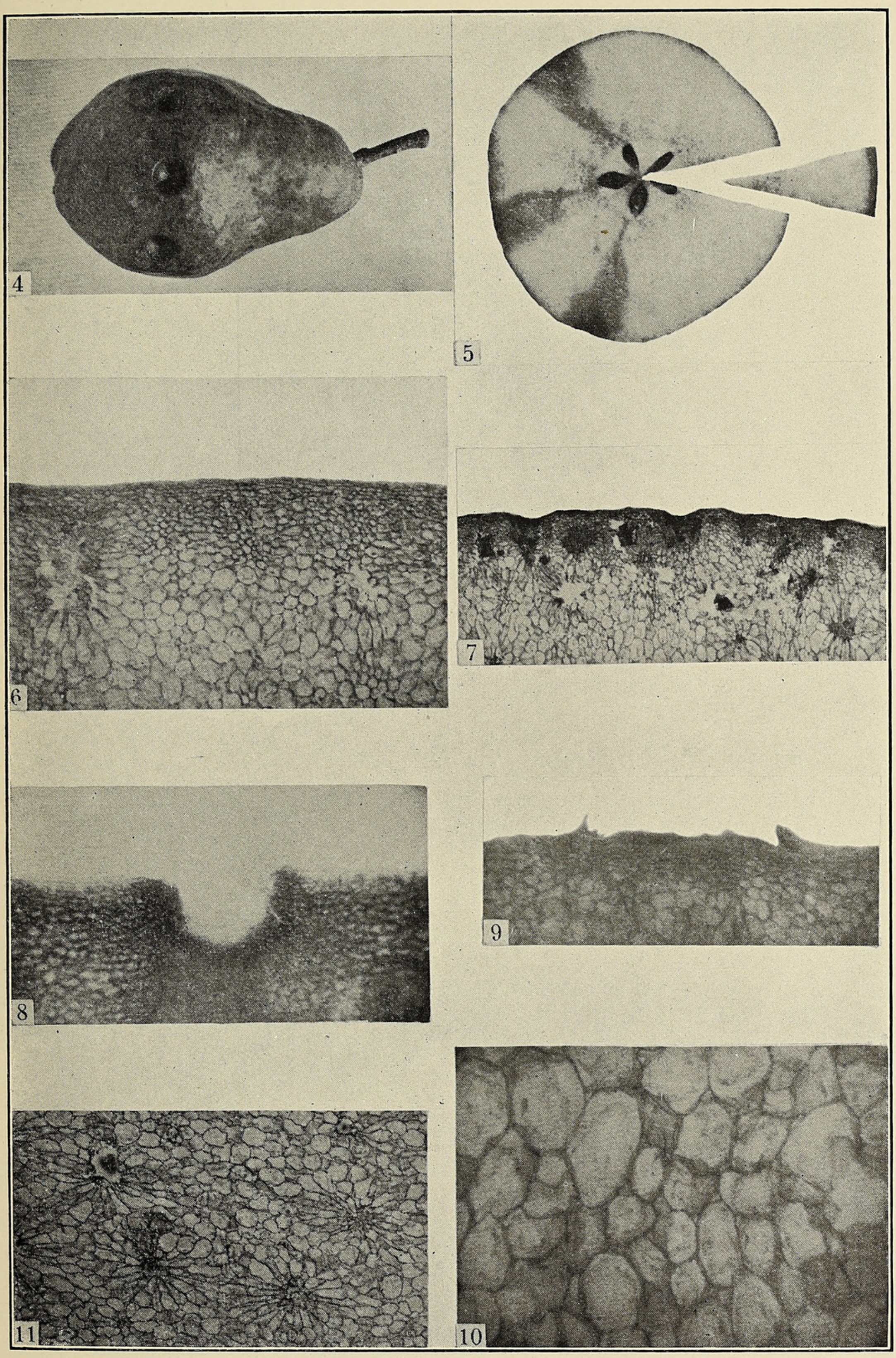
FIG. 7. Scattered groups of stone cells within the subepidermis. × 15.

FIG. 8. A typical lenticel early in the season (August 20). × 90.

FIG. 9. A typical lenticel late in the season (September 17). × 100.

FIG. 10. Cells of the cortex. × 125.

FIG. 11. Groups of stone cells in the cortex. × 25.



MURNEEK: CHANGES IN BARTLETT PEARS