THE ORIGIN OF LINT AND FUZZ HAIRS OF COTTON

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INTRODUCTION

The mature seeds of most varieties of upland cotton are covered with two different types of hairs, (1) the long lint hairs that are extensively used in the manufacture of fabrics, and (2) the short, thick-walled, fuzz hairs (linters) that form a dense, tangled mat close to the surface of the seed. Both lint and fuzz hairs are single-celled, tubular outgrowths that arise from the epidermal cells of the seed coat. Although the principal difference between the lint and fuzz hairs is the much greater length of the lint, it is usually difficult or impossible to draw a sharp line of demarcation between them on this basis. Very short lint hairs and long fuzz hairs may be indistinguishable. It is sometimes possible, however, to distinguish between lint and fuzz by their position on the ovules and seeds. In some varieties of cotton both the lint and fuzz hairs are restricted to specific and sometimes separate areas on the surface of the seed, giving rise to various "patterns." In the so-called naked seed varieties the fuzz hairs are entirely missing, so that removal of the lint leaves the seed coat smooth and free from hairs. In some varieties the lint and fuzz hairs are pigmented differently, and frequently pigment is present in the fuzz when it is entirely absent from the lint hairs. Another indication of an essential difference between these two kinds of hairs is the fact that the pattern of the fuzz-covered areas on the seed may be inherited independently of the lint pattern.

These facts suggest that, although lint and fuzz hairs both arise from the same layer of epidermal cells, some fundamental differences may exist between them. These differences may be the result of variations in the rate of growth of cells that originate at the same time, or lint and fuzz hairs may owe their characteristics to differences in the time or method of their origin. Although the origin and development of lint hairs has been studied, very little is known about the early history of the fuzz hairs, and the early development of the two types appears never to have been studied carefully from a comparative point of view. It is the purpose of this paper to present the results of such a comparative study of the origin and early history of lint and fuzz hairs.

PREVIOUS WORK

Cytological studies of the origin of lint hairs have been undertaken by a number of investigators. Balls (3)² states that the lint hairs all originate as single-celled outgrowths of epidermal cells which "sprout

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² Reference is made by number (italic) to Literature Cited, p. 520.
at the same stage of boll development, on or near the day when the
flower opens.” According to Balls (2), the fuzz hairs, like those of
the lint, arise “in much the same way, at the same time, and from the
same layer of cells.” Singh (8) observed new fibers originating for
a period of 48 hours after flowering, but Gulati (6) presented evidence
that fibers continue to form from epidermal cells for as long as 10
days after the opening of the flower. Farr (4, 5), in a cytological
study based upon American upland cotton, reported that cotton
hairs develop from epidermal cells for a period of 10 or 12 days after
the date of flowering.

The period of fiber origin has also been studied in a very different
way. Turner (9) reported the results of statistical studies of the
number of cotton hairs upon ovules of different ages. He found a
rapid increase in the number of hairs as the ovules grew older and
larger. In one study, 10-day-old ovules were found to have 10,050
hairs, while 1-day-old ovules possessed only 4,530. Turner pointed
out that this increase in hair number must mean that cotton hairs
continue to arise after the day of flowering. Gulati (6) reported
results indicating an even greater increase in number of hairs during
the early stages of ovule growth. No distinction between lint and
fuzz hairs was made in either of these studies.

In studying the variability in length of cotton fibers by statistical
methods, Armstrong and Bennett (1) came to the conclusion that
the number of fibers on the ovules increased until 25 days after the
date upon which the flower opened.

Although all investigators agree that cotton hairs arise from epi-
dermal cells on and soon after the day on which the flower opens,
there is much disagreement as to the number of days after flowering
during which hairs continue to be produced. In none of the studies
of fiber origin has any systematic attempt been made to distinguish
between lint and fuzz hairs. This study was undertaken in an
effort to clarify these points and to determine as accurately as possible
the early developmental history of both lint and fuzz hairs.

MATERIALS AND METHODS

Lint and fuzz hairs both arise from the same layer of epidermal
cells, and they are frequently indistinguishable in appearance during
the early stages of their growth. It is not always possible, therefore,
to determine by observation alone whether the outward extension of
any given epidermal cell is destined to become a lint hair or a fuzz
hair. The fact that certain varieties of cotton have lint hairs but no
fuzz and that other varieties produce lint and fuzz hairs in separate
and restricted areas on the ovule surface suggested a means of identify-
ing the two types of hairs. This study was made, therefore, by com-
paring the developmental histories of hairs produced upon naked
(i.e., fuzz-free) seeds and pattern types (those in which lint and fuzz
hairs are restricted to separate or specific areas on the seed) with
seeds that produced both lint and fuzz hairs over their entire surface.

Six varieties of cotton were used in this study. Four of these—
Mexican 128-6, King Naked, Cleveland Fuzzy Tip, and Nankeen
Lint—are varieties of Gossypium hirsutum L., and two—S × P 30
(Sakel × Pima) and a Bleak Hall strain of sea island—are varieties of \textit{G. barbadense} \textit{L}.

In order to obtain a complete picture of the development of hairs in these varieties, series of ovules were collected in such a way as to give the stages of growth at 24-hour intervals. In the case of Mexican 128–6, three sets of collections were made. On July 11, 217 flowers were tagged, and ovules were collected daily thereafter for 20 days. On July 15 approximately 500 flowers were tagged, and on August 15, 1,000 flowers were tagged. Daily collection from these two taggings continued for 45 days. By this method of tagging, the collection from each of the three dates of flowering constituted a reliable growth series which was representative of a particular day of flowering, and the material of successive days had experienced the same environmental conditions during the earlier periods of growth.

Because only a limited amount of material of the other varieties was available, it was necessary to tag all flowers as they opened each day and to collect the entire crop of bolls of a single variety on a day which would afford an unbroken series. In this way, Sakel × Pima material was collected on August 31, sea island on September 2, King Naked on September 15, Nankeen Lint on September 16, and Cleveland Fuzzy Tip on September 24. All collections were made in the afternoons during the summer of 1936.

After collection, the bolls were opened and the young ovules were dropped immediately into fixing agents. A number of different fixing agents were employed, but the most satisfactory results were obtained with the following formulas:

\[ \begin{align*}
(1) & \quad \text{Formalin} & \quad 4 \\
& \quad \text{Formic acid} & \quad 4 \\
& \quad 50\text{-percent ethyl alcohol} & \quad 92 \\
(2) & \quad \text{Formalin} & \quad 4 \\
& \quad \text{Formic acid} & \quad 4 \\
& \quad \text{N-butyl alcohol saturated with water} & \quad 92 \\
\end{align*} \]

After fixing, the ovules were dehydrated with n-butyl alcohol. Five- and ten-micron longitudinal sections were cut from 60° paraffin and were stained with Heidenhain's haematoxylin for maximum contrast.

\section*{RESULTS WITH VARIETIES STUDIED}

\subsection*{KING NAKED}

The King Naked variety presents the problem in its simplest form, since lint hairs alone are produced. When the lint hairs are removed from the seed, the seed coats are smooth and entirely free from fuzz (fig. 1, A). The mature seeds bear lint hairs over the greater portion of their surface, only the lower fifth or sixth of the seed coats being entirely devoid of fibers (fig. 1, H).

The simplicity of this fiber pattern is reflected at an early age by a comparable simplicity in the time and place of origin of fibers on the growing seed. On the day of flowering, the epidermal layer of the ovule gives no evidence of young fibers or fiberlike processes. Twenty-four hours later, the first fiber initials are seen developing on the chalazal half of the ovule. On the second day after flowering, these fiber initials have elongated noticeably, and no new outgrowths are ordinarily seen on this part of the ovule during this or at any subse-
FIGURE 1.—Seed of King Naked (A), Cleveland Fuzzy Tip (B), sea island (C), Mexican 128-6 (D), Sakel X Pima (E), Nankeen Lint (F), with the lint hairs removed and the fuzz hairs combed out to show their position on the seed and relative abundance. Seed of Mexican 128-6 (G), King Naked (H), with lint hairs combed to show their distribution on the seed.
quent period. It may be seen, however, that new fibers develop in restricted numbers near the micropylar end of the ovule, but these initials serve to extend the surface range over which fibers grow rather than to contribute to the density of the fiber population of the first day. Similarly, on the third day after flowering, a few new fibers may be seen differentiating even nearer the micropylar end of the seed. Other outgrowths may continue to differentiate in this manner for several days, but the number of late fiber initials is extremely small, and in most cases the last outgrowths are seen on about the third day after flowering.

The time and place of origin of fiber initials as described here are represented diagrammatically in figure 2, A. In this diagram, the innermost line outlines the shape of the ovule, particularly in a submedian longitudinal section. The innermost line also represents the day of flowering and is marked 0. Each additional line to the outside represents a day after flowering up to the day of secondary wall formation, which is indicated by the outermost line. No new fibers develop after secondary wall formation has occurred. In the diagram the time and place of origin of new fibers are indicated by heavy black lines. The density of the hair population is suggested approximately by the presence of solid and broken or fragmentary lines, the solid lines representing greater numbers of hairs than the broken or fragmentary lines.

It will be noted that most of the lint hairs of the King Naked variety begin their growth on the day after flowering and that a few others differentiate during the following 2 days. Since the mature seed bears only lint hairs, it is obvious that the lint pattern is established within a period of about 3 days and that this period of lint origin falls very early in the life history of the growing ovule. Differences in fiber length may be observed from the day of fiber origin up to maturity, even in those regions of the epidermis where the fiber initials have appeared at the same time. This would seem to suggest that the length differences between mature fibers may well be due to different rates of growth.

It is interesting to note that papillate outgrowths may be observed over almost the entire surface of the ovule for 6 or 8 days after flowering, but these papillae are extremely minute and no evidence has been found that any of them subsequently elongates even as much as 5 microns.

The initiation of lint hairs in the King Naked variety is a continuous process which persists through a period of 3 or 4 days after flowering. The first hairs are formed around the chalazal end of the ovule on the day after flowering. New fibers differentiate throughout the day, and hair formation progresses from the chalazal region toward the micropylar end of the seed. By the end of the first day, half or more of the ovule may be covered by fiber initials. During the next 2 or 3 days, additional fibers are formed nearer to the micropyle and lint differentiation gradually ceases. Thus, lint hair formation progresses continuously from one end of the ovule to the other.
Figure 2.—Diagrams representing the time of origin and the distribution of the young hair initials on the surface of the ovules. The innermost line represents the surface of the ovule as seen in submedian longitudinal section on the day of flowering. Succeeding lines outside of the innermost line represent successive days after the opening of the flower. Heavy black lines indicate the position on the ovule where young hairs have been observed to originate. The relative number of hairs arising is suggested approximately by the character of the heavy black line. Where the line is solid more fibers originate than where the line is broken. The diagrams show fiber development upon ovules of varieties as follows: A, King Naked; B, sea island; C, Cleveland Fuzzy Tip; D, Sakel X Pima; E, Mexican 128-6; F, Nankeen Lint.
CLEVELAND FUZZY TIP

As the name indicates, in Cleveland Fuzzy Tip the fuzz hairs are restricted to a small area immediately surrounding the micropylar end of the seed (fig. 1, B). The lint hairs are usually produced over three-fourths or more of the seed surface at the chalazal end, but frequently they are limited to only about half of this portion of the seed. In this variety, therefore, both lint and fuzz hairs are present, but each hair type occupies a specific and different area on the seed coat. Although the problem is complicated in this case by the presence of both lint and fuzz, the fact that the hairs of both types are restricted to definite and separate portions of the seed coat makes it possible to determine the time and method by which each hair type originates.

On the day of flowering, the epidermis gives no evidence of fiber differentiation at any point. On the following day, outgrowths from epidermal cells of the seed coat appear in large numbers over half or more of the ovule surface at the chalazal end. As with the King Naked variety, new fibers originated for several days after flowering on portions of the ovule successively closer to the micropylar end. Unlike the King Naked variety, a few hairs were found to arise at the chalazal end of the seed on the second, third, and fourth days after flowering. The small number of these fibers is indicated by broken lines in the diagram (fig. 2, C).

About 6 days after flowering, proliferations from epidermal cells are formed in the region covered by fuzz in mature seeds. These outgrowths can be identified as fuzz hair initials by their position, since mature seeds bear no lint hairs in this area. As the diagram indicates, fuzz hairs continue to arise at the micropylar end of the ovule for 5 or 6 days. No hairs were observed to develop on any other portion of the ovules during this period. It seems clear, therefore, that in this variety, at least, lint and fuzz hairs originate at different times, the fuzz arising only after the complete pattern of lint hairs has been established.

The amount of lint-bearing surface in Cleveland Fuzzy Tip differs considerably from seed to seed, and this variability at maturity is reflected in a comparable variability during fiber initiation. In some instances, lint hairs differentiate only from the chalazal half of the seed, so that the final pattern is almost identical with that of sea island. In other instances, lint hairs differentiate from most of the seed surface, and since this appears to be the more common occurrence, the diagram for this variety (fig. 2, C) has been constructed to indicate that lint hairs arise from all of the seed surface except the fuzz-bearing portion.

MEXICAN 128-6

In the Mexican variety both lint and fuzz hairs are present over the entire surface of the mature seeds (fig. 1, D), so that the hair initials cannot be identified as lint or fuzz by their position on the young ovule.

On the day before flowering, a limited number of hair initials become differentiated from epidermal cells at the chalazal end of the ovule. On the day of flowering, however, hairs appear in great abundance (fig. 3, B) over most of the ovule surface, though few, if any, appear in the area adjacent to the micropyle (fig. 2, E). As in the other varieties already described, the first fibers arise at the chalazal end of the ovule, and during the same day other hairs appear
FIGURE 3.—Cross sections of epidermal layer of ovules: A, Mexican 128-6, the day before flowering; B, Mexican 128-6, the day of flowering; C, Mexican 128-6, 24 hours after the opening of the flower; D, Mexican 128-6, 5 days after flowering; E, sea island, 24 hours after the opening of the flower; F, sea island, second day after flowering.
progressively nearer the micropylar end of the ovule until it is covered with young fibers, except only the micropylar fifth or sixth of its surface area. On the day after flowering, new hairs continue to form nearer the micropylar end of the ovule and a few can be seen arising at the chalazal end as well. A small number of fibers continue to be developed from epidermal cells near the micropyle for 3 or 4 days (fig. 2, E). The Mexican variety differs from those previously described in having a much larger number of hair initials and also in the rapidity with which the ovule surface becomes covered with young hairs. Almost the entire surface of the young ovule bears elongating hairs within 48 hours of the day of flowering.

On the fourth or fifth day after flowering, a second outburst of fiber formation occurs (fig. 2, E). Fiber initials may be seen arising from newly formed epidermal cells between the bases of the first-formed hairs (fig. 3, D). These hair initials, like those produced on the day of flowering, first appear at the chalazal end of the ovule, and the younger hairs arise progressively nearer the micropylar end of the ovule. Within approximately 48 hours of their first appearance, almost the entire ovule surface is again covered with young hair initials. This second group of hairs continues to arise from epidermal cells of the ovule surface for a period of 4 or 5 days, and the last to be formed arise, as in previous cases, in the micropylar region. The sequence of fiber origin in the Mexican variety is shown diagrammatically in figure 2, E.

To interpret these observations it is necessary to recall the sequence of events described for the King Naked and the Cleveland Fuzzy Tip varieties. In these varieties it was shown that the lint hair pattern is largely established within 48 hours of the day of flowering. It was further shown that the fuzz hairs when they are present do not appear until the lint pattern had been fully determined.

A similar sequence of events apparently takes place in the Mexican variety. One set of hair initials originates within a few days of flowering, and a second set of hairs develops over the whole surface of the ovule several days later. The hairs produced on and immediately following the day of flowering correspond almost exactly in their position and time of origin to the lint hairs of the Cleveland Fuzzy Tip and King Naked varieties (fig. 2, A and C). It seems probable, therefore, that the first hair initials originating on ovules of the Mexican variety also develop into lint hairs. Following the establishment of these first-formed hairs, which are presumably the lint initials, there is an interval of several days in which very few new hairs originate.

On the fourth or fifth day after flowering, a second period of hair production is begun (fig. 2, E). This corresponds to the period in which the fuzz hairs develop in the Cleveland Fuzzy Tip variety. Since fuzz hairs cover the entire surface of the seed in the Mexican variety, and since the hairs arising in this second period of fiber initiation also appear over the entire surface of the ovule, it seems probable that they represent the fuzz hair initials. As will become apparent later, there is additional evidence which also indicates that the first-formed hairs develop into lint fibers and that hair initials arising several days after the opening of the flower give rise to the fuzz hairs. No significant differences in the history of hair origin and development were observed on the ovules by the three different series of Mexican studied.
NANKEEN LINT

Nankeen Lint is a variety of American upland cotton with brown lint and extremely dense fuzz. Both lint and fuzz hairs are found over the entire seed surface (fig. 1, F), but the fuzz is more prominent than in the other varieties studied.

As indicated in figure 2, F, the hairs arise in much the same manner as do those of the Mexican variety. On the day of flowering, large numbers of hairs are formed by outward extensions of the epidermal cells. Differentiation of hairs continues in regions nearer the micropylar end of the seed for 4 or 5 days after the opening of the flower. It seems highly probable that the hairs originating during the first few days after flowering give rise to lint hairs as do the King Naked and Cleveland Fuzzy Tip and the varieties of Gossypium barbadense that were studied. As in all fuzz-bearing varieties, the ovules of Nankeen Lint exhibit a second period of rapid hair production. This begins about 6 days after the flower opens, and active production of new hairs over the entire surface of the ovule continues for 3 or 4 days. After the tenth day relatively few new hairs are produced, and these are restricted to the micropylar end of the ovule. This prolific formation of hairs on and soon after the sixth day after flowering is exactly what would be expected, considering the varieties previously described, and suggests strongly that the fuzz hairs originate at this time. In all the varieties in which the fuzz hairs are restricted to specific areas the hairs in these regions appear about 5 or 6 days after the flower opens. This delayed appearance of hairs also occurs in Nankeen Lint, and the large number of hairs produced is clearly correlated with the dense fuzz hair population characteristic of this variety.

SEA ISLAND

Sea-island cotton, in which the lint and fuzz hairs are conspicuously restricted to specific areas on the seed, was studied as a representative of a different species of cotton (Gossypium barbadense). The lint is usually limited to the chalazal half or two-thirds of the seed, while the fuzz hairs form a dense growth at the extreme micropylar end (fig. 1, C).

On the day of flowering, some of the epidermal cells at the chalazal end of the ovule show evidence of slight protuberances. These cells are few in number and exhibit no appreciable change in size or appearance during the next 24 hours (fig. 3, E). On the second day after flowering, however, large numbers of hairs originate as outgrowths from epidermal cells in the chalazal half of the ovule (fig. 3, F). Since the papillate outgrowths observed on the day of flowering did not increase in size or number during the succeeding 24 hours, the second day after flowering is more properly regarded as the first day of fiber origin (fig. 2, B). On the third day after flowering, these hair initials have grown somewhat in length and new hairs may be seen arising at the micropylar margin of the zone in which hairs were formed on the second day. The area of the ovule surface on which hairs are borne is likewise increased slightly by the origin of a few new hairs on the fourth day after flowering.

Since the portion of the mature seed corresponding to the area in which these hairs are formed bears no fuzz, it is obvious that the hairs arising during the first 4 days after flowering develop into lint hairs.
On the seventh day after the opening of the flower, hairs begin to arise at the extreme micropylar end of the ovule. These hairs continue to form for 3 or 4 days. Since no lint hairs are present in this portion of the seed, these later-formed hairs must develop into fuzz hairs.

It is clear, therefore, that aside from a slower development of hair initials, sea-island cotton conforms essentially to the pattern described for the Cleveland Fuzzy Tip variety. In both cases the lint hairs appear first and the lint hair pattern is fully established upon the ovule before any of the fuzz hairs originate.

**SAKEL X PIMA**

The mature seeds of Sakel × Pima have both lint and fuzz hairs. The lint pattern is very similar to that of sea island and Cleveland Fuzzy Tip. The fuzz hair pattern is very different, however, for fuzz occurs irregularly over the entire surface of the seed. The fuzz hairs at the micropylar end are much like those of sea island, but on the rest of the seed the fuzz is very short and brown, adheres closely to the seed coat (fig. 1, E), and contains tanniferous substances.

In Sakel × Pima, hairs were observed to originate from epidermal cells on the chalazal half of the ovule on the day after the opening of the flower. New hairs continue to form during the next 3 or 4 days, but they are restricted to a small zone at the margin of the area upon which hairs were initiated during the first day after the opening of the flower (fig. 2, D). For reasons that will become apparent later, these first-formed hairs very probably develop into the lint hairs.

A few days after the flower opens, the epidermal cells of the seed coat become altered in appearance. This alteration appears to be due to the accumulation of mucilaginous and tanninlike compounds in the cell vacuoles. This accumulation seems to bear no relation to the age of the individual cells of the epidermal layer, for these substances are present in newly divided cells as well as in cells that are several days old. The presence of these substances in the vacuoles of the hairs is evidence that such hairs originated several days after the opening of the flower. Hairs produced 24 or 48 hours after flowering apparently do not contain these substances. Since the lint hairs of this variety are free from such mucilaginous and tanniferous deposits, it seems clear that they originated during the first few days after the flower opened.

Five or six days after flowering, hair initials appear near the micropyle, and they continue to arise for several days (fig. 2, D). This is the portion of the seed that bears conspicuous fuzz hairs and no lint, so it is obvious that the hair initials in this position develop into fuzz. Occasional epidermal cells on the chalazal half of the ovule begin to produce hairs on about the eighth day after flowering. These first appear near the chalazal end and arise successively nearer to the micropylar end of the seed (fig. 2, D). These hairs contain the mucilaginous and tanniferous deposits generally present in the epidermal layer and so can be identified with reasonable certainty as fuzz initials, since the mature fuzz hairs of this variety contain these substances, whereas they are absent from lint hairs.

In Sakel × Pima the evidence suggests clearly that the lint hairs are formed within a few days of the opening of the flower and that the
lint hair pattern is fully determined before the fuzz hairs appear. The fuzz hairs first originate about 5 days after flowering in the micro-
pylar regions, but some 8 or 9 days after blossoming additional fuzz
hairs are initiated upon the remaining surface of the ovule.

DISCUSSION

From the data that have been obtained in this study it is possible
to draw certain definite conclusions and to formulate a hypothesis
relative to the origin of lint and fuzz hairs. Before examining the
theoretical considerations it will be advisable to set forth briefly
the facts that are known.

In all the ovules examined in this study, with the single exception
of the King Naked variety, on which lint hairs alone are present,
young hairs were observed to originate at two different periods. The
first period was on or very soon after the day of flowering, and the
second period usually began 5 or 6 days after the opening of the flower.
In all those varieties in which the lint hairs are present only upon re-
stricted areas of the mature seeds, and in which it is therefore possible
to identify the lint hair initials beyond question, nearly all the lint
hairs were found to originate within 2 or 3 days after the opening of
the flower. Few if any new lint hairs are initiated in these varieties
later than 5 days after the opening of the flower. In those varieties
where fuzz hairs are restricted to areas devoid of lint hairs and where
the fuzz hair initials can therefore be identified with certainty, the
fuzz begins to develop only after the lint pattern has been completely
established. This means that the fuzz hairs originate in a period from
5 to 10 days after the flower has opened.

With the exception of Sakel × Pima, the time of lint and fuzz
origin cannot be determined with certainty in the varieties that have
both lint and fuzz hairs over the entire surface of the seed. The two
varieties that have a dense fuzz population over the seed surface
(Mexican and Nankeen Lint) exhibit many aspects of hair develop-
ment that appear similar to those of the pattern types. There is, in
other words, a very real analogy between their behavior in the matter
of hair origin and the behavior of the varieties in which lint and fuzz
can be identified by the position of the hair initials in the ovule.
In such varieties or types as King Naked, Cleveland Fuzzy Tip, sea
island, and Sakel × Pima, where the lint hair initials can be identi-
fied without question, they have been found to originate on or soon
after the flower opens. A similar phenomenon occurs in the Mexican
and Nankeen Lint varieties. By analogy, it might be assumed that
these first hair initials give rise to the lint hairs. In Cleveland Fuzzy
Tip, sea island, and Sakel × Pima, where the fuzz hair initials can be
identified clearly, the fuzz hairs are found to originate from 6 to 10
days after flowering and well after the lint hair pattern is established.
Similarly, in the Mexican and Nankeen varieties a number of hairs
are observed to originate from 5 to 10 days after flowering and well
after the pattern of the first-formed hairs has been determined. By
analogy, these might be regarded as the fuzz hair initials. Analogies,
however, are uncertain foundations upon which to erect trustworthy
conclusions. It is possible, even probable, that the first set of hair
initials in the Mexican and Nankeen Lint varieties is the lint hair
initials, and that the second set, as in the other varieties, represents
the fuzz hair initials. In the absence of further evidence, however, it would not be possible to assert positively that the first-formed hairs produce the lint and that the second set of hair initials gives rise to the fuzz in these varieties.

Fortunately, there is evidence of a different sort which strengthens the assumption that the lint hairs develop from the hairs formed soon after the opening of the flower and that the fuzz hairs originate from the hair initials that appear 5 or more days after flowering. The statistical studies of Turner (9), for example, show that there is a decided increase in the total number of hairs on the cotton ovules as they grow older. One-day-old ovules of the Nandyal 14 variety were found to possess some 4,530 hairs, while 28-day ovules had 16,420 hairs. Likewise, 1-day-old ovules of the Punjab-American 4-F variety were estimated to have 5,980 hairs, in contrast to the 25,090 hairs counted upon the 28-day-old ovules. These data become highly suggestive when considered in the light of the number of lint hairs found upon mature seeds of these varieties. Nandyal 14 was found to have only 4,000 lint hairs at maturity, and Punjab-American 4-F had approximately 7,900. The number of lint hairs on mature seed, therefore, is not very different from the number of hairs found upon 1-day ovules. This is exactly what would be expected from the results of the present study, since wherever lint hairs could be positively identified at the time of their origin they were found to arise within a day or two of the day of flowering. The increase in the number of hairs upon the older ovules that is reported by Turner can be explained by pointing out that the fuzz hairs, wherever they could be positively identified at the time of their origin, have been found to originate in a period between 5 and 10 or more days after the opening of the flower. The data obtained by Turner from a purely statistical study harmonize very well with the results of the cytological study here reported.

Another line of evidence of a very different kind that supports the hypothesis of early origin of the lint and later origin of the fuzz is that reported by Harrison (7) as a result of his studies of metaxenia in cotton. Harrison found that hybrids between inbred Pima and Hopi strains showed definite evidence of metaxenia. One of these experiments is of interest in relation to the problem of lint and fuzz origin. Harrison reported that when Hopi pollen was used upon Pima the number of lint hairs produced upon the resulting seeds was not different from those upon inbred Pima seeds but the amount of fuzz was appreciably reduced. These results harmonize nicely with those of the present study. If lint hairs originate within 24 or 48 hours of the time of flower opening they could hardly be influenced by a hybrid embryo. Fertilization does not occur until after the lint hair pattern has been established. Fuzz hairs, however, presumably originate after fertilization has been accomplished, and the density of the fuzz pattern could, therefore, be influenced by the hybrid embryo. The results of Harrison’s work may be interpreted as supporting the thesis that fuzz hairs arise after the lint pattern has been fully determined.

It seems clear from the foregoing discussion that there is considerable evidence in support of the hypothesis that lint hairs arise on or very soon after the day of flowering, while the fuzz hairs do not appear until 5 or more days after the flower opens. This is known to be true of those varieties studied in which the lint and fuzz initials could be identified by their position on the ovules. The history of hair origin
in the varieties studied in which lint and fuzz hairs could not be identified by position or appearance at the time of their origin is thoroughly consistent with early development of lint and later origin of fuzz. The early appearance of lint hairs is further suggested by statistical studies of hair density at different ages and by experiments designed to demonstrate metaxenia in cotton. The thesis that lint hairs arise early and that fuzz hairs originate only after the lint hair population has been fully determined seems, therefore, to be justified by the evidence presented. 

**SUMMARY**

The time and place of origin of lint and fuzz hairs on the ovules of six selected varieties of cotton have been studied. The hairs in all varieties were found to have an essentially similar developmental history.

In the King Naked variety most of the lint fibers originate on the day of flowering and additional lint may differentiate during the next 2, 3, or 4 days.

In Cleveland Fuzzy Tip, lint initials differentiate in abundance on the day after flowering and others make their appearance in the following 3 or 4 days. Fuzz fibers originate continuously at the micropylar end of the ovule from about the sixth to the eleventh day.

In Mexican 128-6, hairs that are presumably the lint initials appear in abundance on the day of flowering and during the next 3 or 4 days in areas near the micropylar end of the ovule. Hairs that presumably give rise to fuzz originate on about the fourth day after flowering and continue to arise for a period of 3 or 4 days.

In Nankeen Lint, hairs believed to be the lint initials differentiate from the epidermal cells on the day of flowering and continue to form in the region of the micropyle for the next 4 or 5 days. Hairs believed to be the fuzz initials first appear in abundance on the sixth day after flowering and continue to originate for a period of about 5 or more days.

In sea island, almost all of the lint fibers originate on the second day after flowering, but a small number of others may arise on the following 2 or 3 days. The fuzz initials arise on about the seventh, eighth, and ninth days after flowering.

In Sakel × Pima, hairs that are presumably the lint initials appear on the day after flowering, and a few others develop during the next 3 or 4 days. The fuzz at the micropylar end of the seed originates between the fifth and tenth days after flowering. The fuzz on other portions of the seed apparently begins to develop on about the eighth day after the flower opens.

It is suggested that lint hairs originate when or soon after the cotton flower opens, and that the first fuzz hairs appear only after the lint population has been fully determined. It is further shown that this thesis is consistent with the results of other investigators.

**LITERATURE CITED**

Origin of Lint and Fuzz Hairs of Cotton

(2) BAlls, W. Lawrence.
   1915. THE DEVELOPMENT AND PROPERTIES OF RAW COTTON. 221 pp., illus. London.

(3) ________
   1928. STUDIES OF QUALITY IN COTTON. 376 pp., illus. London.

(4) FARR, Wanda K.
   1931. COTTON FIBERS: I. ORIGIN AND EARLY STAGES OF ELONGATION.

(5) ________
   1933. COTTON FIBERS: III. CELL DIVISIONS IN THE EPIDERMAL LAYER OF THE OVULE SUBSEQUENT TO FERTILIZATION.

(6) Gulati, A. N.
   1930. A NOTE ON THE DIFFERENTIATION OF HAIRS FROM THE EPIDERMIS OF COTTON SEEDS.

(7) Harrison, George J.
   1931. METAXENIA IN COTTON.

(8) Singh, T. C. N.

(9) Turner, A. J.
   1929. GINNING PERCENTAGE AND LINT INDEX OF COTTON IN RELATION TO THE NUMBER OF COTTON FIBRES PER SEED.—THE EFFECT OF ENVIRONMENT ON GINNING PERCENTAGE AND THE DETERMINATION OF UNIT-FIBRE WEIGHT.