REPRODUCTIVE DEVELOPMENT

The cotton plant, due to its indeterminate growth habit, continues both vegetative and reproductive development throughout the remainder of the season. Reproductive growth commences with the formation of the floral buds in the apical part of the plant which give rise to the flowers (Figure 15) and subsequent bolls (Figure 13).

Cotton has a distinctive and predictable flowering pattern. The first flowers to open are low on the plant, usually on main-stem nodes six or seven and on the first position along a fruiting branch. About three days elapse between the

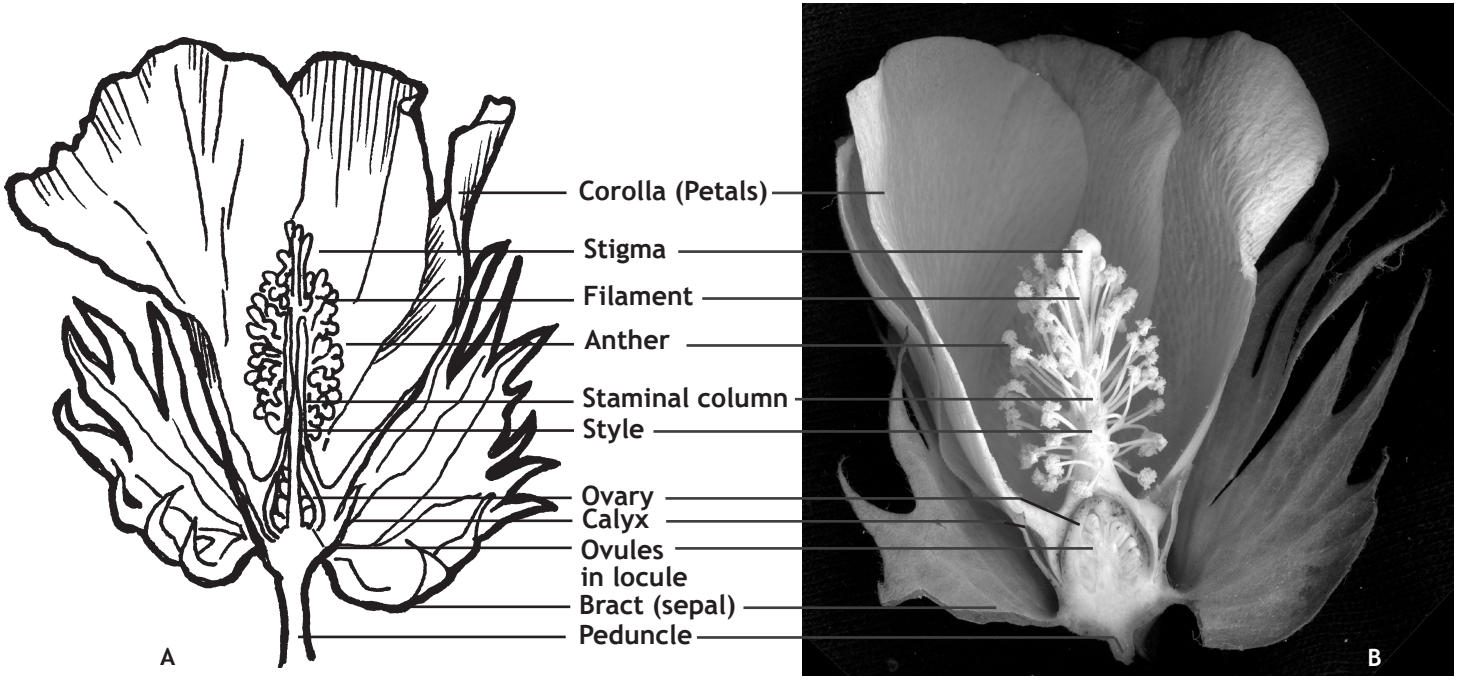


Figure 15. Diagram (A) and photograph (B) of a cotton flower on the day of anthesis. Petals and bracts are prominent. The male reproductive organs (stamens) encircle the female organ (pistil consisting of stigma, style and ovary). (A, D. Oosterhuis; B, R.W. Seagull)

opening of a flower on a given fruiting branch and the opening of a flower at the same relative position on the next higher fruiting branch. On the other hand, the time interval for the development of two successive flowers on the same branch is about six days. The order is thus spirally outward and upward. Flowers continue to be produced (indeterminant growth) as long as the plant is actively growing. In an agricultural setting, active plant growth is stopped by defoliation or frost.

Cotton is genetically programmed to produce seed for sexual reproduction. For the plant, the fibers that coat the seed evolved to facilitate seed dispersal, probably functioning to entangle in fur and feathers so that seeds were carried away. Wild cotton plants produce much smaller seeds with far fewer and shorter fibers. Humans dramatically influenced the evolution of domestic cotton by selecting plants that produce large quantities of fiber (Figure 16). Thus the original function of the fiber on the seed coat, to ensure propagation of the species by spreading the seed to new locations, has been superceded by a new function. Humans select seed for propagation based on fiber production. The end result is the same —

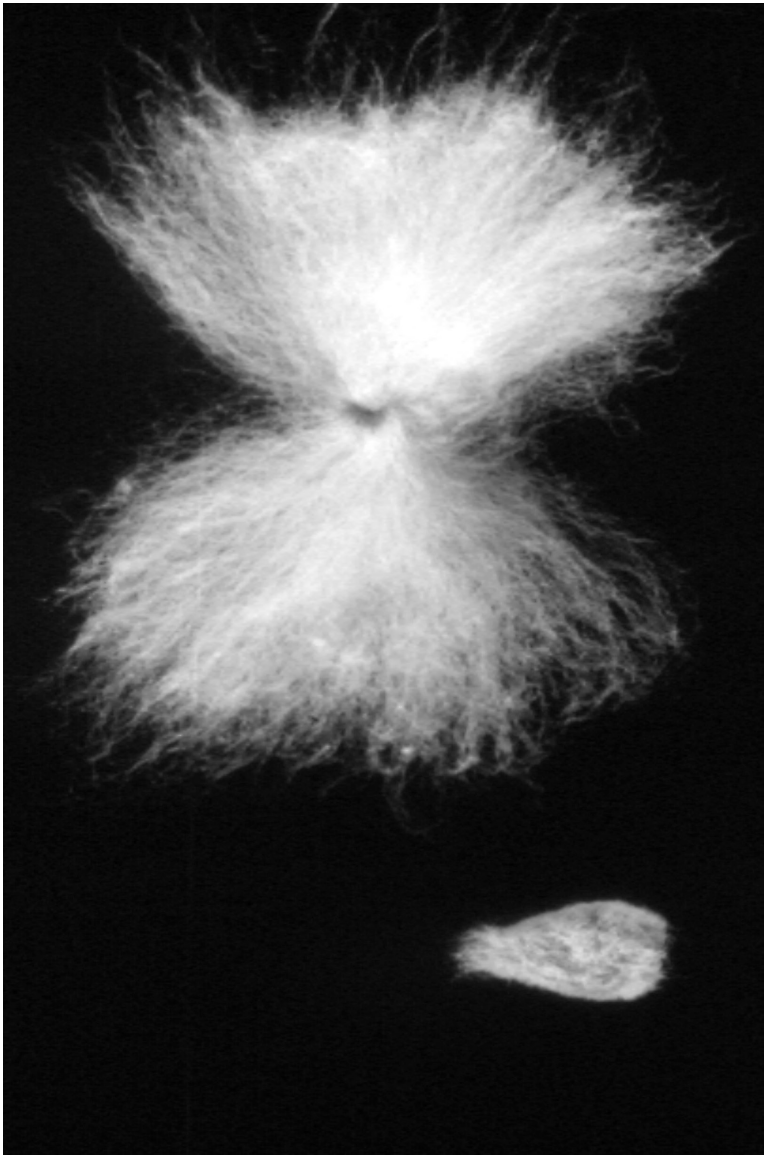


Figure 16. A mature cotton seed with fibers splayed out. Below; a ginned seed. (C.H. Haigler)

continuation of the species. The seed contains the embryonic plant for the next generation, composed of cotyledons, a root, a stem and leaves (Figure 9).

Squares

The buds appear first as small, green, triangular structures known as squares. The first squares (pinhead squares) are usually visible about five weeks after planting and the first flowers about three weeks later. New squares will appear in the top of the plant every three days and will appear on each fruiting branch at approximately six-day intervals. The total time for a flower bud to develop (from pinhead square until flower opening) is approximately six to seven weeks.

Flowers

The cotton flower is large and showy (Figure 15). On the outside of the flower are three large green bracts that enclose and protect the growing flower parts. The bracts are all that is visible of the square. Immediately inside the bracts are the reduced sepals which tightly enclose the five conspicuous white petals. The staminal column, composed of numerous stamens (male reproductive organ) each with a two-lobed anther (Figure 17) surrounds the style. The female reproductive organ consists of the stigma (pollen receiving structure), style (structure that supports the stigma) and ovary (container for the developing ovules). The ovary is composed of three to five compartments (carpels) each with ovules attached to the central column in the locule (Figure 18).

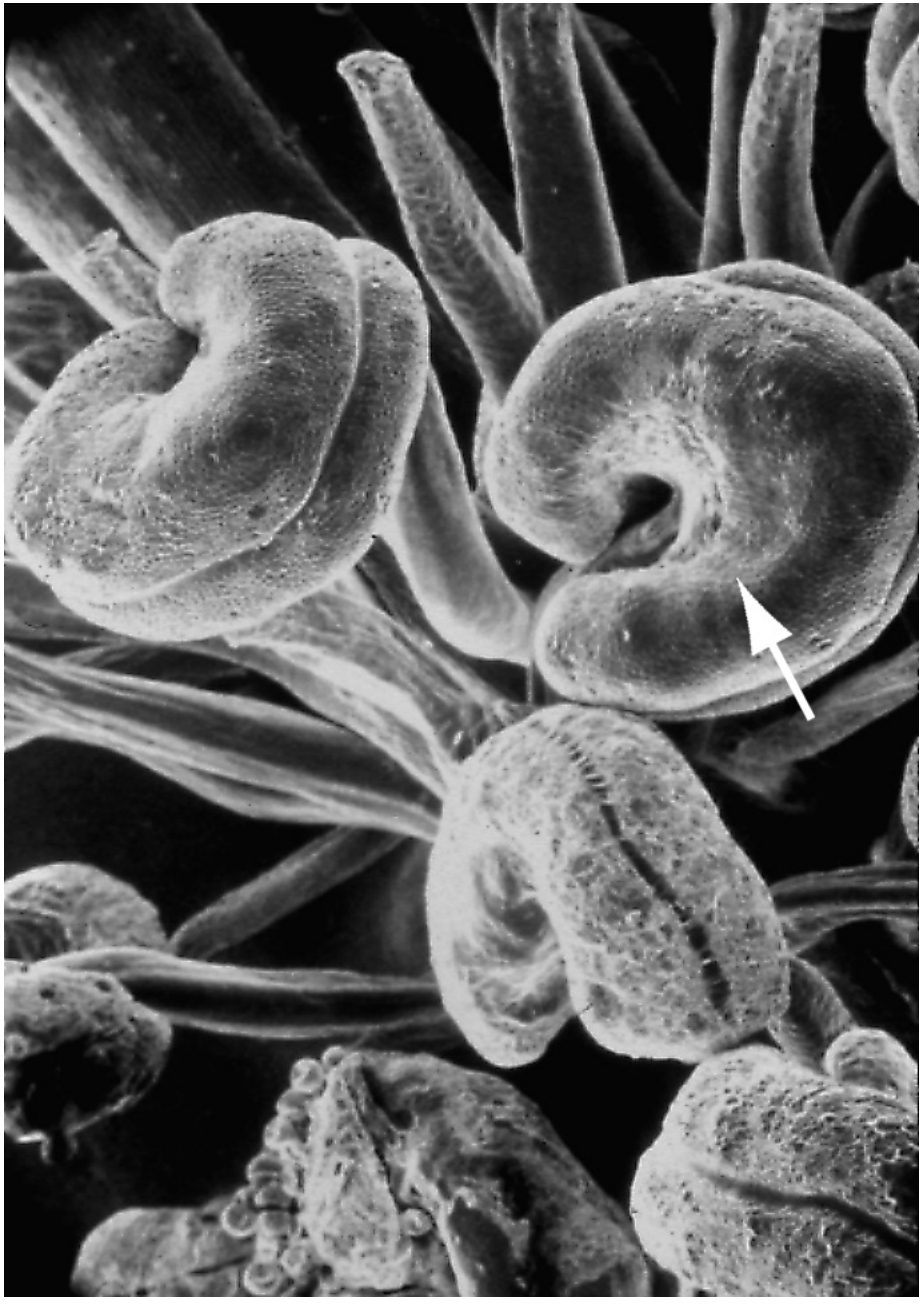


Figure 17. A scanning electron microscopic (SEM) image of anthers (pollen producing organ) (arrow) from a mature cotton flower ready to shed pollen (J. McD. Stewart).

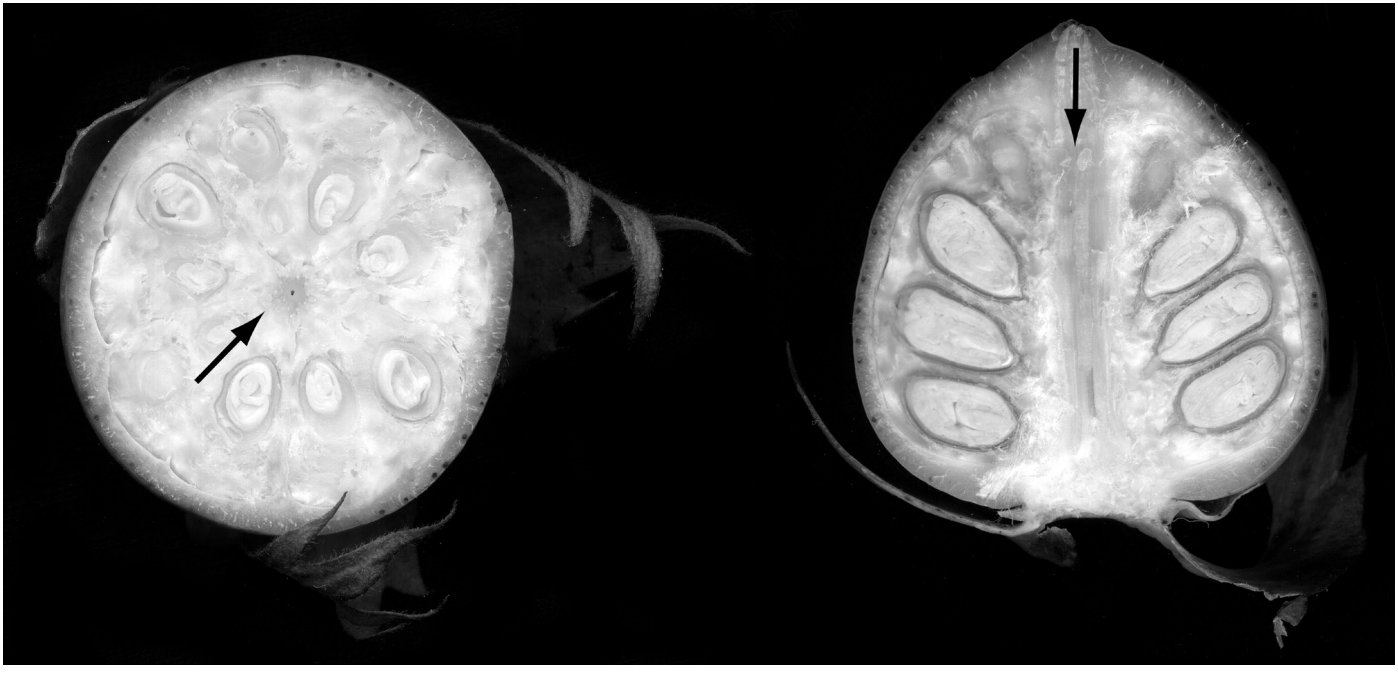


Figure 18. A photograph of a boll showing the seeds attached to the central placenta. On the left is a boll in cross section showing the seeds surrounding the central placenta (arrow). On the right is a longitudinal section showing seeds on either side of the central placenta (arrow). (R.W. Seagull)

Within the ovary, each ovule is somewhat "tear-drop" shaped and attached to the ovary near its "pointed end" by a short stalk-like structure (the funiculus) that transports nutrients from the parent plant to the growing ovule (Figure 19).

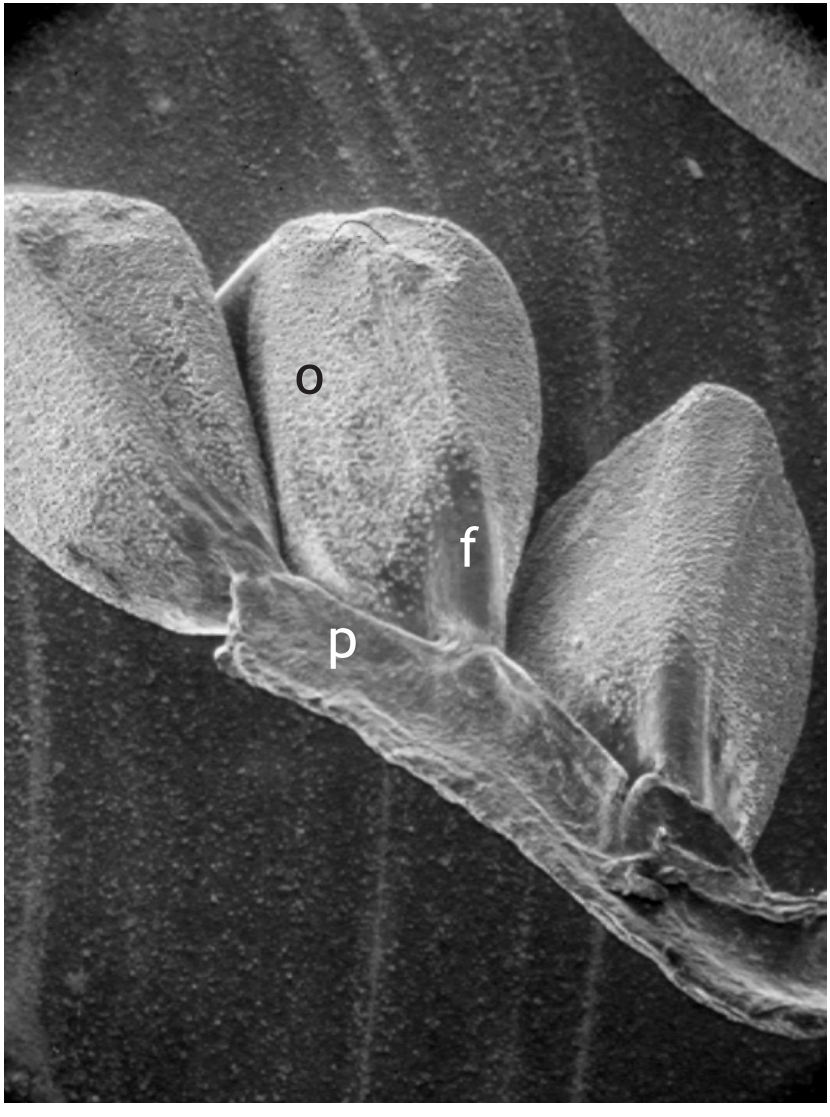


Figure 19. A SEM view of ovules dissected from the boll and receiving nourishment from the plant through the funiculus (a short stalk-like attachment) (f) between the ovule (o) and placenta (p) of the boll. (J. McD. Stewart)

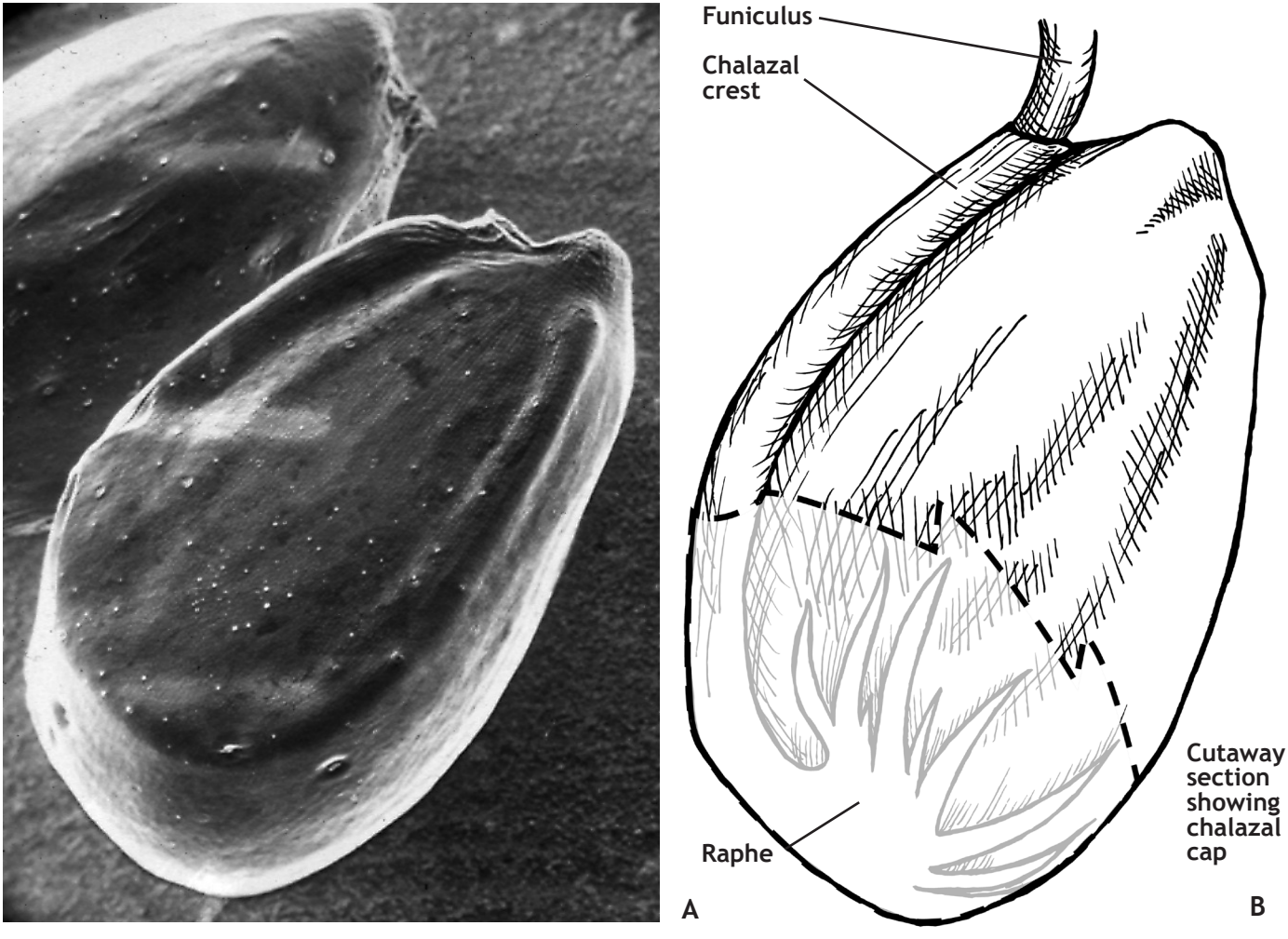


Figure 20. An SEM image (A) and diagram (B) of an ovule illustrating the point of attachment of the funiculus and the raphe of the ovule. The diagram shows the nutrient supply system of the ovule. The funiculus attaches the seed to the parent plant. The raphe extends along the side of the seed forming a crest. The raphe contains vascular tissue which branches when it reaches the blunt end of the seed (chalazal). The vascular tissue branches from an internal handlike structure within the chalazal cap that distributes nutrients to the tissue of the ovule.
(A, J. McD. Stewart; B, K. Charlton)

The raphe extends along the side of the ovule forming the "crest" and terminates internally in a large, "hand-like" structure at the chalazal end (wide end) of the ovule (Figure 20). As nutrients enter the ovule, the embryo sac and surrounding integuments expand. The integuments and other tissues encase the embryo sac and where the integuments come together at the "pointed end" of the ovule, a small opening (micropyle) is created (Figure 21).

Figure 21. A SEM view of the micropyle, a small hole (arrow) for entry into the embryo sac (egg chamber) at the base (pointed end) of the ovule.
(J. McD. Stewart)

Pollination and fertilization

On the day of anthesis, the flower opens its white petals at dawn and anthers shed pollen within a few hours. The pollen often adheres to the stigma of the same flower (self-pollinated) (Figure 22), although some insect pollination can occur between different flowers on different plants (cross-pollination).

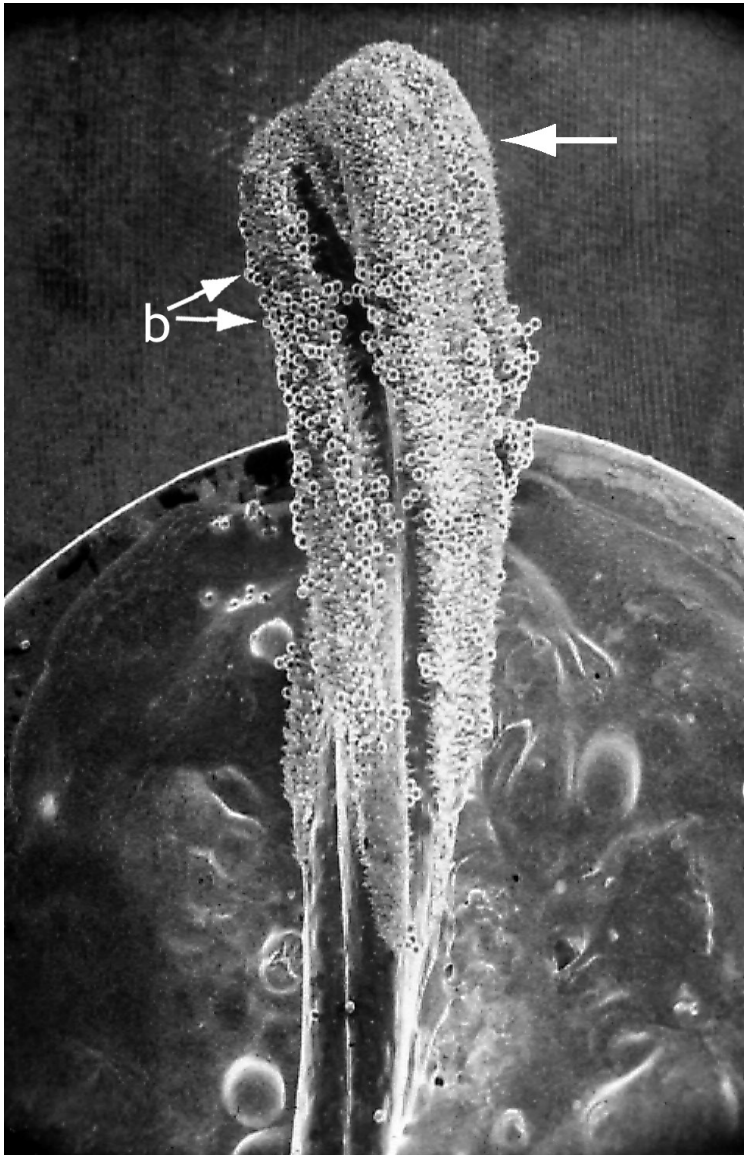
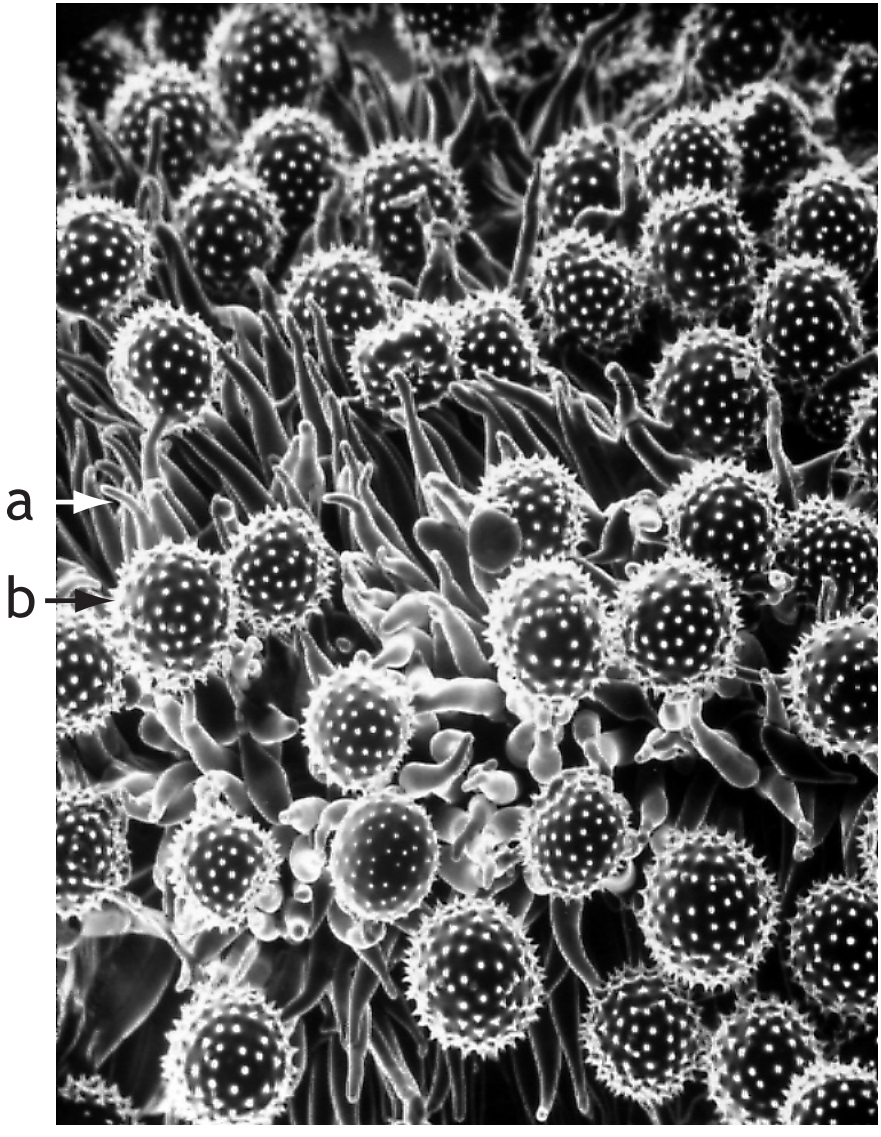


Figure 22. A scanning electron microscopy (SEM) view of the stigma (pollen receiving organ) (arrow) of a mature cotton flower. The numerous small spheres (b) are pollen grains attached to the stigma. Figure 23 is an enlargement of the grains. (J. McD. Stewart)



Long hairs on the stigma entrap the sticky pollen grains (Figure 23).

Figure 23. A SEM of mature pollen grains after landing on the stigma. Elongated cells (a) on the stigma help hold the pollen grains (b). (J. McD. Stewart)

Pollen grains germinate to produce a pollen tube (Figure 24) that grows down the style.

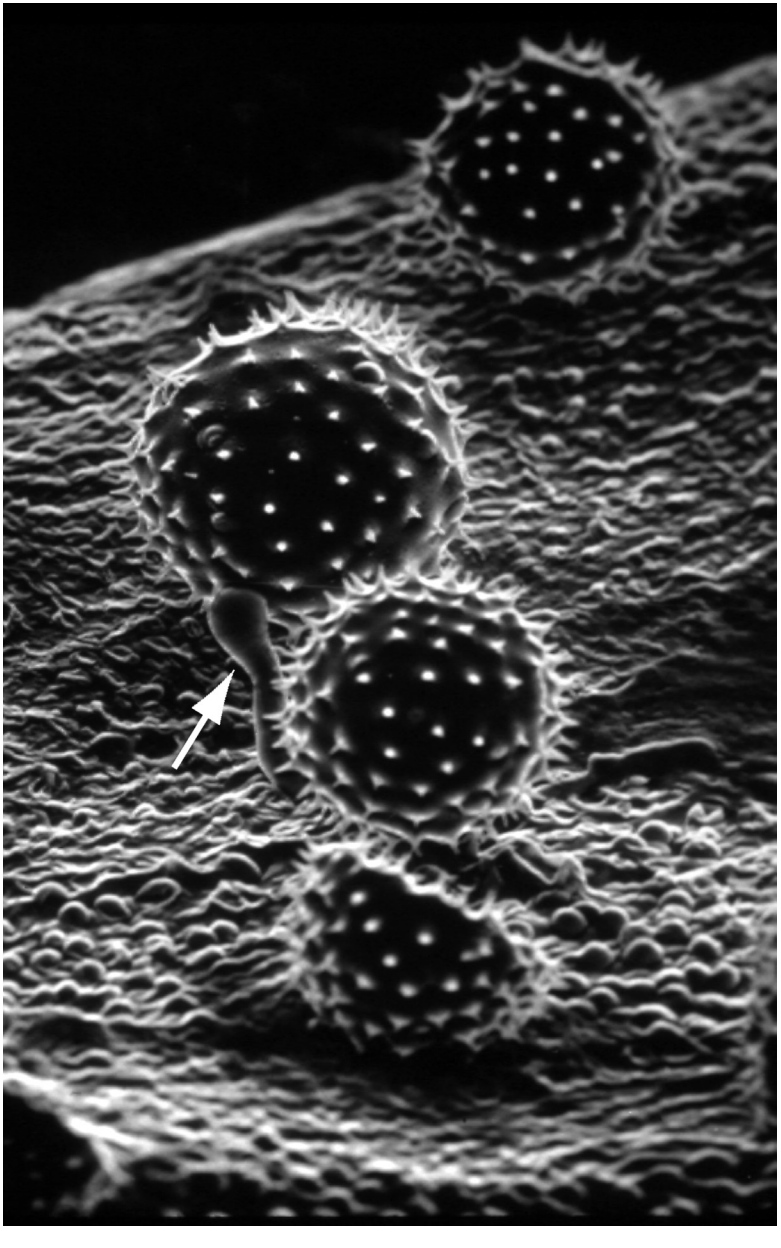
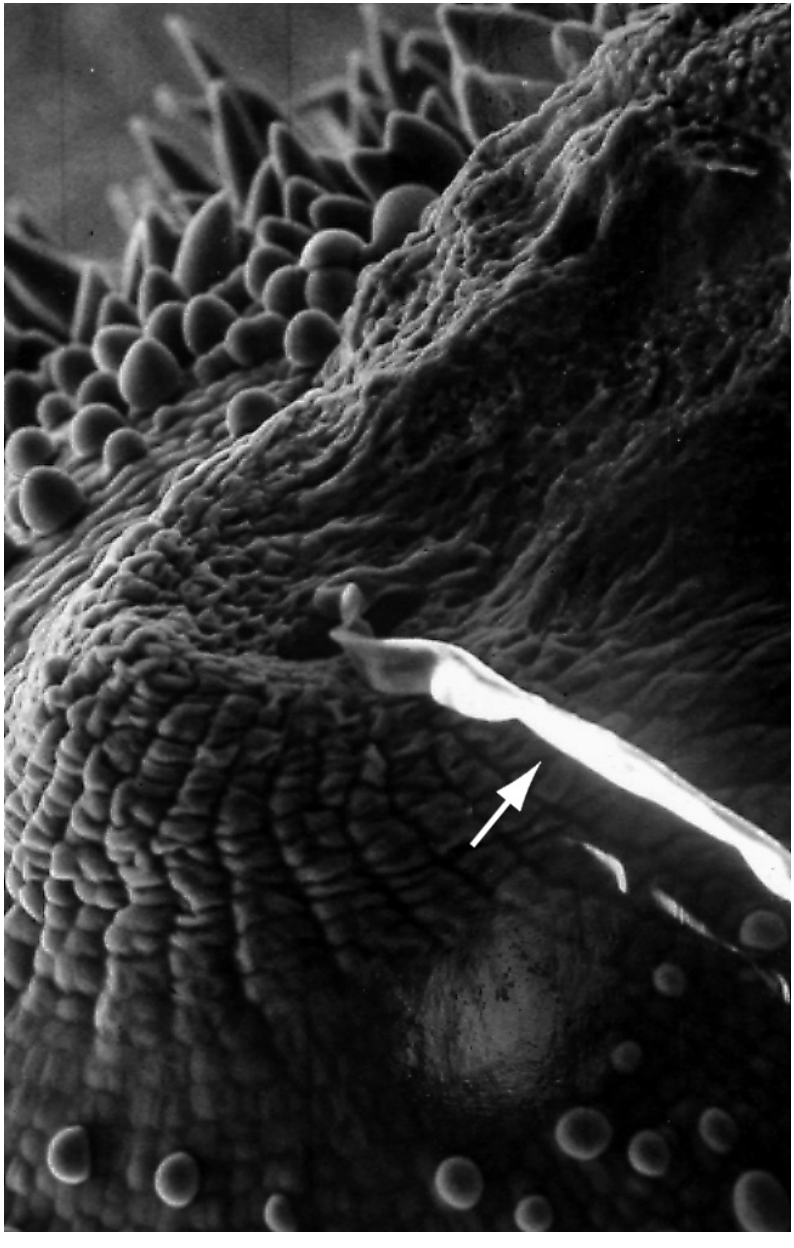


Figure 24. A SEM of germinating pollen grain that produces a pollen tube (arrow) which carries sperm cells to the developing egg cell in the ovule. (J. McD. Stewart)



The pollen tube enters the micropyle (Figure 25) to fertilize the egg cell inside the ovule (immature seeds), usually between 12 and 24 hours after pollination. The petals of the cotton flower are creamy yellow on the day of anthesis, but turn a pink-red color the following day and wither and usually fall off within three days.

Figure 25. Using SEM, a pollen tube (arrow) is seen entering the micropyle to reach the embryo sac containing the egg cell. (J. McD. Stewart)

SEED AND BOLL DEVELOPMENT

Initially the embryo is very small and the endosperm comprises most of the embryo sac (Figure 26). The endosperm swells as it fills with nutrients from the parent plant. As the ovule matures into the seed, the stored nutrients are transferred from the endosperm to the developing cotyledons of the embryo. During seed germination and early seedling growth, these nutrients are used to support the plant until it can photosynthesize and make its own food. By the time the seed is ready to germinate, the endosperm is not detectable and the embryo consists of two large cotyledons and the embryonic axis, including radicle, hypocotyl and epicotyl (Figure 9).

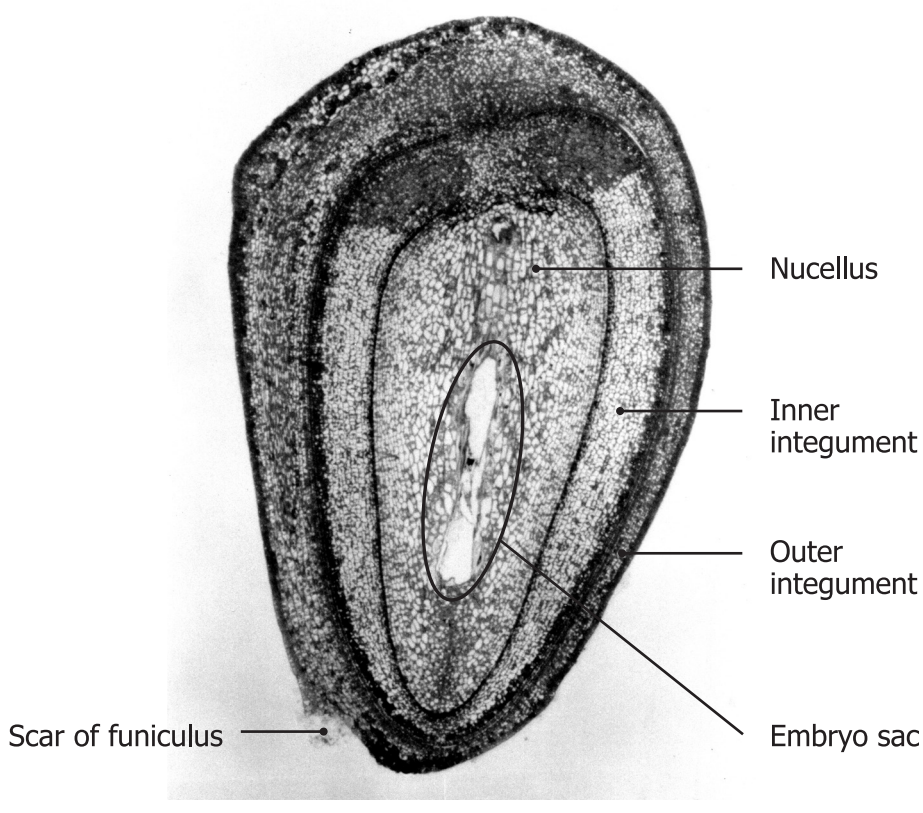


Figure 26. A light micrograph (LM) of a longitudinal section of ovule on day of anthesis illustrating a portion of the embryo sac, nucellus, inner and outer integuments, and scar of funiculus. (K.R. Jacobsen and J. Jernstedt).

Seeds attain their full size about three weeks after fertilization, but do not reach maturity until the boll opens. Only ovules that are fertilized and develop an embryo reach maturity. Immature or aborted ovules, called motes, are often found in mature bolls. Fertilization and fiber production are linked processes, in that fertilization is required for optimum fiber growth and development on the plant. Unfertilized ovules will develop fibers; however, the extent of fiber development is severely limited and is one of the causes of textile motes (undeveloped seeds with immature fibers) (Figure 27).

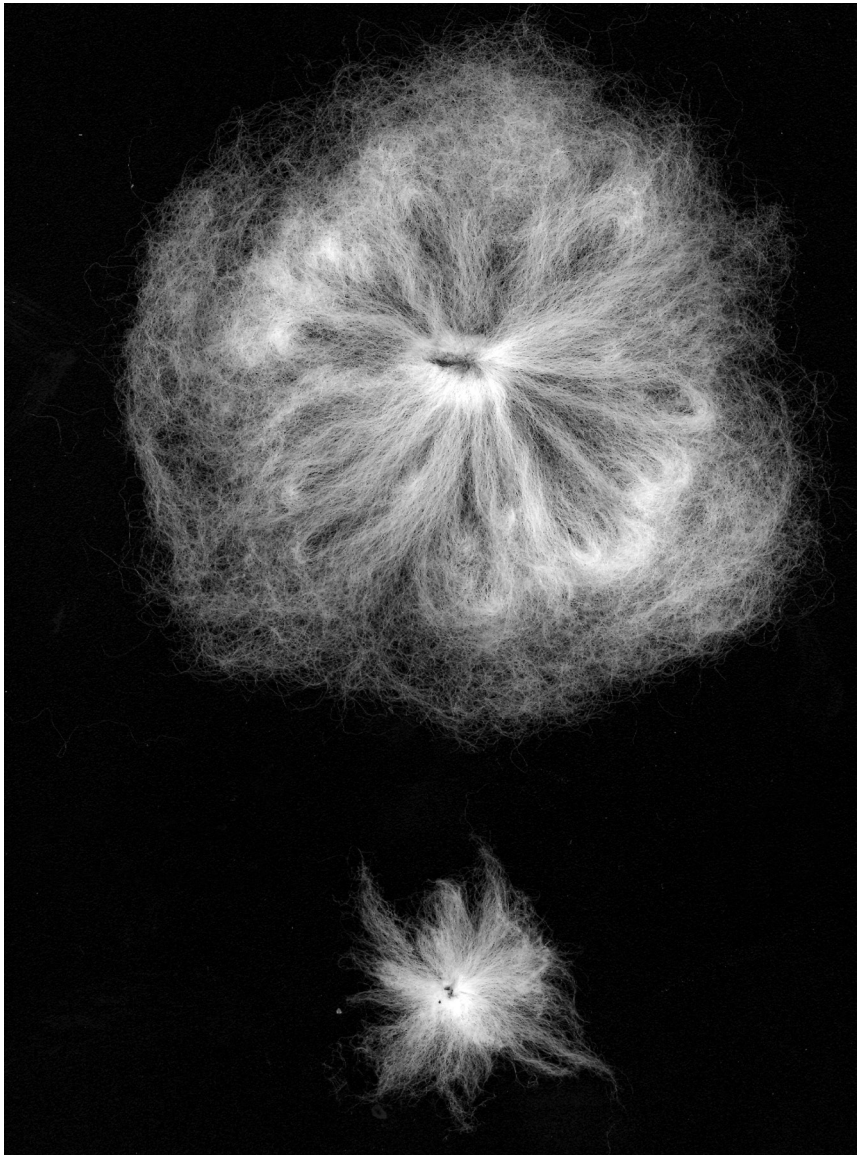


Figure 27. If the egg in the ovule is not fertilized by sperm from the pollen, then the seed and fibers do not develop properly. Motes are immature seeds and bare abnormal fibers. Ovule and fibers on top exhibit normal growth and development. The mote on the bottom has a much smaller seed and shorter fibers.
(P. Gould)

The boll, or fruit, of the cotton plant varies in form and size but is generally a spherical or ovoid leathery capsule, light green in color, and with a few pigment glands (Figure 28). The boll grows rapidly after fertilization, especially between 7-18 days, and full size is reached in about 20 to 25 days. Maturation of the boll, from anthesis to the time of boll opening, usually takes about 50 days but this varies with genotype and environmental conditions. The boll is composed of three to five locules (compartments of the ovary) each with eight or nine seeds attached to the central column (Figures 18, 28). At maturity the boll splits along suture lines in the ovary wall.

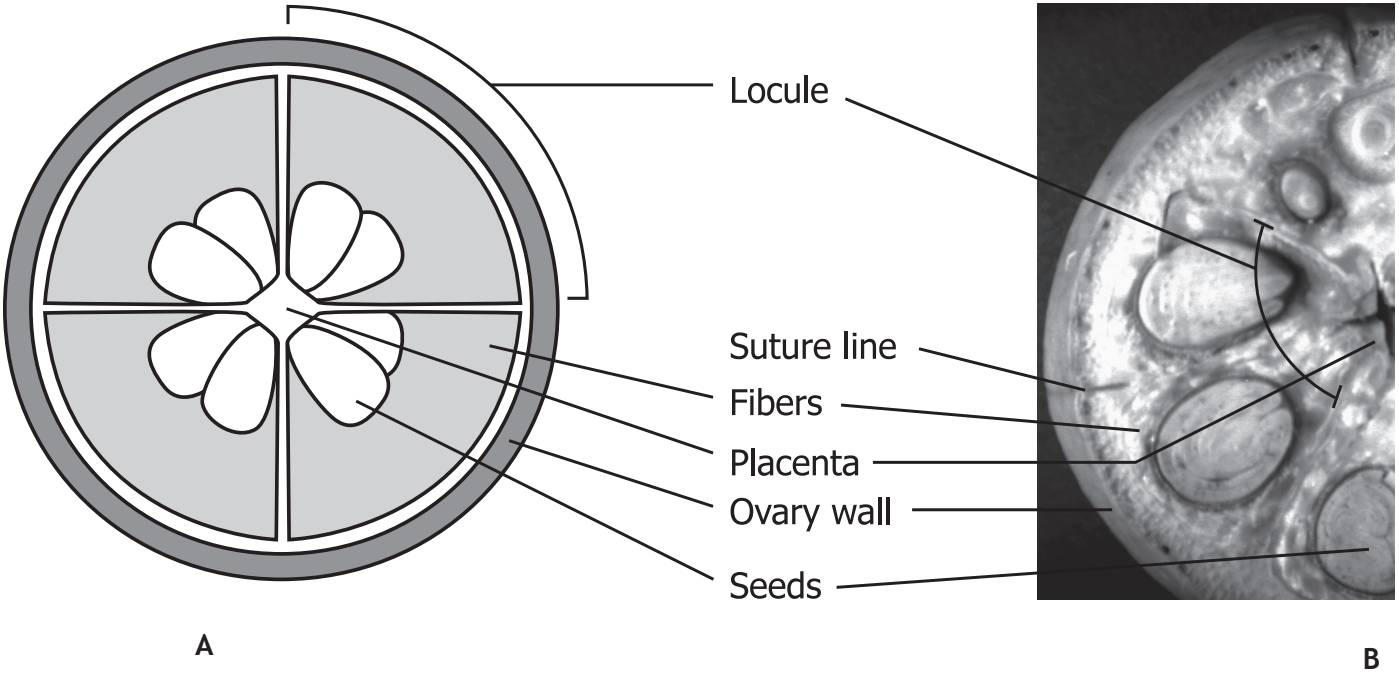


Figure 28. A cross section through a developing boll. The boll is divided into compartments or locules. Ovules appear near the center of the boll and between the ovules and boll wall one finds the mass of developing fibers. (A, K. Charlton; B, R.W. Seagull)

The mature white seed-cotton within expands greatly, pushing out beyond the capsule, forming a white fluffy mass divided into locs (Figure 29). About 300 bolls are required to produce a pound of lint and there are about 145,000 bolls per bale of lint.

The fertilized ovule develops into a seed if the young boll is not shed. Shedding occurs either before anthesis (squares) or after fertilization (developing bolls). Flowers are not shed. The shedding of squares and young bolls is a natural occurrence in cotton that is accentuated by adverse environmental conditions including extended overcast weather, extreme high temperatures, water stress, and insect damage. A cotton plant in a typical field commonly sheds about 60% of its squares and young bolls, mostly in the younger regions of the plant (i.e., ends of branches and main stem).

Figure 29. Mature open cotton boll with five locs. (R.W. Seagull)