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A young amateur experiments with a plant that collapses its leaves when it is touched

Conducted by C. L. Stong

Nearly everyone has heard about Venus's-flytrap, sundew, mimosa and similar plants that are capable of animal-like movements. But few residents of northern latitudes are familiar with any of the several hundred so-called "sensitive" plants because most are tropical, or at least semitropical. We now learn, however, that one grows in Brooklyn. The movements of the Brooklyn plant are not so swift or eye-catching as those of Venus's-flytrap, but they are quite as fascinating to Jack Rudloe, the high school boy who studies them. Rudloe, who now lives in Tallahassee, Fla., explains how he found the plant, how he has experimented with it and what he has learned about it.

"While taking a short cut across a vacant lot in Brooklyn four summers ago," he writes, "I happened to brush against a small green shrub with fern-like leaves. The plant had reddish-brown stems and an abundance of small yellow flowers so attractive that I stopped for a closer look. One feature was particularly interesting: the stem of each leaf bore a small, glandlike structure about the size of a pinhead, which on the younger leaves was brilliant red and strikingly beautiful when viewed through a magnifying glass. I had scarcely begun to examine the gland on one leaf when I became conscious of a change in the plant. It was moving. The leaves were folding up, slowly but nonetheless obviously [*see illustration on next page*]. What made it move?

"I spent the rest of the summer trying to find out and became a regular visitor to the lot. At night the leaves closed tightly and the leaf stems would droop at a sharp angle. Hot days or intense sunlight produced much the same effect. I could make a leaf close and droop merely by striking it several times with my finger. It was obvious that the movements were not caused by differences in growth rate. The responses were much too quick. The leaves would start to fold within seconds after being stimulated. Unless the plant was damaged in the process, it would recover from even the most violent disturbance within an hour.

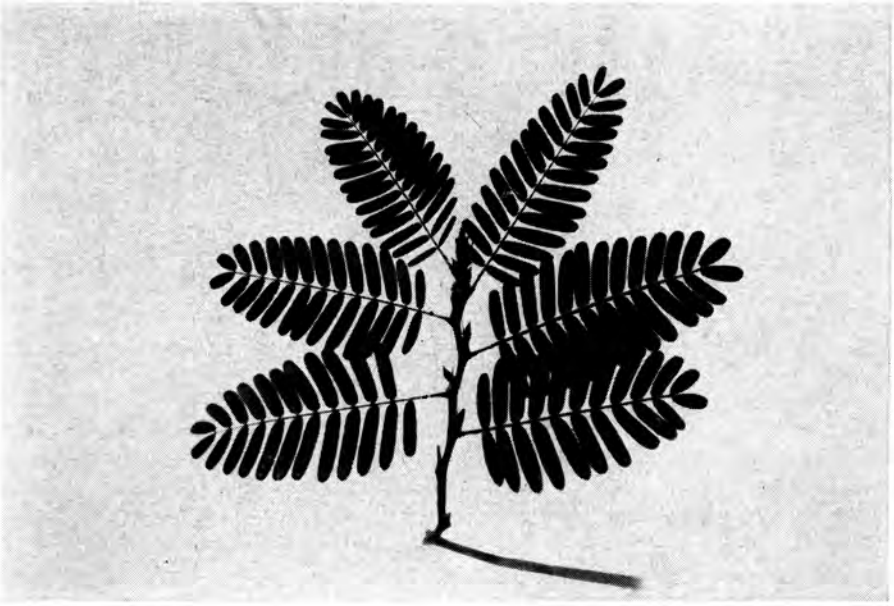
"After a few weeks I decided to transplant a few specimens to our apartment for more convenient study. All attempts failed. I discovered that even the slightest damage to the root system killed the plant. Toward the end of August the field specimens came to seed. Each plant bore an abundance of long green pods. The pods dried by October, and I collected enough seeds to fill a one-ounce bottle—a lifetime supply. I put a capsule of calcium carbonate into the bottle to absorb moisture. Then, before frost set in, I took a few specimens to the Brooklyn Botanic Garden, where they were identified as *Cassia nictitans,* the wild sensitive pea.

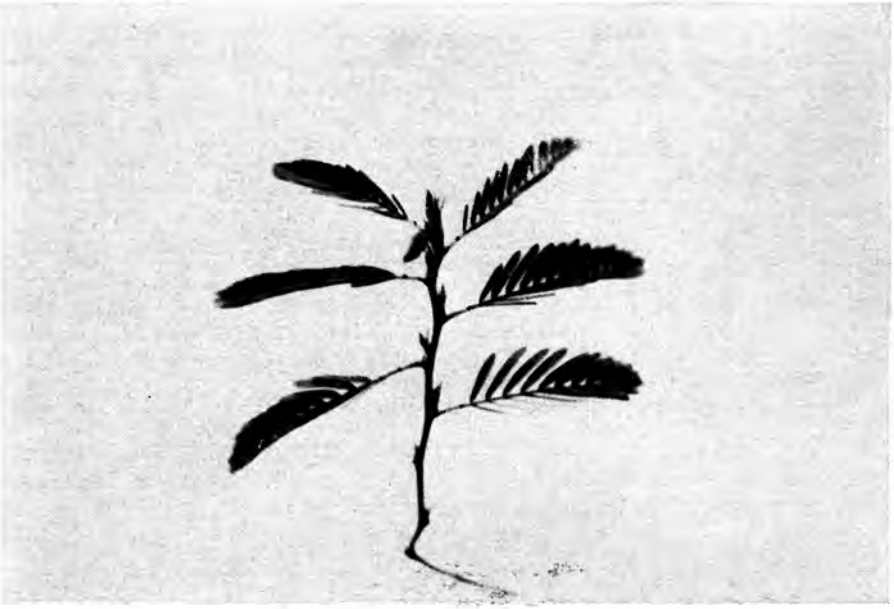
"The movements of *Cassia nictitans* are far more sluggish than those of the Venus's-flytrap or even of *Mimosa pudica,* the sensitive house plant that is so popular with gardeners in the southern U. S. When disturbed, the leaflets of mimosa snap shut within two seconds. Those of Cassia require from three to four minutes and will not close fully unless they are mechanically stimulated at least three times.

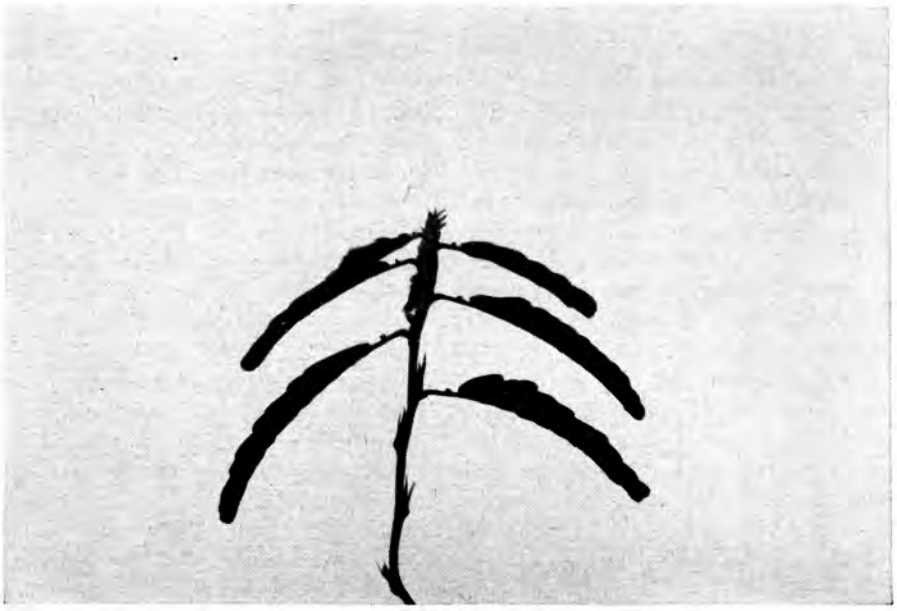
"During the following winter I attempted to grow some Cassia but without exception the results were disappointing. The seeds germinated well and came up promptly. Unfortunately the plants developed just as promptly. Having attained runt size in three or four weeks, they flowered, went to seed and died. I tried adjusting the soil, the room temperature and every other variable I could think of without success. Finally I simply gave up and put the seeds away.

"Subsequently we moved to Florida. One day in 1959, while unpacking a box of hobby materials, I came across the forgotten seeds. We live close to the campus of Florida State University, and during a visit to the campus shortly after finding the bottle I arranged to plant a crop in the university greenhouse, where the environment can be controlled. Once again the seeds germinated well, but the crop failed as usual. All of the young plants flowered within a month of planting. This seemed strange because I had made a careful record of summer temperature at the lot in Brooklyn and had duplicated it in the greenhouse. Finally I took the problem to George W. Keitt, Jr., a plant physiologist at the university. He suggested that the long November nights might be responsible for triggering the premature flowering [see "Light and Plant Development," by W. L. Butler and Robert J. Downs; SCIENTIFIC AMERICAN, December, 1960]. So I installed a bank of electric lights above the plants and connected it to an automatic timer set to turn on at 4 p.m. and off at 2 a.m. This solved the problem. Within two months I had a flourishing crop of normal, healthy plants. Many more have since been grown.

"While in Brooklyn I had gone through the literature in an attempt to learn about sensitive plants. Hundreds of different kinds have been described. All plants are capable of some movement, of course, particularly that resulting from unequal growth or the absorption or loss of water. Sensitive plants, on the other hand, have evolved a special motor organ, the pulvinus, that is responsible for an altogether different kind of movement. The pulvinus is an enlargement at the base of the leaflet and at the base of the leaf stem, or petiole. The center of the pulvinus contains a strand of vascular tissue surrounded by a cylinder of thin-walled cells that are separated by relatively large intercellular spaces. Some mechanism in the plant, not fully understood, controls the permeability of the cell walls. In certain states the cells become gorged with a fluid that stiffens the whole structure. In other states the fluid is secreted in the intercellular spaces and the pulvinus loses







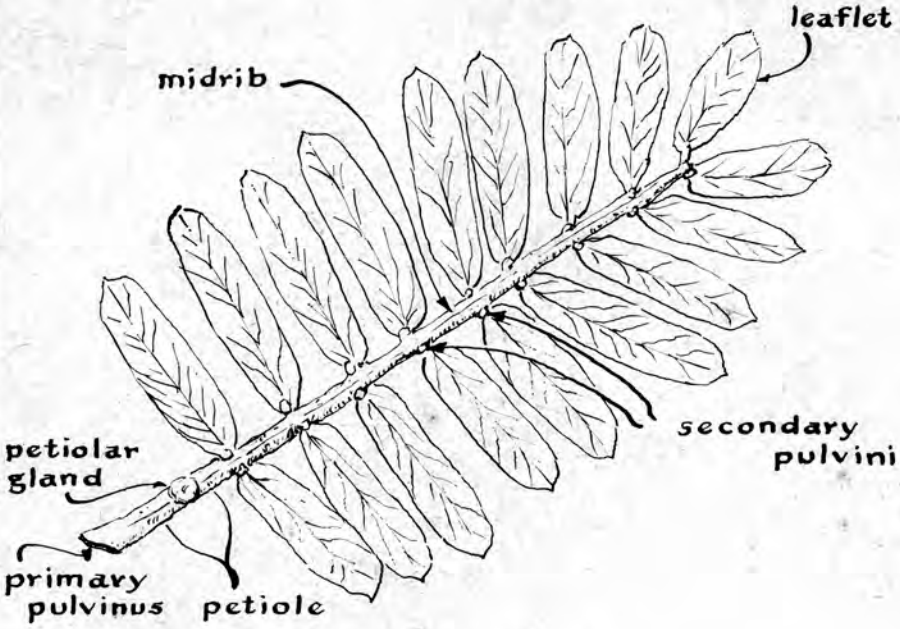
The sensitive pea (Cassia nictitans) *folds its leaves after it has been touched*

its stiffness. Such changes in permeability can occur, moreover, within selected groups of cells, such as those on one side of the pulvinus, with the consequence that one group of cells becomes flaccid while the opposing group remains turgid and the organ bends. A substantial amount of energy is thus made available for mechanical work and accounts for the movement of sensitive plants. Although the mechanism of energy conversion may differ fundamentally from that of animal muscle, the resulting action is comparable. The pulvinus can readily elevate a leaf against the force of gravity, for example.

"Unfortunately the literature makes few references to *Cassia nictitans* and barely mentions the petiolar gland. The specimens that I have observed normally grow to a height of between six and eight inches as a single stalk with leaves attached to primary pulvini on alternate sides about every half inch from the middle to the top of the stalk. Each leaf consists of a midrib that supports about a score of leaflets spaced uniformly in opposing pairs along its length. Each leaflet is coupled to the midrib through a secondary pulvinus, as illustrated in the accompanying drawing [*top of page 184*]. The petiolar gland is situated on the dorsal side of the petiole about midway between the last set of leaflets and the primary pulvinus [*see bottom illustration on page 184*].

"The gland had first caught my interest when flies buzzing around the plants in Brooklyn were attracted to it; it is a mushroom-shaped structure with a slightly depressed, elliptical top about a millimeter wide and less than a millimeter in height. During certain phases of the plant's life the gland secretes a sticky, transparent sap that collects as a drop in the depression at the top of the gland. It was this sap that attracted the flies. They fed on it. If permitted to collect undisturbed, the sap dries into a hard ball that eventually drops off. The gland then begins to secrete additional sap and the cycle repeats. When a hot dissection needle is applied to the secretion in either the liquid or solid state, the resulting smoke has the odor of burnt sugar and a black residue forms that appears to be carbon. The one chemical test that I have made so far, however, failed to indicate the presence of sugar.

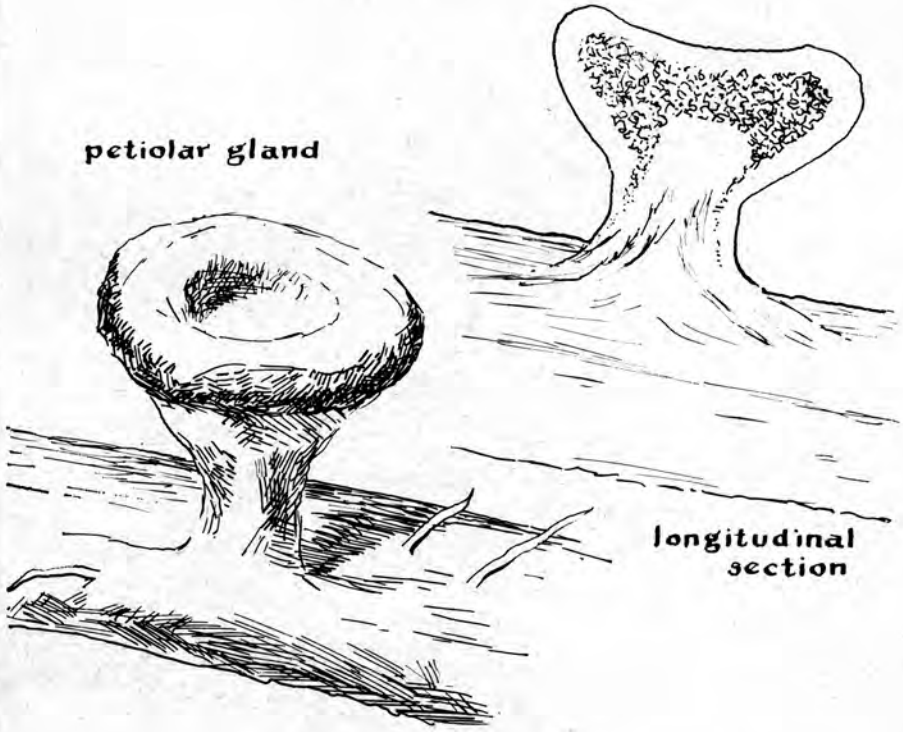
"What is the function of this gland? In what way, if any, does it influence the movements of the plant? Because the reference books gave no information on this point, I decided to remove the glands from some plants to see what



The leaf of Cassia nictitans

would happen. This would not necessarily show how the gland functions, but it might indicate whether there is any relationship between the gland and the action of the pulvini.

"First, I made a goniometer for measuring the angular closure of the leaflets. This was simply a sheet of glass about four inches wide and five inches long on which I painted a pattern of 17 radial lines, a fourfold bisection of a 180-degree angle. Each of the 16 sectors is an angle of 11.25 degrees. The sectors were numbered serially in the clockwise direction from the reference line as shown by the accompanying illustration [*page 187*]. You merely hold the goniometer between the eye and leaf, center the apex of the radial pattern on the axis of the midrib and turn the glass so the reference line is aligned with the leaflets on one side of the leaf. The opposing leaflets are then observed through one of the remaining spaces, unless the leaf is fully



Petiolar gland of Cassia nictitans

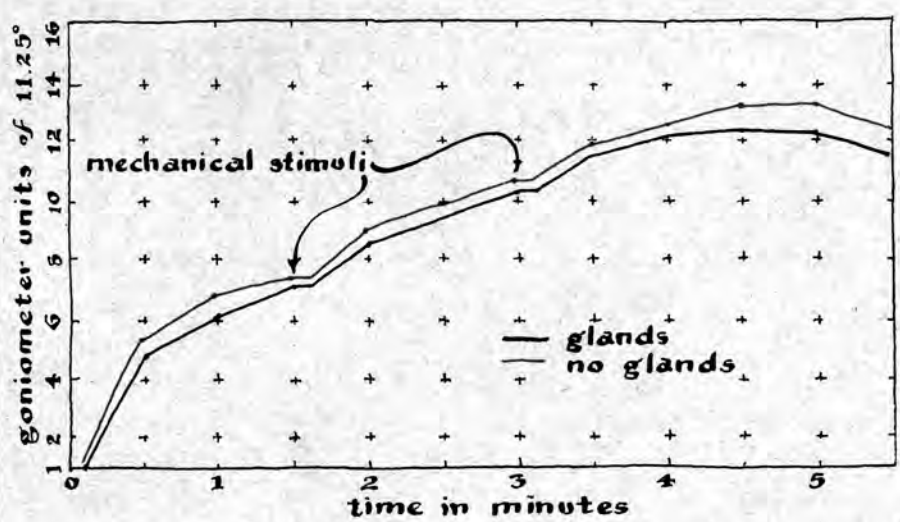
closed. To calculate the amount of closure per leaflet I multiply the number of sectors that the leaflets span by 11.25 and divide by two. To determine the rate of closure or opening I make a series of timed measurements and plot the resulting data on rectangular co-ordinate graph paper.

"In preparation for the first experiment I selected three groups of uniform, mature plants. The glands were removed from one group by placing the pointed end of a dissecting needle against the stalk of the gland and pressing the tip toward the apex of the leaf. The glands came off easily, taking along a small amount of vascular tissue from the stalk at its point of attachment to the petiole. Later I learned from experience that the risk of leaving tissue from the stalk embedded in the petiole increases with the age of the leaf. It is best to work with relatively young leaves. The removal of a gland causes only a small wound that heals in about a week.

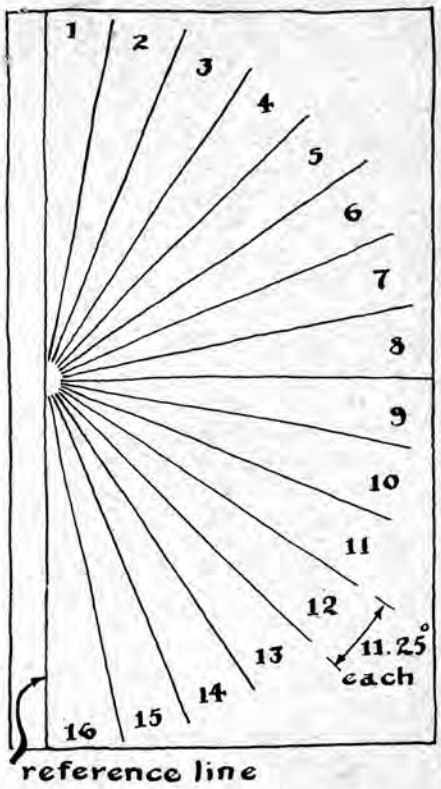
"Would the mere wounding of the petioles, apart from the removal of the glands, influence the sensitivity of the plants? In anticipation of this question the petioles of the second group were nicked in a few places between the gland and the stem. The wounds were just as severe as though the glands had been removed. But the glands were left intact. This test was discontinued after the first few experiments because the behavior of the nicked plants was identical with that of the control group. The control group was not modified. The three groups were then permitted to recover for one week.

"What effect, if any, would the presence or absence of the petiolar gland have on the response of the plant to a light blow, as when struck by the finger? To investigate the question I improvised a simple apparatus for dropping a series of weights on a selected part of the plant so that the intensity of successive impacts could be reproduced. A 10-inch length of quarter-inch aluminum tubing was supported vertically in a clamp on a ring stand, with the bottom of the tube about a foot above the bench. A slot wide enough to admit a piece of cardboard was sawed halfway through the tube near the top. When placed in the slot, the cardboard served as a support for a pellet. When the cardboard was withdrawn, the pellet would drop through the tube and strike the plant beneath. Pellets of three weights were used. One of papier-mâché weighed .32 gram; one of wax, .49 gram; one consisting of a pellet of 00 buckshot, 3.21 grams. The tube was aimed by trial and error (at first mostly error) so that the pellets struck the midrib of a selected leaf.

"No significant differences were observed between the behavior of glanded and glandless leaves. But the experiments did disclose several interesting responses. The leaflets would not close fully, for example, when stimulated by a single blow, however intense. Each initial stimulus was followed by a latent period of five to eight seconds. Movement then began and continued for 90 seconds. If not restimulated, the leaflets would then come to rest for 30 seconds and begin to reopen. Restimulation at the end of the initial 90 seconds of movement was followed by a brief latent period. A second and third stimulation would in each case be followed by 60 seconds of movement. Three stimuli produced full closure of all



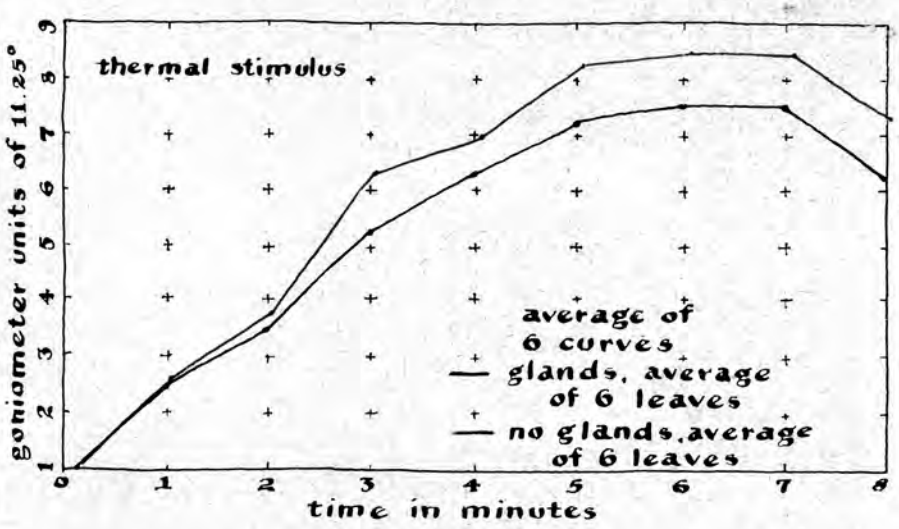
Graph showing response of plant to impact

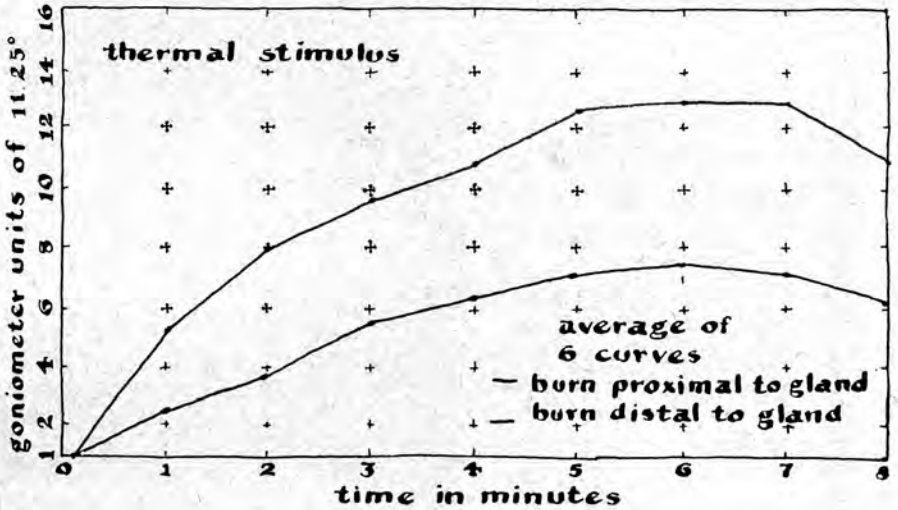


Goniometer for measuring leaf movements

leaflets and made the entire leaf droop. Maximum movement was induced by the initial impact with progressively less movement following the second and third blows. The initial rate of closure following each blow appeared to vary directly with the intensity of the impact, but not significantly [*see illustration on opposite page*].

"Would the application of heat trigger the pulvini? As the initial test I applied the tip of a hot dissecting needle to the top of the gland of the control plants and to the scar tissue of the glanded plants. No movement was apparent for eight seconds. Then the leaflets of all plants began to close, continued for six minutes, stopped for a minute and then began to open. The glandless leaves closed about five degrees per minute faster than the control plants, as illustrated by the accompanying graph [*top illustration on next page*]. The difference is not great and may not be significant. It would appear to indicate, however, that the gland is an irritable center. The stimulated gland resulted in movement at least comparable with that of the stimulated petiole. During a subsequent run of this same experiment I accidentally touched the hot needle to the petiole of a control plant in the area between the gland and the first pair of leaflets. I was about to discard the plant when I noticed that the leaflets were closing at





Response of plant to heat applied to gland (top) *and to petiole* (bottom)

an abnormally high rate. This suggested another experiment.

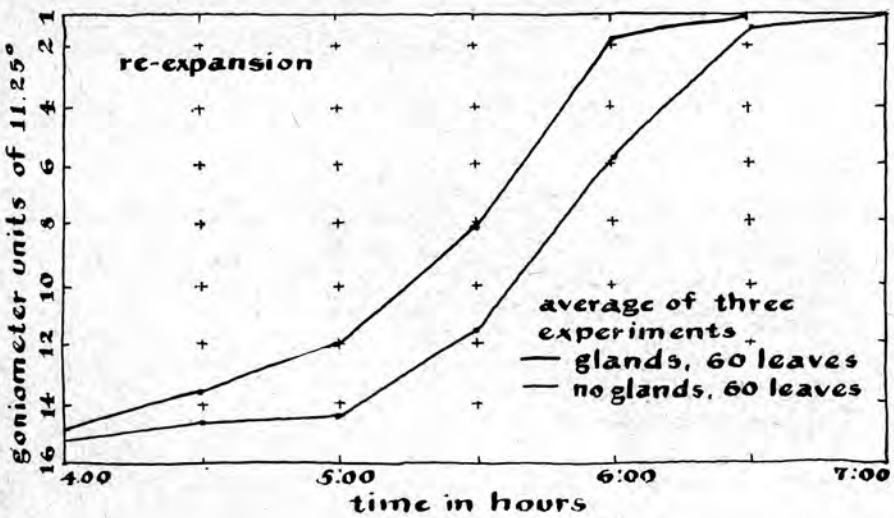
"Two groups of unaltered plants were selected. The heated tip of the needle was touched to the petioles of one group at a point about two millimeters above the gland (between the gland and the leaflets). The petioles of the second group were similarly stimulated between the gland and the stalk of the plant. The comparative reaction of the two groups was astonishing. The leaflets of the group that was stimulated between the gland and the leaflets moved through twice the angle of the second group in the same period of time [*bottom illustration on this page*]. In addition to the difference in rate of movement the plants reacted in another interesting way. The midrib darkened and the secondary pulvini, which form the junctions between the midrib and the leaflets, changed color from pale white to dark green. The heat doubtless influences the chemistry of the midrib, but the altered appearance of the pulvini may be due to differences of light refraction caused by the redistribution of the fluid in the permeable cells.

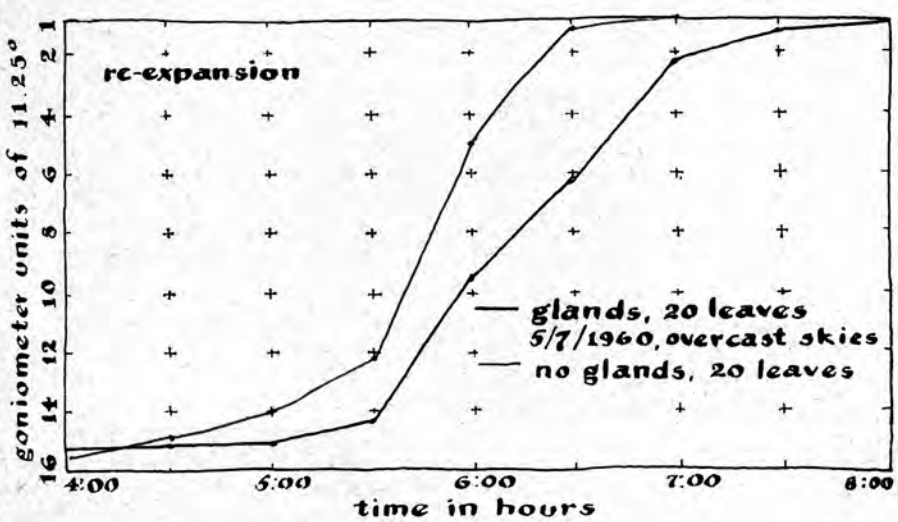
"The leaves of *Cassia nictitans* close tightly at night, with a sharp forward and upward movement. Is the gland involved? Two groups of plants were removed from the artificial light and placed near a large window with a northwest exposure. To simplify measurement all but the four most vigorous leaves were removed from each plant. The glands were also removed from one group. The plants were then permitted to recover. (Recovery was judged to be complete when the plant reacted normally to physical stimuli.) Closure of the two groups required about two hours; the rates of closure were almost identical, although the glandless group re-

sponded at a higher initial rate. No change of color was observed in either the midribs or the pulvini.

"Subsequently I ran another series of tests with a different set of plants to check the rate of re-expansion in the morning. The plants were similarly prepared but were shifted to a window with a southeast exposure. The experiments were made in May, 1960, beginning in total darkness at about 4 a.m. The plants without glands were observed to open at a substantially lower rate than the controls, less than half as fast during the initial phase, and required 30 minutes longer than the controls to open fully [*see top illustration on this page*]. The most interesting response, however, was observed on May 7. In contrast with the previous sunny mornings, there was intense rain and the sky was heavily overcast. The plants with glands opened at a much higher rate than those without glands and were fully open an hour earlier. I can think of no reason for this reversal in behavior, and so far I have not managed to get any counsel concerning an explanation. The data plotted in the next illustration [*bottom of page*] represent the average of observations made over a period of three days in the case of the glandless plants but of only one day in the case of the controls.

"The crop was at its best during May and June. An abundance of large leaves provided an excellent opportunity to test the effects of an acid, an alkali and alcohol as stimulants. Sulfuric acid was prepared in three concentrations for the experiment by adding 12 grams, 144 grams and 588 grams of acid respectively to three vessels, each containing one liter of water. Comparable dilutions of ammonium hydroxide were prepared for the alkali solution. A single dilution of 85 per cent ethyl alcohol (by volume) was used. The stimulants were applied to the glands and petioles with a swab





Response of plant to sunrise on a clear day (top) *and a cloudy one* (bottom)

made by wrapping a few strands of cotton on the roughened tip of a dissecting needle.

"The plants, grouped and prepared as in the earlier experiments, displayed a barely detectable reaction to the weakest dilutions of acid and alkali. The intermediate concentration triggered a more obvious response: movement started in the leaflets closest to the stem of the plant and gradually progressed up the midrib to the terminal pairs. The rate of movement was perceptibly higher in the leaves with glands but in all other respects the reactions of both groups were identical.

"The highest concentration of alkali and the alcohol triggered more interesting responses. When a drop of strong ammonium hydroxide solution was applied to the glands, all leaflets closed quickly in unison, with the stimulus being transmitted first to the first pair of terminal leaflets—the pair at the apex and farthest removed from the gland. When applied to a glandless petiole, however, the alkali induced movement first in the pair of leaflets closest to the petiole and the effect progressed up the midrib to the terminal pair. When alcohol was applied to the gland, the leaflets at the apex responded first and the movement traveled progressively down the midrib to the petiole. When alcohol was applied to a glandless petiole, leaflets closest to the stem responded first and the reaction progressed quickly toward the apex. Immediately after the application of strong acid to the gland, the color of the gland changed from the normal brown (on mature leaves) to a brilliant red. The midrib simultaneously darkened and the pulvini changed color as the stimulus traveled down the midrib at the rate of one millimeter per second.

"The results of these experiments (which I am continuing) have not disclosed the purpose of the gland. They do suggest that the gland is both an irritable center and a transmission organ. Under certain conditions it can influence the movements of the plant. The reaction of the plant when alcohol is applied to the gland even suggests that the gland may be connected to the apex of the leaf by some sort of pipeline. It would be interesting to check this by one of the radioactive-isotope techniques. The experiments have also shown that the plant responds to four stimuli: impact, heat, light and certain chemicals. Finally, they have provided me with a hobby as fascinating as any I can imagine. I urge amateur botanists who are on the prowl for novel specimens to include *Cassia nictitans* in their collections."