Fig. 2. For their independent study projects, Linda King and Steve Roller press plants for a herbarium collection for the college.

independent study projects. Some studies, such as identification of flowering plants, marine algae, lichens, or birds of an area, do not cost the instructor or the college any money. The students enjoy the field work and can do most of the identification after initial help from the instructor. With some money available to the instructor plankton nets, hydrometers, dip nets, and other limnological equipment can be purchased for aquatic studies. Microbiological analyses require the purchase and preparation of media. I have used Millipore (membrane filter) equipment for about half of our bacteriological studies with good reproducibility of results. Larger budgets will allow the purchase of boats or spectrophotometric equipment, but these projects really need not be elaborate. Recently I have obtained funding that allows five students to go out weekly on a research vessel performing coliform counts, other bacterial surveys, and fish and invertebrate studies on San Francisco Bay.

Independent study projects have merit in the experience they give to the student, whether in studying bacterial degradation of crude oil or an enumeration of the lichens in a U.S. Government Survey quadrangle of farmland. I have found student interest is greater when their projects have meaning in relation to real environmental problems rather than biological abstractions. Pure research has merit and the data are meaningful, but the lower-division college student does not have the scientific background required for many such studies. Natural history and environmental data lend thenselves to these students' experience. The knowledge gained in independent study has led a number of students to major in biology, but this is not the purpose. The purpose is to create an awareness and concern in the student about his environment that results in an understanding of biological principles.

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ANATOMY OF A GREEN PEA

I employ the following laboratory exercise in my high school biology course as the culminating experience of the botany unit. It correlates the flower to the fruit as well as demonstrating other botanical concepts. Because the pea pod is the product of a flower, it is a fruit; specifically, a typical legume fruit.

This exercise lends itself nicely to a classroom lab activity. Only simple readily available materials are needed. These include fresh green pea pods (stringbeans or lima beans may be substituted), scalpel or razor blade, hand lens, glass slide, and microscope.

1. Observe the external features of the pea pod (fig. 1). The pea pod is an example of *dry dihiscent* fruit. When it is fully mature, it will split along very definite lines. As it opens, its seeds may be dispersed. Note the two seams that run the full length of the pod. One of the seams is *concave* and runs *into* the pod. The seam on the opposite side is *convex* and either lies flat or *rises* away from the pod.

2. Note the stem end of the pod. The *sepals* from the pea flower remain. There are five sepals. Since the pea plant is classified as a dicotyledon, we would expect its floral parts to be in fives or multiples of five. At the opposite tapered end of the pod, observe the remnants of the *style*. The entire pea pod is an enlarged *ovary*. It has grown considerably from its original size to accommodate the seeds inside.

3. Note the green coloring of the pod. This color usually indicates the presence of chlorophyll in plants. To prove this supposition, cut a very thin slice of the pod and observe it under low power of the microscope. The spherical pale-green structures that you observe are *chloroplasts*. Photosynthesis takes place in these

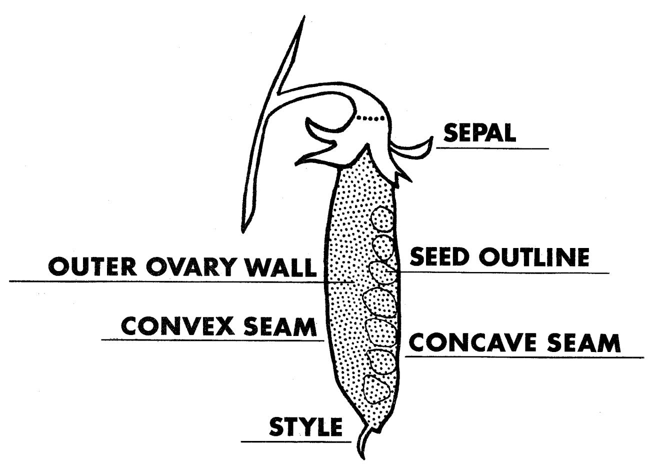

Fig. 1. External view of the pea pod.

structures. Pea pods not only protect the seeds inside but also contribute to their food supply by carrying on photosynthesis.

4. Now observe the internal structures of the pea pod (fig. 2). Carefully open the convex side of the pod

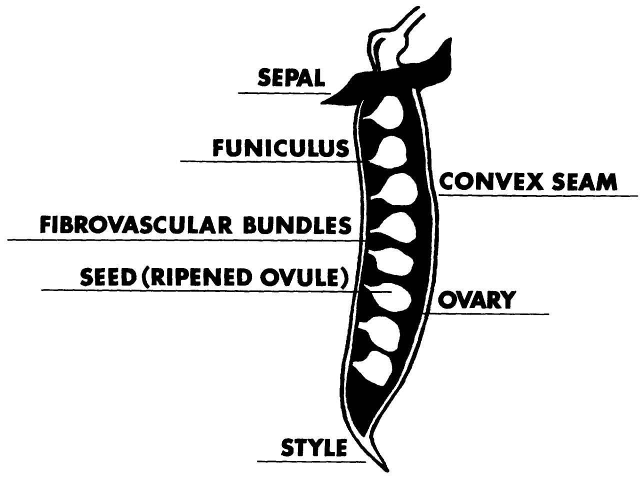

Fig. 2. Internal view of the pea pod.

with the razor blade or scalpel. Remember that this is the *raised* seam, also called the artificial groove. If the concave side is cut in error, the seeds will be disturbed from their natural position.

5. Note the cavity in which each seed lies. The inner ovary wall (as well as the outer ovary wall) is leathery and therefore inedible. The ovary wall in the string-bean, however, is edible. Note the position of the peas (ripened ovules). Observe the alternating pattern in the opened pod. This is an example of the survival mechanism. Since the peas are attached to two *fibrovascular bundles*, if one of the bundles is destroyed and unable to bring nourishment to the seeds, the other bundle would be able to keep the remaining seeds alive. Note any undeveloped peas in the pod. There are two reasons for this condition. Either one of the fibrovascular bundles was destroyed, or the ovule was not fertilized and therefore could not develop into a mature seed.

6. Count the number of peas in the pod. Are any two of them alike? The old adage "as alike as two peas in a pod" is a stretch of biological truth. Since peas are produced as a result of sexual reproduction, we can always expect to find variation.

7. Note the structures to which the seeds are attached. These are the *fibrovascular bundles*, tubes which bring nutritive materials to the peas as they are developing. The stalk connecting the seeds to these bundles is the *funiculus*. The indentation on the seed where the funiculus is attached is the *hilum*.

8. Remove a well-formed pea from the pod. Cut off the seed coat and lay open the two parts of the seed. Note the two flat-faced halves. These are the *cotyledons*. Since there are two, the botanist has classified the pea as a dicotyledon. Two cotyledons and five

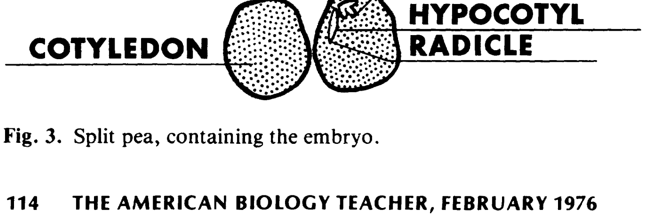

Fig. 3. Split pea, containing the embryo.

floral parts, as noted earlier, confirm the fact that the pea is a dicotyledon.

9. Note the small nib between the cotyledons. This is the embryo plant (fig.3). It is the product of sexual reproduction. The food stored in the cotyledon would have been enzymatically converted to usable nutrients to nourish the embryo until it was capable of making its own food.

10. Make a complete sketch of all the structures you have observed externally and internally. To review your understanding, give the function of each structure named in your diagrams.

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INEXPENSIVE OCULAR MICROMETERS

High school biology teachers frequently want their students to accurately measure the size of a particular microscopic specimen. Because of the high cost of ocular micrometers and stage micrometers, many teachers resort to having their students estimate the number of times a specimen could be placed end to end across the diameter of the field of view and then divide that diameter by the estimated number of specimens for an approximation of specimen size.

A. Amaro (1965) presented a technique for producing relatively inexpensive ocular micrometers, but his article did not provide the necessary data to duplicate the method of production. The article motivated me to experiment with a technique for making fairly good quality ocular micrometers at a cost of about ten cents each. The equipment and materials are as follows:

Single lens reflex camera (35-mm with 50-mm lens)
Reflected light-light meter
Copy stand with pair of flood lamps (3200 °K)
HC 135-36 High Contrast Copy film ASA 64
Black matte finish construction paper (14 by 16 inch)
White self-adhesive label cut into 11 strips (1/16 inch by 1 inch)
Microscope slide
Canada Balsam
Transparent metric ruler cut into 1-cm increments

The white strips are placed parallel to each other in approximately the center of the black construction paper. The camera, on the copy stand, is focused on the white lines so that the lines pattern covers a very small area on the viewer. Many viewers have a small focusing circle which is about the correct length for the white lines to cover. Each flood lamp is positioned so that the illumination is even. (To determine if illumination is even, hold a pencil so that one end of the pencil is touching a piece of paper. Then, adjust the flood lamps until the shadows cast on both sides of the paper are equal in darkness.) Determine the correct