PLANT PHYSIOLOGY AT THE INSTITUTE

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Many of our alumni are probably unaware of the existence of a plant physiology research group at the Institute, in part because this type of research is relatively new to Cal Tech, and in part because plant physiology has seemed somewhat far removed from engineering, physics, and even from chemistry. Research on plant growth is, however, well established in the biology division and in the following pages I will attempt to give you a resumé of the past accomplishments and present aims of this work.

The study of plant physiology was initiated in 1930, when Dr. Herman Dolk came to the Institute from Utrecht, Holland. Dr. Dolk was a specialist in the study (new to this country) of the plant "growth hormone," a substance which regulates and controls the growth of the stems of plants. He supervised the construction of a laboratory (on the corner of San Pasqual and Michigan Avenues) suitable for the growth of plants under conditions of controlled temperature, humidity, and light, and he began, with K. V. Thimann, an investigation of the chemical nature of the stem growth regulating hormone. Although Doctors Dolk and Thimann contributed significantly to this study, still the isolation and structure determination of "auxin," as the new substance was called, was left to Doctors Kogl and Haagen-Smit, of the University of Utrecht. Doctor Haagen-Smit, parenthetically, is now a member of the staff of the Institute. In the spring of 1932 Doctor Dolk lost his life in an automobile accident, and Dr. F. W. Went, also from the University of Utrecht, was asked to fill his place. Doctor Went earlier had done extensive work on the plant growth hormone, and in fact the first extraction of the active substance from the plant as well as the accurate biological method of assaying for it are due to him. With this assay method it was established, first, that auxin is formed in the uppermost tips of plants, and, second, that the substance travels from the tip downward (in very minute amounts) to the growing regions of the plant. If the auxin producing tip is removed, no auxin reaches the lower portions of the stem and growth accordingly stops.

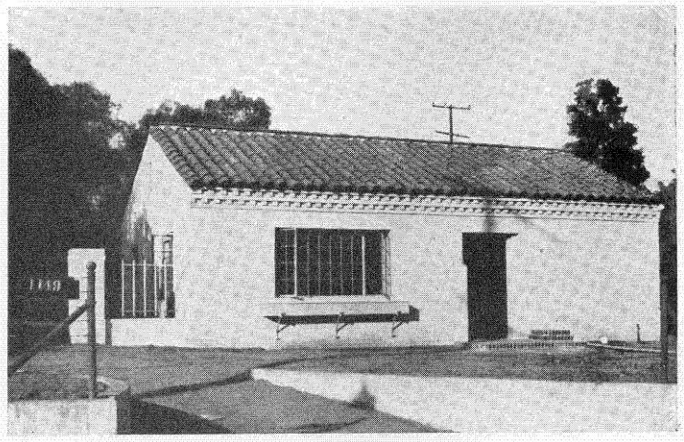
In 1933 Doctor Thimann and his student, Folke Skoog, '32, found that the auxin produced by the tip of the plant is not only essential for the growth of the side (or "auxillary") buds. We all know that in a normal plant most of the side buds do not grow out into branches. This is because the auxin produced by the tip of the normal shoot travels downward and prevents the side shoots from growing out. If we cut off the tip of the shoot, however, new side branches do grow out. If we cut off the tip but supply the cut surface with pure auxin, the pure auxin is able to substitute for the auxin normally made by the tip and the side branches do not grow out. This is, in short, a scientific explanation for the result of pruning. Doctor Thimann, to whom much of the early work in auxin must be credited, left the Institute for Harvard University in 1935.

One of the accomplishments of the plant physiology department, which has been of considerable practical value, has been the elucidation of the chemical nature of the substances which cause the formation of roots on stem cuttings (slips). It was found that indole acetic acid, a relatively simple substance readily obtainable by synthesis, possesses the power of initiating roots on cuttings. Thus if cuttings of lemon (or of many other species of plants) are allowed to soak for a few hours in a dilute solution of indole acetic acid, many roots are formed on the treated portions within a few days. This finding has been of immense practical value to nurseries, which frequently must propagate plants by cuttings.

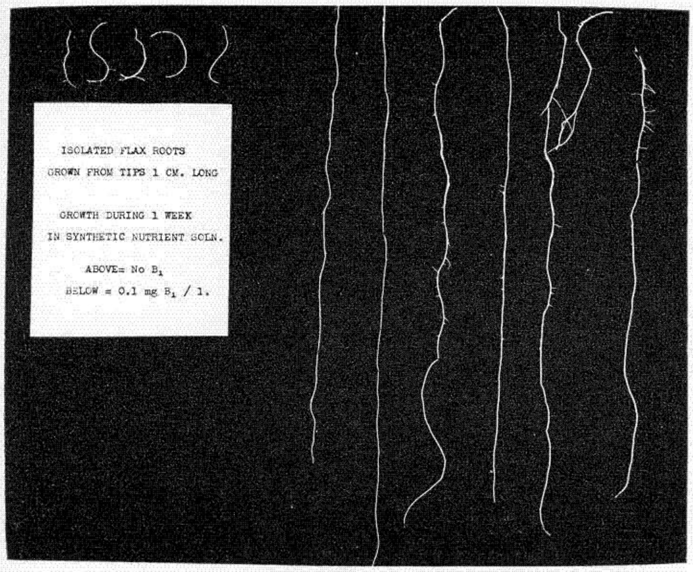
Dr. J. van Overbeek, of the University of Utrecht, joined the department in 1934. One of his many investigations on auxin has been a study of why dwarf plants are dwarfed. He has worked primarily with a pygmy race of corn, a race whose dwarf stature is inherited and is determined by a single genetic factor. Doctor van Overbeek found that although the dwarf plants manufacture plenty of auxin or "growth hormone," still they differ from normal plants in that they oxidize the substance rapidly. Since oxidized auxin does not promote growth, the plants remain dwarf. The genetic factor for dwarfing in this case is a genetic factor for production of an enzyme which speeds up the oxidation of auxin.

VITAMIN B_1

In 1935 a program was initiated for finding still other hormones involved in the regulation of different phases of plant growth. As a result of this work it was found that vitamin B_1 is an essential factor in the growth of roots. In the normal plant vitamin B_1 is synthesized in the green leaves and is then



THE PLANT PHYSIOLOGY LABORATORY



transported downward to the roots, where it is used in root growth. Hence in the experimental work use was made of "isolated roots," that is roots severed from the top of the plant and grown under bacteria free conditions in nutrient solution containing the necessary inorganic salts, sugar (which is supplied to the roots by the leaves in the normal plant), and vitamin B_1. If the vitamin B_1 is omitted, such isolated roots do not grow. If it is present in amounts as little as 0.001 mg. per liter, growth of the roots may continue at a rate almost as great as that found on the normal plant. Other growth substances for roots have been found by using this same technique. Thus some kinds of roots need only vitamin B_1 as an added growth substances, other kinds of roots need vitamin B_1 and nicotinic acid, and still other kinds need vitamin B_1, nicotinic acid, and vitamin B_6.

Although the leaves of many kinds of plants make all of the vitamin B_1 which the plants need, still there are some species in which the leaves do not make as much of the vitamin as the roots can utilize, and it has been found that root growth of these kinds of plants can be speeded up by feeding the plants vitamin B_1. Since increased root growth generally brings about increased top growth, the application of vitamin B_1 has caused an increase in general growth over the growth of untreated control plants with certain species under experimental conditions. This finding has unfortunately been subjected to greatly exaggerated publicity with the result that vitamin B_1 is now offered for sale as a plant "stimulant" even though there is as yet no experimental evidence that applications of the vitamin have value under practical conditions. It is, however, well established that vitamin B_1 applications (and in some cases application of nicotinic acid and vitamin B_6 as well) bring about increased growth of roots on cuttings, particularly when the cuttings have first been treated with indole acetic acid for the formation of embryonic roots. It seems probable that vitamin B_1 will find a definite place in agricultural and horticultural practice.

WOUND HORMONES

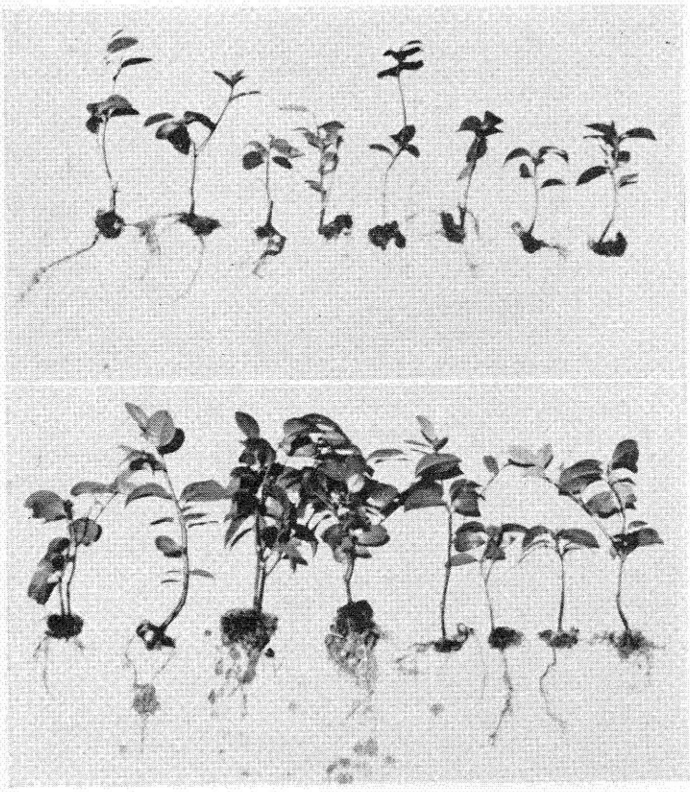
Another group of plant growth substances which has been studied at the Institute is the group of the "wound hormones" which, as has been known for 25 years, are liberated by wounded plant cells and which promote healing of the wound. The isolation and synthesis of a plant wound hormone was first accomplished at the Institute by Dr. James English, Jr., of the Chemistry division, in close collaboration with the plant physiology group. This substance has been called "traumatic acid" but its isolation is so recent it has not been possible as yet to find out whether or not it will have practical applications.

Dr. A. J. Haagen-Smit, organic chemist of the University of Utrecht, joined the staff of the Institute in 1937, and the isolation and identification of further plant hormones are being prosecuted under his direction and in collaboration with the plant physiology group. The investigation of the special growth substances which regulate the growth of leaves has been particularly successful. It is known that mature leaves make substances that are required for the growth of the younger leaves. It seems probable that adenine (a purine related to uric acid) is one of these factors and that adenine is to be regarded as just as much a "leaf growth hormone" as vitamin B_1 is a "root growth hormone."

The gift of a new greenhouse in 1939 now permits a much more exact investigation than heretofore of the effect of external factors on plant growth. In this air conditioned greenhouse it is possible to maintain in four separate rooms different combinations of temperature, humidity and light intensity or quality. It is hence possible to study the interaction of these different environmental factors as they influence plants. It has already been possible to demonstrate the very considerable effect which high atmospheric humidity exerts in promoting plant growth.

It may seem from the preceding that work in plant physiology at the Institute has centered on subjects capable of immediate practical application. It is indeed true that practical uses have

Primula malacoides with and without Vitamin B_1 after 6 weeks.



Camellias grown in sand without and with Vitamin B_1.

been found for the discoveries which have been made concerning the plant growth hormones. It also is true, however, that investigation of the more theoretical aspects of this subject has been prosecuted. Thus an answer to the question of how auxin promotes growth has been sought since 1932. With the cooperation of Dr. J. Koepfli, of the Chemistry Division, the exact atomic configuration essential to growth activity in the auxin molecule has been determined. Studies of the movement of auxin within the plant have been made particularly by W. G. Clark. The atomic configuration essential for vitamin B_1 activity has been determined in collaboration with Dr. E. R. Buchman, of the Chemistry Division, and the relation of vitamin B_1 to enzymatic activity in the plant has been elucidated. In fact the practical uses for plant hormones are a by-product of the more theoretical studies.

Another activity of the plant physiology group has been the training of students capable of carrying on independent growth hormone research and of spreading the growth hormone lore to other institutions. Much of the work mentioned above is associated with one or another of the students who have obtained the Ph.D. degree in plant physiology at the Institute.

I hope that I have made it clear that plant physiology as it is understood at the Institute is the study of the plant with the object of determining the chemical substances or processes related to each individual plant activity. This "chemical plant physiology" requires the cooperation of chemists, physiologists and hybrid chemical physiologists, and such cooperation is abundantly realized at the Institute. Despite the considerable progress made during the past ten years, there is no danger of an immediate scarcity of new problems, for it is now clear that there are hormones for the regulation of the different phases of plant growth from the germination of the seed to the falling of the fruit.

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The Author—James F. Bonner did his undergraduate work at the University of Utah. He came to the California Institute in 1931 as the first graduate student in plant physiology. He obtained his Doctor's degree in 1934 and then spent a year in Holland and Zurich as a National Research Council Fellow. Since 1935 he has been at the Institute as, successively, Research Assistant, Instructor, and, now, Assistant Professor of Plant Physiology. The work on vitamins and wound hormone mentioned in the article has been done by him in conjunction with the various people mentioned.

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Alumni You Should Know

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The first little four-passenger Fairchild plane lifted its rubber feet from the sand of a racetrack in Lima, Peru, on September 13, 1928. The little ship buzzed its way from Lima to Talara inaugurating the first scheduled air service on the South American west coast. Harris was general manager of the line as well as chief pilot.

For the most part of the succeeding ten years Harris has lived in Lima, Peru, directing the extension of "Panagra" up and down the west coast until now it extends from the Panama Canal to Valparaiso, Chile, and then makes a spectacular hop over the high Andes to Buenos Aires on the east coast, connecting with other parts of the Pan American system at both ends.

Recently Harris has moved to the New York headquarters of the system where, when not away on a flying trip over the far-flung lines of the System he occupies the lofty office with the little white map on the wall as Executive Vice-President of Pan American-Grace. Besides the little white map, among the prominent furnishings of his office is a History of Latin America, a globe and a map of the commercial air lines of the world, perhaps evidence of plans for further conquest.

— Chester F. Carlson, '30.

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