# World Soil and Fertilizer Resources in Relation to Food Needs

**Robert M. Salter,** *Chief,*
*Bureau of Plant Industry, Soils, and Agricultural Engineering,*
*U. S. Department of Agriculture, Beltsville, Maryland*

HUNGER AND STARVATION HAVE stalked the footsteps of man since the dawn of history. Only with the bloom of modern science in the last half century has there for the first time come hope that these gaunt specters could be banished if man but willed it so. Through the centuries those in positions of leadership have been prone to accept the misery of hunger as an unavoidable fact of life, the result of population pressure on a limited food supply.

In the midst of the most destructive war in history the leaders of the Allied Nations determined that one of the goals of victory should be *freedom from want.* To some, science appears to offer a basis of fact for this ideal. Here in our own country, farmers applied the results of agricultural research so efficiently during the war years that, despite many difficulties, production of food crops reached and held an unprecedented peak. It seems reasonable that, with the peace, benefits of agricultural research may be extended still further and that all the people of the world may be better fed.

The high ideals that came with the fervor of the war are now being evaluated coolly in the light of peacetime realities. The peoples of the warring nations are determined to be practical. With skeptical minds they are asking: Is it, after all, reasonable to hope that the world can produce enough to feed all its human inhabitants? Can the world's soil grow all the crops that would be needed? Are fertilizer sources great enough? Do we have the technology and management ability to produce the crops and maintain the soils? These questions do not encompass the whole problem by any means, but these are questions I am being asked. I am glad to try to answer them, for I am convinced that we do have the soils we need, we do have the fertilizer resources, we have available the management ability, and we could produce enough food for all.

But how much is enough? We have an answer suitable for our purpose from the recent "World Food Survey" made by the Food and Agriculture Organization of the United Nations. By 1960, if everyone is to have an adequate diet, the world will need, according to the estimates of this survey, the following increases beyond prewar production: cereals, 21 per cent; roots and tubers, 27; sugar, 12; fats and oils, 34; pulses and nuts, 80; fruits and vegetables, 163; meat, 46; and milk, 100.

**The information contained in this paper was presented as a part of a panel before Section O (Agriculture) at the annual meeting of the AAAS, Boston, December 30, 1946.**

Considering only the natural physical resources needed to obtain these increases in food production, and with acute awareness of many other problems involved, there are two obvious courses we can follow in seeking higher food production the world over. First, and perhaps as the easier course, we could obtain much of the increase through more intensive and more efficient use of the land now farmed. Second, with our knowledge of world soil types, we could expand production in the areas having undeveloped soil resources.

Some of the possibilities of intensive and efficient production are readily evident in our own war experiences. Production of food crops was maintained at about 35 per cent above the period 1935–39. Admittedly, weather was more favorable than during the prewar years, but even with no more favorable weather the production would have been 20 per cent greater, despite the fact that the labor force was actually 6 per cent smaller.

Our experiment stations and our more successful farmers provide many illustrations of the opportunity for increasing food crop yields and animal production by applying these improved agricultural techniques more widely. Thus, the limiting factors to increased production seem to be lack of education and lack of capital rather than any limits of physical production capacity. For example, recent experiments on corn culture in the Southeast under ordinary farm conditions show that corn yields for that area can be more than doubled by a combination of improved practices. In addition to regular fertilization practices, these include heavy nitrogen treatment combined with the growing of adapted hybrids, closer spacing to take advantage of heavier fertilization, and early and shallow cultivation for weed control. By 1960 perhaps, 50-bushel-per-acre corn production in the Southeast will be the rule rather than, as today, the exception.

This and many other examples would indicate also that the estimates of production possibilities after the war, under prosperity conditions, made cooperatively by the U. S. Department of Agriculture and the landgrant colleges, are really conservative, though they may appear somewhat optimistic. According to these estimates, by 1950 appreciable increases in production per acre of most of our principal crops over that obtained in the 1935–39 period can be readily attained. The estimated increases were as follows: corn, 31 per cent; hay, 28; wheat, 18; rice, 13; peanuts, 20; sugar beets 17; potatoes, 22; and sweet potatoes, 31.

TABLE 1

ESTIMATED ATTAINABLE INCREASE IN YIELD DUE TO IMPROVED PRACTICES

| Crop | | Yield 1935–39 | Yield 1960 |
|---|---|---|---|
| *USSR* | | | |
| Wheat | bushels | 10.0 | 12.0 |
| Rye | " | 12.7 | 13.5 |
| Corn | " | 16.3 | 20.0 |
| Oats | " | 22.2 | 28.0 |
| Barley | " | 14.9 | 18.0 |
| Sugar beets | tons | 6.1 | 8.0 |
| Potatoes | bushels | 121.5 | 180.0 |
| *India* | | | |
| Wheat | bushels | 10.7 | 20.0 |
| Rice | " | 26.2 | 40.0 |
| Corn | " | 12.9 | 20.0 |
| Barley | " | 16.5 | 20.0 |
| Peanuts | pounds | 400.0 | 600.0 |
| *China* | | | |
| Wheat | bushels | 14.9 | 18.0 |
| Rice | " | 52.5 | 70.0 |
| Corn | " | 24.2 | 35.0 |
| Barley | " | 21.8 | 24.0 |
| Peanuts | pounds | 769.0 | 1,000.0 |
| Soybeans | bushels | 16.8 | 20.0 |
| Dry beans | pounds | 730.0 | 1,000.0 |
| Potatoes | bushels | 100.0 | 150.0 |
| *United States* | | | |
| Corn | bushels | 28.1 | 36.7 |
| Oats | " | 31.7 | 38.5 |
| Hay | tons | 1.4 | 1.8 |
| Potatoes | bushels | 124.0 | 152.0 |
| Soybeans | " | 18.5 | 21.9 |
| Peanuts | pounds | 765.0 | 916.0 |
| Wheat | bushels | 12.4 | 14.6 |
| Rice | " | 47.5 | 53.6 |

The United States, which alone cannot feed the hungry of the world, must look to other countries also to intensify food production, preferably in the food-deficient areas. Prior to the war, Europe, with the exception of Poland, Russia, and the Balkans, had reached a high degree of intensified farming in relation to its soil resources. Significant increases in the more highly developed European countries are thus doubtful. If, however, we take into account yield increases readily attainable in different soil regions of the United States, we can safely predict those in other countries possessing the same great soil groups. Such predictions for China, India, and the Soviet Union, the world's three most populous countries, are given in Table 1. These take into account the present reported average yields and the general intensity of present cropping practices, in so far as they are known. Yield increases considered attainable in these countries by 1960 are substantially equivalent to those considered attainable in the United States by 1950, as reported in *Peace-time adjustments in farming*, (U. S. Department of Agriculture, Miscellaneous Publ. No. 593).

It is impossible with the data available to make predictions on possible production in increases by individual crops the world over, because acreage, yield, and production of many important crops are not reported by all countries. Also, much of the world's food supply comes from animal products, and the efficiency of this production in different countries is not known. But we can estimate probable increases in world production of the principal 8 classes of food, by applying to each class the percentage increases of about the same magnitude as those thought attainable by 1950 for the principal crops in the United States. Table 2 is an estimation of the world food supply possible in 1960 as a result of more intensive and better farming methods on present cropland compared with the supply needed in 1960 to give all the people of the world an adequate diet, as estimated in the FAO survey.

TABLE 2

PREWAR FOOD PRODUCTION AND PERCENTAGE INCREASES ATTAINABLE FROM MORE INTENSIVE USE OF PRESENT CROPLAND*

| | Cereals | Roots and tubers† | Sugar | Fats and oils | Pulses and nuts | Fruits and vegetables‡ | Meat | Milk |
|---|---|---|---|---|---|---|---|---|
| Prewar production (millions of metric tons) | 300.4 | 153.2 | 30.0 | 15.2 | 36.2 | 156.3 | 65.6 | 150.2 |
| Increase attainable from present cropland (%) | 20 | 50 | 15 | 20 | 20 | 35 | 20 | 20 |
| Attainable production from present cropland (millions of tons) | 360.0 | 230.0 | 34.5 | 18.0 | 43.4 | 211.0 | 78.7 | 180.2 |
| World food needs in 1960 (millions of tons) | 363.5 | 194.5 | 33.6 | 20.4 | 65.2 | 411.0 | 95.8 | 300.0 |

* For 70 countries including 90 per cent of world population.
† Including bananas.
‡ Including eggs and fish.

In arriving at these estimates it is necessary to assume that the total prewar world food supply equaled prewar food consumption. The figures for prewar world food supplies were therefore obtained by multiplying per capita consumption, as reported in the FAO survey, by world population. Larger percentage increases were applied to roots and tubers and to fruits and vegetables because of the apparent opportunity for greatly increasing yields of these crops by the generous use of fertilizers.

On the basis of these estimates, world food needs in 1960 could be met for sugar and for roots and tubers on existing cropland, the need for cereals could virtually be met, but production of all other classes of food would fall short of the need.

It should be borne in mind, however, that the increases assumed to be attainable on existing cropland are conservative. There seems little doubt that a general use of high rates of fertilization on soils that will respond, coupled with modern techniques of insect and disease control, a change in land use patterns, selection of the best varieties, flood and erosion control, and adoption of other lesser techniques, would result in even larger increases.

There are even greater opportunities, but more difficulties perhaps, in increasing food production by bringing new lands into cultivation. At present only 7–10 per cent of the total world land area is cultivated. Except for some desert areas, perpetual snow and ice, tundra, and the most rugged mountains, there is virtually no limit to the acreage that can be brought into cultivation, save the economic limits of costs and returns. When we consider the great soil groups of the world and the relatively small extent to which some of them are already in cultivation, these possibilities become more apparent.

Soil maps have been made of many parts of the world. During the past few years our Bureau has made serious attempts to assemble these into a series of maps of uniform nomenclature, so that various regions can be compared, and to fill in unmapped areas through careful study of climatic, geological, and other relevant data. Although this research is uncompleted, it has given soil scientists an opportunity to arrive at a few general preliminary judgments about our soil resources. A very small-scale, exceedingly generalized map of the world compiled some time ago may be useful to indicate the location of the food soil area of the world (Fig. 1).

Snow and ice, tundra, mountains, and deserts total 48 per cent of the world land areas. We can assume that these areas have no practical possibilities for extension of agriculture. The chernozem, chestnut, gray forest, podzol (including gray-brown podzolic), the red soils of the tropics and subtropics, and alluvial soils occupy an estimated 52 per cent. In this 52 per cent we can look for areas for expansion of agriculture. The chernozem and chestnut soils are now largely under cultivation, and no great expansion into new areas can be foreseen. Some reclamation of alluvial soils, either by drainage or irrigation, or both, should be possible in the tropics.

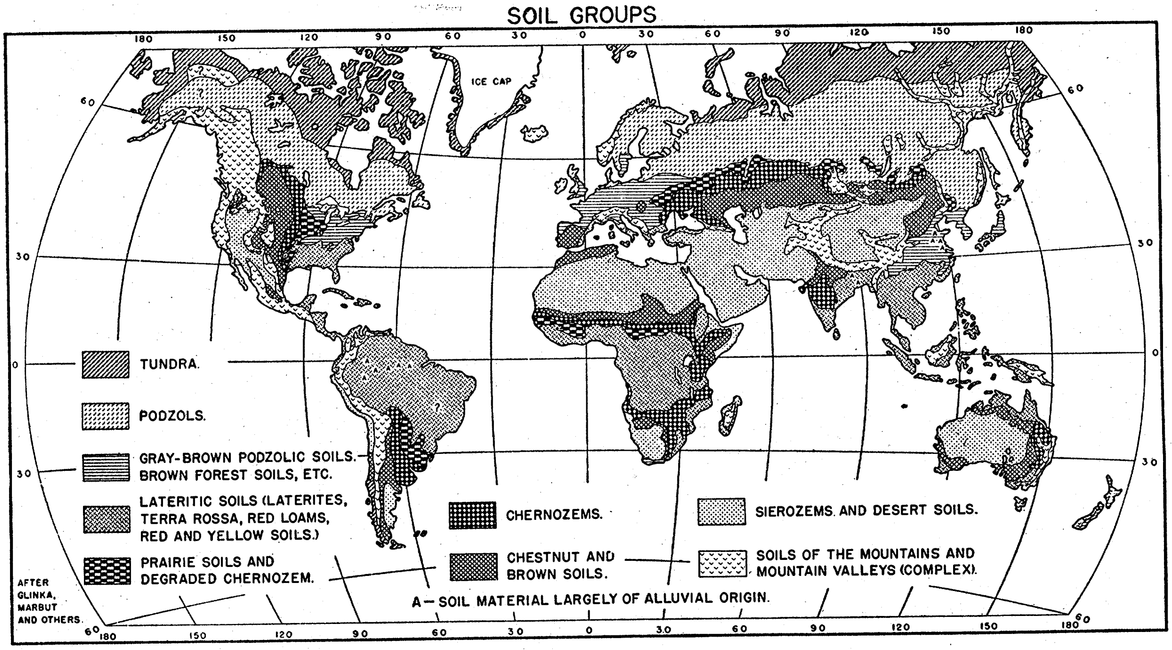


FIG. 1. Schematic map of important soil groups.

Prassolov (*Pedology*, 1946, No. 2) estimates the areas of the world in 10 broad classes of soils, as follows:

| | Per cent |
|---|---|
| Chernozems<br>Chernozem soils of prairies<br>Black soils of tropical regions | 6 |
| Chestnut soils of dry steppes, (including Solonetz) | 7 |
| Gray forest<br>Brown forest<br>Slightly leached soils of dry forests | 7 |
| Alluvial soils, marshes, and swamps of tropical regions | 4 |
| Podzols (including bogs) | 9 |
| Red soils of subtropics<br>Reddish-brown soils of tropical savannas<br>Red soils of tropical forests<br>Lateritic soils | 19 |
| Sierozems and other soils of desert steppes and oases (including Solonchaks)<br>Sands and stony soils of the deserts | 17 |
| Mountain tundra<br>Mountain meadows<br>Mountain-forest podzols<br>Mountain-forest brown soils<br>Mountain-forest red soils<br>Soils of mountain steppes<br>High mountain deserts | 16 |
| Tundra | 4 |
| Everlasting snow and ice | 11 |

The podzols of the North Temperate Zone and the red soils of the tropics and subtropics constitute the extensive soils onto which great expansion of food production might be possible. Although these occupy an estimated 28 per cent of the world land area, probably less than 1 per cent is now under cultivation. It is recognized, of course, that a large proportion of these soils are unsuitable for agriculture because of the unfavorable topography and stoniness.

The principal areas of red soils are in Africa, South America, southeastern Asia, including India, the Pacific Islands, and southeastern North America. Most areas of red soils are now in use in southeastern Asia and India, and large areas are in use in some of the Pacific Islands and in the United States; but their resources are almost untouched in Africa and South America. If we assume that only 20 per cent of the red soils of the tropics in South America and Africa alone were to be brought into production, about 900,000,000 acres would be added for food production. To these potential cultivated new areas of red soils may be added a large area of uncultivated tropical soils found on the great islands of Sumatra, Borneo, New Guinea, and Madagascar. Assuming, then, that at least another 100,000,000 acres of red tropical and alluvial soils are available in these and other warm parts of the world, the total of 1,000,000,000 acres of tropical and subtropical soils may be used in calculating world soil potentialities.

The podzols, located almost wholly in the northern part of the Northern Hemisphere, are found mostly in Soviet Russia, Canada, and the United States. If we were to assume that only 10 per cent of these soils were brought into cultivation, another 300,000,000 acres would be added to the world acreage for food production.

The world's uncultivated areas are, of course, generally less fertile than those already under cultivation. To maintain continued productivity, these would need fairly-heavy fertilization. The question of serious erosion, especially in the tropical areas, must be met if there is to be expansion in this direction. In the last two decades, however, a body of science dealing with erosion control has been developed, which gives us confidence that the problem can be met adequately. We can develop; we need not exploit.

If this huge body of 1,300,000,000 acres of new land were brought into production, what would be the world food picture? Here again, we must estimate by making comparisons with production figures from similar areas. For estimating the possible production of the 1,000,000,000 acres of tropical land, we have chosen the Philippines as a yardstick because it is one of the few tropical countries that can be considered fairly representative of the tropical soil region and that had even approximately complete food-production records. Finland was chosen similarly as representative of the 300,000,000 acres available in the podzol group. By applying the approximate production per acre of the principal classes of food obtained in the Philippines to the above acreage of tropical soils and that obtained in Finland to the acreage of podzol soils, we arrive at the data presented in Table 3.

World food needs in 1960 could thus be met for all classes of food except meat, milk, and pulses and nuts, by production increases on present cropland acreage plus the production of 1,000,000,000 acres of tropical soils, if these soils were used as intensively and for the same classes of food products as are the cultivated soils of the Philippines. We could have more than enough cereals, roots and tubers, sugar, fats and oils, and fruits and vegetables. In addition, the need for pulses and nuts could be easily met or exceeded by shifting some of the production of coconuts from oil to edible nuts.

If production of 300,000,000 acres of North Temperate Zone soils were added to the increase from the present cropland and used as intensively and for the same classes of food products as are the cultivated soils of Finland, the world food needs in 1960 would be met for cereals, roots and tubers, sugar, and milk, and, in addition, the need for fats and oils would be very nearly met.

World production from all our three sources combined —present world cropland, 1,000,000,000 acres of new tropical, and 300,000,000 acres of extratropical soils—would exceed world food needs for all classes of food except pulses and nuts, under the assumption used, and would exceed them for all classes if part of the production of coconuts were shifted from coconut oil to edible nuts. Production of cereals, roots and tubers, sugar, and fats and oils would be far in excess of what is needed.

TABLE 3

POTENTIAL FOOD PRODUCTION IN MILLIONS OF METRIC TONS FROM MORE INTENSIVE USE OF EXISTING CROPLAND PLUS DEVELOPMENT OF ADDITIONAL LAND NOT NOW CULTIVATED

| | Cereals | Roots and tubers | Sugar | Fats and oils | Pulses and nuts | Fruits and vegetables | Meat | Milk |
|---|---|---|---|---|---|---|---|---|
| Attainable production from present cropland.... | 360.0 | 230.0 | 34.5 | 18.0 | 43.4 | 211.0 | 78.7 | 180.2 |
| Attainable production from present cropland plus 1,000,000,000 new acres tropical soils*...... | 717.5 | 469.5 | 177.5 | 69.5 | 55.4 | 470.0 | 89.4 | 188.8 |
| Attainable production from present cropland plus 300,000,000 new acres land outside tropics†.................. | 395.5 | 296.0 | 35.1 | 19.4 | 44.2 | 211.0 | 86.1 | 314.6 |
| Attainable production from all above sources.... | 753.0 | 535.5 | 178.1 | 70.9 | 56.2 | 470.0 | 96.8 | 323.2 |
| World food needs in 1960.... | 363.5 | 194.5 | 33.6 | 20.4 | 65.2 | 411.0 | 95.8 | 300.0 |

* Obtained by applying approximate average production per crop acre in the Philippine Islands to 1,000,000,000 acres.

† Obtained by applying approximate average production per crop acre in Finland to 300,000,000 acres of Northern Hemisphere soils. Fats and oils and fruits and vegetables are *underestimated* because Finnish production figures on farm-made butter, meat, fruits, and vegetables were unavailable.

To meet world food needs, then, much less than all of these sources of production could be required if efforts were made to produce primarily those classes of foods in deficit.

In discussing potential world food production, either through intensified farming of old land or by developing new areas, there is one overlying factor affecting both. Greatly increased quantities of fertilizer will be required. How adequate are world supplies of fertilizers?

Since nitrogen fertilizer can be manufactured by fixation of nitrogen from the atmosphere, world supplies are limited only by the capacity of plants to produce. This plant capacity was expanded greatly in the last decade because nitrates are a necessity of war.

With phosphate and potash, on the other hand, we must depend on natural deposits to fill world needs. Table 4 compares probable phosphate and potash supplies with potential needs for meeting world food goals. Again it is necessary to make several assumptions. First, we assume that present world cropland would scarcely need a heavier rate of application than is now used in France. It will be noted that the rate of fertilization in France is several times the present world rate. Second, we assume that the additional 1,000,000,000 acres of tropical soils would scarcely need heavier applications than the rate in Hawaii, which is among the highest for all tropical areas. Third, we assume that the 300,000,000 acres of extratropical soils will again need no heavier rate of application than that of France. Thus, in all three areas for comparative purposes we have chosen countries that use fertilizer at a relatively high rate, so that the estimate on world reserves would be conservative.

TABLE 4

FERTILIZER IN RELATION TO EXPANDED FOOD PRODUCTION*

*Rate of fertilizer use in kg./hectare of land used for crops:*

| | $P_2O_5$ | $K_2O$ |
|---|---|---|
| World.................................... | 5.0 | 3.2 |
| United States............................. | 4.9 | 2.6 |
| France.................................... | 17.1 | 12.7 |
| Hawaii.................................... | 41.0 | 80.0 |

*World annual requirement of fertilizer under expanded food production:*

| | $P_2O_5$ (metric tons) | $K_2O$ (metric tons) |
|---|---|---|
| On 1,940,000,000 acres existing cropland at rate of France............................ | 13,425,000 | 9,970,000 |
| On 1,000,000,000 acres (new) tropical soils at rate of Hawaii........................ | 16,400,000 | 32,000,000 |
| On 300,000,000 new acres extratropical soils at rate of France......................... | 2,000,000 | 1,500,000 |
| Total................................ | 31,825,000 | 43,470,000 |
| | $P_2O_5$ (billion metric tons) | $K_2O$ (billion metric tons) |
| Probable world reserves.................. | 66 | 22.5 |
| | (years) | (years) |
| Years supply will last under expanded food production.............................. | 2,000 | 500 |

* Data on fertilizer use from USDA Misc. Publ. 593.

The resulting quantities of fertilizer used under these conditions would be about 8 times the present consumption of phosphate and nearly 18 times the present consumption of potash. Even so, the known world reserves of phosphate would last more than 2,000 years and the known reserves of potash 500 years. The world has not been thoroughly explored for these minerals. Doubtless the actual reserves greatly exceed the known reserves.

There are also many sources of potash other than those included in the probable reserves that may be developed when economical methods of extraction are devised. This latter point again emphasizes how conservative these estimates are, for no allowance was made for technical improvements, which are sure to come in the fertilizer industry.

Here, then, is an affirmative answer to the question: Do we have the natural resources to meet world food goals by 1960? This answer is a challenge to all men, not to scientists only, for it raises immediately an even more critical question: Can we mobilize these resources to produce the needed food? This question begs many answers, because it involves the whole field of human relationships.

Science may discover and point the way, but it cannot dictate. The full measure of success in economic, social, and political action comes only with the will of the majority—not from the desires of one group.

If the people of the world really have the determination to give battle to the problem of hunger, if they are willing to extend a small part of the energy and capital poured into World War II, only then can we see hope of victory.

# Modern Concepts of Inflammation

**Valy Menkin**

*Department of Surgical Research and Agnes Barr Chase Foundation for Surgical Research, Temple University School of Medicine, Philadelphia*

INFLAMMATION IS THE PHYSICAL BASIS OF infectious diseases, although inflammation and infection should not be considered as synonymous terms. Inflammation implies a more inclusive concept. It is a manifestation of severe cellular injury in higher forms. As such, the inflammatory reaction requires the presence of vascular and lymphatic structures as well as tissue cells. The reaction, which is initiated by a disturbance in fluid exchange, manifested primarily by an increase in capillary permeability, tends to be stereopatterned. It can be modified by the nature of the irritant, which, per se, has its specific chemical affinity with the tissues of the host. Furthermore, the topographical location of the injury doubtless alters the ultimate picture of the lesion. Nevertheless, close scrutiny reveals throughout a fundamental pattern which is largely referable to various basic common denominators or biochemical units liberated by injured cells, irrespective of the nature of the stimulating irritant. It therefore behooves us to concentrate on a study of the biochemistry of injured cells.

The initial increased capillary permeability and the early migration of polymorphonuclear cells is primarily caused by a polypeptide to which there may be attached a prosthetic group. This substance, called *leucotaxine*, was identified in exudative material some 10 years ago. It is not possible here to go into the details employed in its isolation and properties. Suffice it to say that leucotaxine has no similarity to histamine and, as such, has no relation to the so-called hypothetical H-substance of the late Sir Thomas Lewis. It evidently is wholly different from hyaluronidase, acetylcholine, or adenine compounds. Cullumbine and Rydon in Great Britain have recently confirmed by a somewhat different procedure of extraction its presence in exudates and also its properties (*Brit. J. exp. Path.*, 1946, **27**, 33).

Leucotaxine fails to alter the number of circulating leucocytes when administered intravenously. It appears as if the state of leucocytosis accompanying a number of inflammatory processes is caused by a wholly different basic factor or common denominator. When exudative material, particularly, though not always, at an alkaline pH, is injected into the blood stream of a normal dog, a rise in the number of circulating leucocytes occurs. This rise may take place in an hour in some animals, whereas in others it may be significant in only three to four hours. Thus, a leucocytosis-promoting factor is liberated by injured cells, which can in turn be recovered from exudates. Neither normal blood serum nor saline can produce any such prompt response as exudative material. The factor abbreviated as the LPF is thermolabile and nondiffusible. It can be extracted in the pseudoglobulin fraction of exudates by fractionation with $(NH_4)_2SO_4$. Recent cataphoretic studies in collaboration with Dr. Gerald Cooper and Mr. Dillon, of the Duke University School of Medicine, suggest its association with the $\alpha^1$ and $\alpha^2$ globulins of exudates. In as yet unpublished studies by the writer, it has been found that by aging the LPF the material seems to denaturate spontaneously, and then it becomes insoluble. The active principle, however, splits off from the original protein molecule as a soluble component, which in preliminary tests appears to be polypeptide in nature.

**Alpha Omega Alpha Lecture delivered at the Woman's Medical College of Pennsylvania, Philadelphia, November 8, 1946. Presented also as a seminar before the Department of Biology, Bryn Mawr College, January 8, 1947.**