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Ground Water in North America

The fast-growing demands on this natural resource expose a need to resolve many hydrologic unknowns.

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Most of the fresh water in the habitable parts of the globe is ground water. Although we hear from many sources that our world is shrinking rapidly, it still has about 130 million square kilometers of continental and insular dry land. Beneath this land is a ground-water resource that has been estimated to be in the order of 4 million cubic kilometers within 0.8 kilometer of the land surface (*1*)—and very few water-wells have been drilled beyond that depth. A proportionate share for North America would be 717,000 cubic kilometers, sufficient to cover the continent with a sheet of water 30 meters thick. If the ground water were uniformly distributed geographically, every hectare of land (2.5 acres) would be underlain by 123 million liters of water; and if it were distributed equitably among the continent's 250 million people, each would receive about 2850 million liters (750 million gallons).

But the ground-water resource is not distributed uniformly. Probably less than 10 percent of the rocks of the upper crust are of the types—especially gravel and sand, sandstone, limestone, basalt—that yield water readily to wells. These reservoir-rocks are extensive and thick in some places, lenticular or thin in others, and in some large areas not found at all. Some of the reservoirs are offered more replenishment from rain or from streams than they can accept; others receive negligible inflow. Moreover, an unmeasured but sizable proportion of the available ground water does not meet prevailing high standards of purity. And finally, these natural peculiarities are not the only source of man's difficulties with the ground-water supply. By his use of land and water man may alter the behavior of ground water in unpredictable—or, more properly, unpredicted—ways, with sometimes dismaying and irreversible effects.

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The Hydrologic Equation

The central concept of the science of hydrology is the so-called hydrologic cycle—the circulation of water from the oceans through the atmosphere to the land, and thence by runoff overland or by infiltration and underground movement back to the sea, or alternatively back to the atmosphere by evapotranspiration. The hydrologic equation is a statement of the principle of the conservation of matter as applied to the hydrologic cycle: the total inflow to a receptacle during a given period is equal to the total outflow plus any change in storage within the receptacle during the same period. The receptacle may be a lake or reservoir, an aquifer or ground-water reservoir, or all the water-bearing elements in a river basin. Equations for successive short periods depict the unsteady state induced by climatic fluctuations. The longer the period chosen, the closer the several items approach the steady state of the average climate, until ultimately the changes in storage become infinitesimal and the hydrologic equation expresses the overall balance in nature between inflow and outflow. For numerous aquifers and ground-water reservoirs this natural balance has been documented by quantitative data (*2*).

The dynamic equilibrium of the hydrologic cycle provides the basis of a misconception often observed in popular notions regarding ground-water conservation. Conservation is vaguely interpreted as "wise" use of natural resources, involving maintenance of a sustained yield from those resources that are classed as renewable. Fresh water, since nature replenishes the supply by rain and snow, is regarded as a renewable resource. But as to ground water the hydrologic equation limits the degree of this renewability—essentially to the amount of overflow, or natural discharge, from the ground-water reservoir, plus whatever recharge man can induce artificially. The total volume of water stored underground (and accessible to pumps) is many times larger than this quantity, indeed several times larger than the volume of annual precipitation. It is because much of our ground water is *not* renewable that we have serious problems of "overdevelopment" and depletion of the resource.

To many people the conservation slogan "Hold the raindrop where it falls" represents a cure for all our water problems. The slogan is an apt one for the national soil-and-water conservation program, for it epitomizes the fact that most soils can absorb significant amounts of water from precipitation and retain it for subsequent use by plants; the alternative disposal of that water would be overland runoff. Originally the primary objectives of the national program were increase of available water for plant growth and consequent reduction of runoff and erosion; it was recognized that *total* prevention of runoff was impracticable, and that both erosion and underground water supplies were influenced in numerous and varied ways by geologic conditions (*3*). Unquestionably there are many regions where maximizing infiltration will also increase ground-water storage. But on a nationwide basis the concept is not an appropriate philosophy for the management of the ground-water resource, for the obvious reason that neither the available reservoir space underground nor the natural recharge areas match the rainfall pattern.

The Effects of Wells

In occupancy and use of the land, man has modified the natural ground-water balance in various ways (*4*): inflow may have been increased by construction of reservoirs, canals, or irrigation projects, or decreased by construction of impermeable surfaces in cities, or modified by changes of soil permeability due to agriculture; storage and outflow may have been modified by drainage projects or by artificial or induced cutting or filling. But the most significant, most numerous, and most widespread modifications of the natural ground-water balance have resulted from the use of wells.

A new well necessarily upsets any previous equilibrium, for all water discharged from the well must be balanced by a loss of water somewhere. This loss is always to some extent, and in many cases largely, from storage in the aquifer, as evidenced by the deepening and expansion of the so-called "cone of depression"—the form taken by the water table as it changes in response to the demands of the well. Over time, as stored water is depleted, the cone may spread to a recharge area where, because of the pumping, additional water from rain or stream or pond is induced to enter the aquifer, thus making up at least in part for further discharge by the well. Again, after sufficient time has elapsed for the cone to reach an area of natural discharge—a spring or stream—further discharge by the well will be compensated in part by diminution in that natural discharge.

The common claim that we are "running out of water" is generally supported by evidence of widespread depletion of storage in ground-water reservoirs, evidence based chiefly on declining water levels in wells. From well hydraulics we know that the wells must deplete the accumulated storage in order to set up the conditions necessary for establishing the basin-wide equilibrium that can provide a sustained yield; the process starts with the withdrawals from the first well and continues throughout a period of increasing development and use of wells, and probably longer. Storage depletion will also occur where the withdrawals are in equilibrium with average recharge, whenever the recharge drops below average during droughts. On the other hand, because of the magnitude of accumulated reserves, water can be pumped from wells at aggregate rates far in excess of the capabilities of natural or artificial recharge. Where that happens, there is no possibility of ultimate equilibrium, and water will continue to be withdrawn from storage. To the nondiscriminating these quite different situations are all similar—water levels in wells are dropping—and are all equal cause for apprehension. The basic differences become apparent in hydrologic analyses.

The term "safe yield" is likely to come forth when apprehension is aroused by falling water levels. The term was originally defined by Meinzer (*5*) as the rate at which water can be withdrawn from an aquifer for human use without depleting the supply to such an extent that further withdrawal at that rate is not economically feasible. Obviously, under this definition the safe yield may vary from place to place and from time to time because of such economic factors as the cost of obtaining the water and its value to the economy. With this obeisance to economic considerations, the concept has in it the implication of wise management of a renewable resource for perennial supply. The concept can be applied to a single well pumping under steady-state conditions —as long as no additional wells are drilled to upset the equilibrium. More generally it pertains to ground-water reservoirs in which the aggregate pumping has reached a steady state after inducing all possible recharge and eliminating as much as possible of the natural discharge—in other words, an ultimate condition. Again, we know from well hydraulics that storage depletion is inevitable prior to this steady state; but in many areas an estimate of "safe yield" is demanded in the hope that by limiting the pumpage to that quantity such depletion can be prevented.

Hydraulic theory provides us with general models of the behavior and effects of wells. A brief summary of its development may begin with the work of Henry Darcy, who in 1856 established experimentally the law of the linear relation of the velocity of ground water to the hydraulic gradient. Jules Dupuit in 1863 made the first formal mathematical analysis of the hydraulics of wells, hypothesizing a well in the center of a small circular island of uniform sand in a fresh-water lake. Similar but more general analyses of steady-state conditions by Adolph Thiem in 1870 and Gunther Thiem in 1906 have greater practical application, but still require a formidable list of simplifying assumptions (*6*). For the nonsteady conditions that change with time, the "nonequilibrium formula," developed in 1935 by C. V. Theis, permits quantitative determination of the aquifer characteristics of transmissivity and storage based on tests conducted over a limited period of time; with this knowledge, the behavior and effects of a well can be predicted far into the future. Ideal environments are so rare, however, that numerous additional mathematical analyses have been required in order to trim the general models to fit the special conditions found in nature (*7*). Mathematical analyses have also been made of aquifers that are hydraulically related to a surface stream network, and of other types of ground-water problems (*8*).

The mathematical analysis of an entire aquifier or ground-water basin becomes increasingly difficult with increase in the number of pumping wells and may get out of hand entirely where the natural geohydrologic boundary conditions are complex. Geologic studies of the rocks that constitute the porous natural media within which water can flow or be stored show the complexity in all scales of the framework in which water occurs and moves beneath the land surface —a complexity that greatly limits the applicability of empirical formulas that were developed by practice and of solutions that were developed from theory. Because of this multiplicity of factors electric analog models are potentially a great boon; their uses are discussed later in this article.

Present Stages of Development

In much of North America ground-water development is not far beyond the pioneer stage. There are extensive areas in which no development at all has taken place, either because they are unoccupied or because they are blessed with sufficient surface water for current needs. There are extensive areas in which the degree of development has caused little change in the natural environment, and man can still exploit and make limited use of the ground-water resource, leaving the management of the system to nature. And there are the many stages of increasing development, where the withdrawals of ground water have exceeded in varying degree the natural capabilities for replenishment, giving rise to a variety of problems—as for example, the draining of the productive aquifer near Lubbock, Texas; the intrusion of saline water into fresh aquifers at Baltimore, Maryland, Galveston, Texas, Tampa, Florida, and Long Beach, California; the great pumping lifts in deep wells near Chicago, Illinois; the subsidence of the land surface in Mexico City and in parts of the Central Valley of California. Some problems have developed in regions of abundant water supply, as for example in downtown Portland, Oregon, flanked by the Willamette River and only 8 kilometers from the Columbia; there the ground water is being depleted by pumping for air conditioning (*9*).

Broadly speaking, scientific studies to date have been adapted to the stages of existing resource development. In areas where ground water has not yet been tapped, the scientific efforts are principally toward basic-data collection and topographic and geologic mapping (*10*). In areas of slight demand for ground water, shallow wells meet consumption requirements and also provide the basis for making maps of the water table and for deducing direction of ground-water movement. In areas of greater consumption, deep wells provide geologic sections and a three-dimensional picture of aquifers and open the door to scientific studies of the effects of contrasting permeabilities of rocks and the influences of geologic structure. Turbine pumps, with their capabilities of large and controlled withdrawals, enable us to utilize techniques for quantitative determination of aquifer characteristics. In restricted areas of intensive development involving perhaps thousands of wells, areal or basin-wide analyses are made of storage and movement of water. Critical problems have been subjected to detailed scientific investigation; most of these problems have arisen in the United States, where areas of intensive pumping are larger and more numerous, but some have occurred in other North American countries (*11*).

Prospects for the Future

We have been discussing ground water more or less as if it were separate and distinct from the rest of the hydrologic cycle. Such segregation has been common among hydrologists as well as the general public, and is reflected in legislation, in the division of responsibility among government agencies, in development and regulation. Yet it is clear that this isolation can be maintained only when and where water is being mined from underground storage. Any water pumped from wells under equilibrium conditions is necessarily diverted into the aquifer from somewhere else, perhaps from other aquifers, perhaps from streams or lakes, perhaps from wetlands—ideally, but not necessarily, from places where it was of no use to anyone. There are enough examples of streamflow depletion by ground-water development, and of ground-water pollution from wastes released into surface waters, to attest to the close though variable relation between surface water and ground water.

Man has coped with the complexity of water by trying to compartmentalize it. The partition committed by hydrologists—into ground water, soil water, surface water, for instance—is as nothing compared with that which has been promulgated by the legal profession, which has on occasion borrowed from the criminal code to term some waters "fugitive" and others, a "common enemy." The legal classification of water includes "percolating waters," "defined underground streams," "underflow of surface streams," "water-courses," and "diffuse surface waters"; all these waters are actually interrelated and interdependent, yet in many jurisdictions unrelated water rights rest upon this classification (*12*).

Water habitually does not subscribe to our efforts at compartmentalization according to special interests in irrigation, industrial use, recreational use, municipal use; or to allocations of fields for the chemist, for the geologist, for the sanitary engineer, for the physicist, for this or that government agency, any more than it does to separation into areas bounded by property lines, county lines, state lines, or even some river-basin boundaries. As the areas of heavy demand expand toward each other and the necessity for water management increases, these artificial boundaries and classifications will have to yield more and more to the realities of the hydrologic cycle.

Many of the specific problems that have confronted mankind in the use of ground water have been solved satisfactorily, and some quite admirably, although numerous solutions have been based upon empirical relationships and have given hydrology the cognomen of a "coefficient science." Such problems are merely facets of the basic problem of understanding the natural water systems and how they function, so that quantitative predictions can be made of their response to all changes in the hydrologic environment caused by man or nature. Many of the basic data now collected bear on this problem—particularly the fluctuations of water levels in wells, the discharge of wells and springs, the characteristics of earth materials penetrated by wells—but a true understanding of the flow system requires far more. For practically all natural systems we know very little of the overall framework—the porous media—in which the water occurs and moves. Underground reservoirs are irregular and intricate in form, and their internal hydrologic characteristics are often complex and non-uniform. Direct measurement of these characteristics, by laboratory techniques or geophysical logging techniques, is impracticable for more than a minuscule portion of the total volume of the aquifer. Pumping tests of wells can give data for a more extensive volume, but there is urgent need for additional indirect methods of determining the spatial distribution of permeability in entire flow systems.

To depict the characteristics of an extensive flow system on a scale that the eye can see and the mind contemplate, it is necessary to reduce the natural scale by several orders of magnitude. Because the underground space available to the water is sensibly composed of microscopic parts, much detail is lost in this reduction, but such loss is essential to an overall comprehension of the flow system. Inasmuch as frictional processes dominate the relations of water to the porous media, the systems commonly respond slowly to any change or disturbance, and it may take several decades or centuries for a system to reach a new balance or equilibrium. Thus, an adequate portrayal must utilize not only the three dimensions of space, but also the fourth dimension, time.

To an increasing degree, models for simulating an aquifer system are being designed by utilizing the correspondence between the basic laws and continuity relationships of laminar liquid flow and those of electrical flow (*13*). The analysis of an aquifer system by electric analog permits the inclusion of more known variables than can be processed by other mathematical techniques or by intuition, and permits the analytical result to be expressed directly in familiar and useful numerical terms (Fig. 1). Necessarily, the validity of the model analysis is directly tied to the completeness and accuracy of the data and interpretations collected and furnished by the field hydrologist. At present, any attempted prediction of reservoir response to a proposed management practice is more likely to show up "unknowns" that must be solved or evaluated than to give satisfactory answers from existing data. Nevertheless, electric analogs provide a potentially powerful tool for depicting and analyzing aquifer systems, both as to the quantity and the quality of the water.

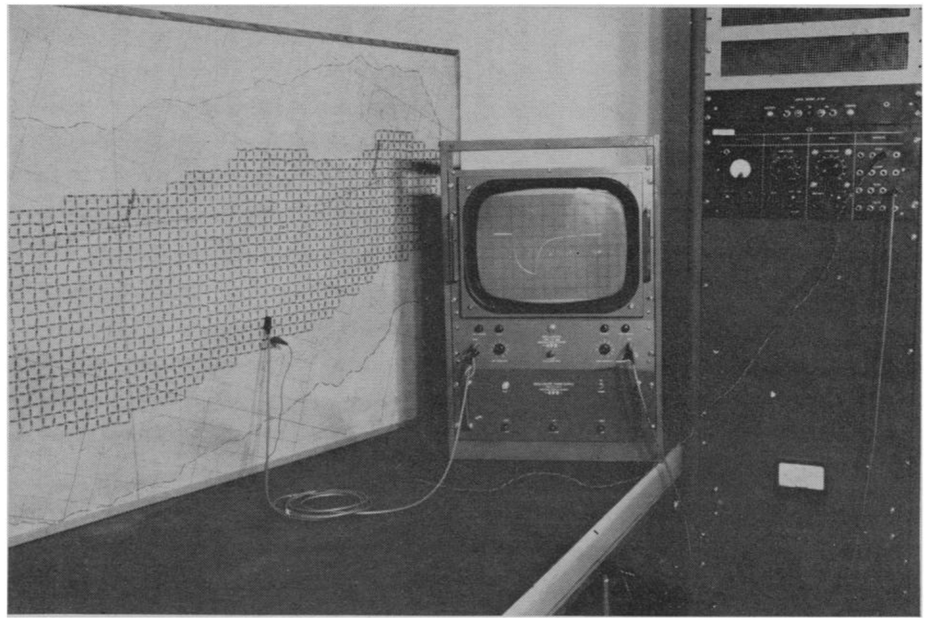

Fig. 1. Analog computer used on a hydrologic problem. A resistance-capacitance network (left) is used to model a ground-water reservoir. A pulse generator (right) simulates pumping from a distant well in which the water level remains constant. The oscilloscope shows the resulting changes in head in the reservoir, in the form of a graph in which water level is plotted against time.

We can expect some change in the traditional concept that the porous media are of value only to the extent that they contain and can yield fresh water. The space itself is being recognized as a valuable resource. In many localities permeable but unsaturated materials are now being utilized for artificial storage of fresh water. Indeed, a basic element in the California Water Plan (*14*) is the cyclic storage of water: recharging underground reservoirs with the surplus surface water of wet periods lasting several years, to be pumped out for use during a subsequent long dry period that is also part of the climatic pattern.

The void space in porous media can also be a valuable resource for storage of fluids other than fresh water. Some underground reservoirs are enclosed tightly enough that they are suitable for economic storage of natural gas. Other reservoir rocks, known to be thoroughly isolated from fresh-water supplies, have been utilized for the brines that accompany the petroleum in oil wells, and we can anticipate progressively greater use of similar reservoirs for the disposal of radioactive wastes, noxious chemicals, and other unwanted byproducts of civilization.

The pore space underground is reduced permanently by pumping water from some confined aquifers, as is evident in the subsidence of the land surface in some regions. As summarized by Poland (*15*):

> Evidence to date shows that the subsidence is chiefly the result of compaction of compressible (clayey) materials in the confined deposits due to decline in artesian head. Compaction of such confined aquifer systems is a complicating factor in estimating ground-water resources. For example, in the central western part of the Central Valley of California, net withdrawal of ground water from 1943 to 1953 was about 4 million acre-feet. The volume of subsidence in the same period was about 2 million acre-feet. Thus, half the withdrawal represents water squeezed out of the aquifer system by compaction, and is available only once. This factor must be considered in estimates of available future supply.

Intensive pumping can be expected to produce subsidence in similar environments elsewhere on the continent.

Artificial recharge will be a prerequisite to effective utilization of underground storage space. As of now, all but a negligible proportion of ground-water replenishment is by natural processes, but we have far fewer quantitative data about ground-water recharge than about ground-water discharge or changes in storage. Partly this is because of our practical interest in the water from wells and springs, partly because we have satisfactory means of measurement of that water. On all aspects of recharge our information is largely qualitative, derived from geologic studies and other inferences. The amount of recharge is commonly the unknown item in the hydrologic equation, subject to calculation by inference from data on discharge and storage changes. We do not understand, measure, or map the vertical component of subsurface flow, which is presumably dominant in recharge, and particularly we lack the means of measuring flow in unsaturated porous media, which occur beneath the land surface in most recharge areas. Here is a major field for basic research, in order to understand how nature does it; also for applied research, to develop the techniques that we must have if we are to improve on the natural pattern of recharge—improvements that must be a part of an effective plan of scientific management of underground reservoirs.

Artificial recharge is closely related to inadvertent recharge that can introduce undesirable elements into the underground storage space. Disposal of soluble wastes upon the land or underground has caused inadvertent recharge and pollution of ground water in many places (*16*), with complications resulting from interactions among the "native" water, the introduced water, and the porous media. In one instance, near Denver, Colorado (*17*), chemical wastes were discharged into holding ponds for 12 years beginning in 1943, and contamination of water pumped for irrigation was first noted in 1951, several miles down gradient from the ponds, By 1961 the shallow ground water was contaminated under an area of 13 square kilometers, and the wastes had served as a mammoth "tracer" to confirm the general direction of flow to the South Platte River. Because of the slow movement of ground water, the effects of underground disposal of wastes may be delayed for years, but damages may persist also for a long time and be very difficult to overcome. Obviously the management of subsurface storage for maintenance of satisfactory water quality requires an understanding of the geochemistry as well as the geophysics of water in relation to the porous media, and this is another major field where research is needed.

Many uses of water depend upon its ability to dissolve, suspend, float, or mix with other materials—in other words, its ability to be polluted. From time immemorial streams have been carrying waste materials from the continent to the oceans, and with the formidable contributions of man many are sometimes so grossly polluted as to make the water unusable and a public nuisance. Biologic and natural organic contaminants are degradable and can be eliminated by adequate treatment. However, our society is also producing inorganic chemicals and synthetics, including waste products of industry, which can be carried by water but which are not degraded by standard treatment and purification processes; these wastes may safely be discharged into a stream only when flow is sufficient for dilution to a harmless concentration. In seeking alternative means of disposal of noxious wastes, the porous media underground may provide an opportunity, if isolated reservoirs can be found, or a hazard, if the waste products are permitted to enter an aquifer whose water is usable. Solution of this problem requires specific knowledge of the porous media at the site where the waste products are disposed of or stored.

In many places of limited supply, the increasing demand for water may induce people to overcome their common prejudice against use of reclaimed water, and their insistence upon "fresh" water for all purposes. Saline and brackish water resources are already receiving increasing attention and appreciation in many places. As an example, Sherwood and Klein (*18*) survey the saline ground water in southern Florida, where some of it is under sufficient artesian pressure to produce flowing wells; the use of brackish water for irrigation, air conditioning and cooling, domestic supplies, and even municipal purposes is increasing. Brackish water may also be used in parts of Everglades National Park during prolonged droughts to sustain the ecology and to control fires. Highly saline aquifers are being utilized for disposal of waste water, and in coastal Miami it may prove feasible to inject artesian water into a shallower fresh aquifer to repel the encroaching sea water.

In most places the chief problem in scientific reservoir management will be to adapt the present cultural pattern to it. It would be far easier to attempt scientific management within the framework of the existing cultural pattern, but in many places this would place limitations so severe as to inhibit any significant modification of the existing pattern of water-supply development. The existing pattern has resulted chiefly from private initiative, and in most localities can best be described as haphazard. Efficient reservoir management would require that withdrawals be from wells so spaced in location, depth, and times and rates of pumping as to take maximum advantage of the storage and flow characteristics of the reservoir under given conditions of replenishment. Thus the spacing pattern should reflect the objectives of withdrawal in each part of the reservoir, whether to salvage water from natural discharge, withdraw the most readily replenishable water, induce additional recharge, or deplete the storage. The hydrologic problems of such reservoir management of course go beyond the ground-water reservoir boundaries, to embrace the waters that can be used for recharge and the effects of diverting the water that would be discharged naturally from the aquifer.

Clearly such management will be achieved only by some regimentation and loss of individual prerogatives. These prerogatives, specified or implied in water rights, vary from place to place and even among individuals in a single locality, but have in common that they are recognized as property rights of which an individual may not be deprived without due process of law. A major attribute of a water right is security in the use of water. There is little concern over water rights when the supply exceeds the needs of all potential users. Judging by the attitude of most urbanites who are served by efficient municipal water systems, people do not have an instinctive interest in water rights as such and are quite willing to delegate their worries to the waterworks, if they have assurance of water when and where they want it. It can safely be predicted, however, that if the increasing use of water continues without a concurrent program that will give to the users assurance of a perennial supply, water rights will become a dominant concern.

A Conclusion

Ground water, or more broadly all the water beneath the land surface, is distinctive in hydrology because of the porous media in which it occurs, and because of the influence of these media upon the flow and storage of the water and upon the chemical constituents in it. Primarily because we know so little about the porous media, we know far less about the water underground than in other phases of the hydrologic cycle. The hydrology of water underground depends heavily upon the earth sciences: geology, geochemistry, geophysics, geomorphology, geohydrology. For effective management of the ground-water resource as an integral part of the total water resources, additional research in all these fields is essential. Some specific fields of research have been suggested in this paper—natural and artificial recharge, the flow of water through unsaturated media, the mechanics of aquifers, hydrogeochemistry. But all these suggested researches should be considered as particular aspects or supporting activities of the overall objective of defining numerically the hydrologic system, and then analyzing regional flow patterns and superimposed chemical systems.

The kaleidoscopic variety of environments in which ground water occurs (*19*), and of modifications made by man, provide magnificent opportunities for any research that results in additional basic data and interpretative achievements. Thus random research, widely dispersed, can add to our total fund of knowledge; but like reproduction by division, its products may be new individuals, in new places, but remarkably similar to what we already have. The interrelation of "unknowns" points to a need for central direction and coordination of all these research efforts. Like water itself, our major water problems tend to resist partitioning, and without coordination of effort they may well remain unsolved.

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Biosynthesis of Unsaturated Fatty Acids in Microorganisms

Structures and biosynthetic pathways are compared and related to physiological properties of the organisms.

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The role that lipids play either as structural components of the cell or in metabolic processes is largely a matter of conjecture. That triglycerides serve as mobile carbon reserves is undisputed, but no definite functions can as yet be assigned to the numerous phospholipids, glycolipids, sphingolipids, cerebrosides, and their structural variants. There is essentially no information on the metabolic consequences arising from structural modifications of a given lipid molecule—for example, when the nitrogenous base of a glycerophosphatide is replaced by another nitrogenous base, by an amino acid, or by a nitrogen-free polyol. Similarly, it is recognized that the length and the degree of unsaturation of a fatty acid residue in ester linkage profoundly affects the properties of lipid molecules, but what these effects are in terms of biological function is only poorly understood. It is evident, at any rate, that the basic structures of the lipids are extremely flexible and allow for a wide variety of modifications. The composition of a lipid molecule in all its details is probably determined not only genetically but also by environment. Thus it is known that nutrition, temperature, and the gaseous atmosphere, as well as other external factors, can modify the lipid pattern of organisms. It is perhaps this flexibility and the ready adjustment of lipid structures to a changing external environment that promises to provide some deeper insight into the structure-function relationships of the lipids.

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As we have pointed out elsewhere (*1*), comparative studies are especially useful for assessing the significance of structural modifications in relation to function. There are marked differences in structure and composition between the lipids of various species, between tissues of the same organism, and also between the cytoplasmic constituents of a given cell. By examining a wide variety of cell types and by making the selection on the basis of distinctive morphological and physiological characteristics, one may hope to detect some systematic pattern in the bewildering diversity of lipid structures.

In order to illustrate the potentialities of the comparative approach, we present in this article some of our results on pathways of biosynthesis of mono-unsaturated and polyunsaturated fatty acids in various groups of microorganisms. Secondly, as an example of environmental effects, we discuss polyunsaturated-fatty-acid patterns in a number of photosynthetic organisms and the relation of these patterns to phototrophic and heterotrophic forms of metabolism.

Biosynthesis and Distribution of Mono-unsaturated Fatty Acids

Most cell constituents arise by a single pathway of synthesis, and the chemical reactions of this pathway are ordinarily the same in all biological systems. However, as has recently been pointed out, there are several exceptions to this principle of biochemical unity (*1*).