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## CONSERVATION AND SCIENTIFIC FORECAST[1]


By ROBERT CUSHMAN MURPHY

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### I

THERE is no denying that it is pleasant to escape now and then from the intimate company of day-by-day colleagues who know one altogether too well, and to fall among such charitable Samaritans as comprise the council, the staff and the membership of your society. On this memorable occasion, I attribute my good fortune entirely to the fact that geographers are the most hospitable of learned men. Some branches of science are, by comparison, highly exclusive and esoteric. To be admitted to the fold a candidate must go through a traditional initiation, and must thereafter hew closely to the line. Not so with geography. If an anthropologist turns his attention to population problems; if a botanist considers the broader aspects of landscape; if an ornithologist endeavors to evaluate factors controlling distribution of life in the sea—it seems that he may have the unexpected reward of being clapped on the back and greeted with the hearty cry, "Man, you're a geographer!" And, to emphasize the welcome, they sometimes give him a gold medal.

I wish that you might all see and feel this beautiful Cullum Medal. It is clear that the designer intended it eventually to go to a student of sea birds, because the obverse shows the figure of a starry-eyed sailor youth, half-clad in ethereal vestments, that would never be approved by any skipper of my acquaintance, standing in the bow of what might be a whaleboat and attempting to put salt on the tail of a gull that is flitting just out of reach. It goes without saying that the medal becomes one of my first treasures. It takes

[1] Address in response to the award of the Cullum Geographical Medal at a meeting of the American Geographical Society, New York, December 20, 1940.

a place among the Penates of the family and, if my two grandsons insist upon rolling it, I'll see that they do so only indoors and on the softest rugs.

I can not help being filled with awe when I contemplate the names of the great souls, thirty-four men and two women, who have received earlier impressions of this medal. They include my boyhood heroes, Fridtjof Nansen and Sir John Murray, as well as others such as Scott, Osborn, the Prince of Monaco and Schokalsky, at whose feet I sat during later years. It would be all too easy to believe that the Cullum Geographical Medal of itself conveys to the recipient a sort of superhuman aura. I shall hasten, however, to check the growth of vanity in that direction by remembering a parchment, received from the hands of the distinguished president of a great university, which states in plain English that the degree endows me forever with certain "rights, privileges and immunities." These I have not yet discovered, particularly the immunities.

## II

I am scheduled to fill the preliminary period, between now and the moment when Professor Sauer comes out for the championship bout, by speaking on "Conservation and Scientific Forecast." Let the emphasis be upon the word "scientific," because most prophecies concerning the supply of renewable natural resources have been based upon hopelessly uncritical opinion and have proved correspondingly ill-founded. Dr. Bowman, formerly director of the American Geographical Society, has given us an example of such discrepancy in his review of the oyster industry of Chesapeake Bay.[2]

More than fifty years ago, Professor W. K. Brooks, of the Johns Hopkins University, foretold with astonishing accuracy the decline and fall of the oyster empire of the Chesapeake. In 1890 he published a book that has stood the test of a half century of criticism. His researches had already revealed a 50 per cent. falling off in the Maryland oyster population within the three-year period of 1879–1882, and he boldly predicted what the subsequent course of events would be if the findings of science were ignored. The fatal changes of the next fifty years represent, as Bowman points out, one of the best validations of scientific forecast. The reasons behind the failure were that the political builders rejected the sound foundations of Brooks. Again and again successive state legislatures sought to protect and encourage the industry by consulting so-called "practical" oystermen. In other words, lay opinion, or what we might call a hunch, was substituted for knowledge based on biological data and application of the inductive method.

It would be easy to multiply similar examples from many fields. Lumbermen have hardly proved well justified in their optimism concerning the subsequent quantity and price of marketable board-feet, nor sportsmen regarding the supply of waterfowl and other game, at least in relation to the increasing demand. Ackerman[3] has recently given us an impressive tabulation based on the marine fisheries of New England, which shows that the annual catch of such former staples as salmon, shad, lobster, mackerel and menhaden has fallen off 70 per cent. or more, mostly during the past one or two generations in which the human population has doubled. In 1889, 173,000,000 pounds of menhaden were taken by New England craft; in 1933, the catch was only one million pounds. Such losses are partly masked by better facilities for transporting an equivalent product from a greater distance, but it is certainly true that, despite the varied conservation activities in the six New England states, no broad plan yet exists to take account of the future of commercial fishing. The end, nevertheless, threatens to be similar in kind and even more critical in human economy than the universally mourned extirpation of the passenger pigeon.

Fortunately, it is possible to point to a few happier and more intelligent examples of study and regulation of the sea fisheries, among which the convention between the United States and Canada for the management of North Pacific halibut stands high in admirable conception and effective results.[4] I mention this, however, mainly to call attention to a fact which some American business men find unwelcome. It is this: when matters take a turn for the better, as they have in the halibut fishery, where do the ultimate springs of action prove to lie? With "practical" commercial fishermen? With the hard-headed, substantial citizens whose money is invested in such ventures? Not at all! We can be thankful enough if these gentlemen merely fall in line and lend their cooperation before the time is too late. The call is nearly always sounded, years before action is taken, by the disinterested and allegedly "impractical" man of science. It is very easy to demonstrate that the great industrial and manufacturing concerns have given far more opportunity and credit to research in pure science than have the organized business interests which draw upon the natural wealth of organic resources. Yet the benefits to be derived from the scientific method are probably as great in the one field as in the other.

[2] Isaiah Bowman, *Scientific Monthly*, 50: 289–298, 1940.

[3] E. A. Ackerman, *Economic Geography*, 14: pp. 233–238, 1938.

[4] H. E. Gregory and Kathleen Barnes, "North Pacific Fisheries. Studies of the Pacific," No. 3, American Council Institute of Pacific Relations, 1939.

III

Now scientific forecast can proceed from information of many different kinds, and it may be interesting to point out certain bearings of modern biological investigation upon our outlook in the sphere of conservation. Too often we have made our estimates upon a basis of certain continuing stable rates of plant and animal productivity. The return has in most cases fallen short of the expectation, even when liberal allowance had been made for improved methods of harvesting and the increased demand caused by an expanding population. The chief source of error has lain in the primary assumption: there is probably no such thing as stability in either numbers or productivity of living organisms, because all of them seem to share in the rhythmic fluctuations that are among the most familiar phenomena in our world and in the universe outside it. Recognition of this truth, and the processes that should stem from it, might go far toward enabling us to plan wisely for the future. It would not solve the whole problem, because mankind may perhaps become increasingly faced with the quandary of "scant means in relation to given ends," but it would be likely at least to give us an ameliorating clue, and I shall presently refer to one case in which the principle has already been acknowledged and put to effective commercial purpose.

The changing populations of many kinds of animals and the alternating yield in the seed crop of plants are phenomena that have been observed during a very long period of history. In numerous instances such shifts are not marked by abrupt or startling breaks. Rather, the pendulum of numbers swings gently up and down, the increase and decrease being at comparable rates, neither of which is excessive, so that periodicity over a course of years becomes evident only after a large amount of quantitative evidence has been collected throughout a considerable term. Five years ago, Wing[5] applied such data to a study of common North American insects, fishes, birds and mammals, and demonstrated by means of convincing graphs the regular and repetitive nature of the fluctuations. He correlated his findings with known cycles in the energy output of the sun and even concluded that different species of animals responded to different components of the solar activity.

Here was a discovery of great importance in connection with any attempt to peer into the future. It applied not only to organisms of which man makes direct use, but also to the much larger proportion which influences the stock of something else that he uses. And because of the complex ecological chains in nature, the second category might include nearly every living thing. Insects that fertilize blossoms, for instance, are quite as essential in the scheme as the fruit that follows, or the meat and fur built up in turn from the fruit, with or without intermediate stages. It brings to mind Shelford's[6] comment that it is all very well to protect fishes directly from seiners and birds from gunners, but it is still more urgent to consider what proportion of either will be *breeding* a few years hence.

Wing's investigations comprised, of course, only relatively short climatic rhythms and some of their parallelisms in the world of life. We are acquainted with still briefer organic cycles that run their course within a few days. Still more familiar are the annual cycles. The German South Polar Expedition found, for example, that at Gaussberg the plankton ratio in the sea was in winter (June to December) 1; in January 7; in February 25; in March 50; in April 20; in May 1, or back to the minimum.[7] Such seasonal periodicity is an outstanding phenomenon in the life of polar waters, but we have learned little about whether there is an appreciable variation from year to year.

Elton,[8] who is recognized as one of the foremost students of animal populations, has in various works described many other specific cycles. Thus mice and the foxes that eat them reach maximum density about every 3.6 years. The sugar-cane froghopper of Trinidad has a period of four years; squirrels of 5; hares and arctic foxes of 10 or 11, which also happens to be the same as that of the beech-mast crop in Britain; wild sheep of 20; the cotton-worm moth of the United States 21; African buffalo 30; elephant 50; and so on. In high latitudes the cycles are usually contemporaneous for similar organisms around the world, but in milder zones closely related creatures may exhibit marked discrepancies on different continental areas. Thus Leopold and Ball[9] found that the rhythmic fluctuations of grouse average about 10 years in North America but only six and a half in Great Britain.

Doubtless there are countless other fluctuations of which we yet know nothing but which are attuned with, or enhanced by, the long-term climatic cycles. Many of us used to smile when aged persons remarked that we no longer experienced the cold winters of their childhood. Granddad's old-fashioned winter was the

[5] L. W. Wing, *Transactions Twenty-first American Game Conference*, pp. 345–363, 1935.

[6] V. E. Shelford, "Animal Communities in Temperate America," 1937.

[7] Cited in, Richard Hesse, W. C. Allee and K. P. Schmidt: "Ecological Animal Geography," 1937.

[8] C. E. Elton: *British Journal of Experimental Biology*, 2: 119–163, 1924; "Animal Ecology and Evolution," 1930; *Journal of Hygiene*, 31: 435–546, 1931; "Animal Ecology," 1935; "Evolution" (edited by G. R. de Beer), pp. 127–137, 1938.

[9] Aldo Leopold and J. N. Ball, *Canadian Field-Naturalist*, 45: 162–167, 1931.

slightly derisive term, and it was usually attributed to senility or to the better heating apparatus of our own day. Yet an abundant meteorological record now indicates that the impression is by no means an idle tale. For more than a hundred years, and particularly since the turn of the present century, we have actually witnessed a world-wide trend toward milder climate, which transcends the short-term ups and downs of sunspot cycles.

Now all this may seem somewhat vague data to serve as the foundation of scientific forecasts bearing upon conservation problems. They are, nevertheless, matters about which we urgently need to learn more. They will have to be included in the reckoning before we can begin to figure accurately about the future availability of many kinds of organic products for which we find a use or a dire need. Such foresight might protect us from making the slight overdrafts on natural resources that are different only in degree from the gross overdrafts which we can already see and combat. For whether we use many times too much or only a little too much of the resources we can not create, the result in the long run will be the same, namely, depletion. We are already wise enough to discard as a complete fallacy the argument that a species is in no danger because it is still common.

## IV

Better known than the moderate and often obscure types of fluctuation in numbers and productivity are those in which organisms swing through such a wide arc that no observer can fail to be aware of them. These are the spectacular rhythms, in which increase to the point of overpopulation is followed by a rapid and catastrophic die-off, so that for a number of subsequent seasons an area that had swarmed with a particular form of life may seem to be without a trace of it. Always, however, a sufficient nucleus remains to start the upswing of the cycle. It is a remarkable fact that although many large groups of animals approach extinction at regular intervals, they have rarely attained it since the last Ice Age except when man has added the dead weight of his hand to the falling beam of the scales. For as Elton has said, to have the right enemies is a biological advantage, but of all the disasters, including predators, floods, droughts, fires, avalanches and disease, the worst for the flora and fauna of primitive regions is the introduction of civilized European man.

The rhythmic population growths, which are followed by a "boiling over," mass emigration, general mortality and other apparent abnormalities, are characteristic of a great many forms of life both on the land and in the sea. There is now an enormous scientific literature on this subject with which many of you are acquainted. The famous case of the lemmings is known to nearly everybody. An example nearer home is that of the outbursts of tent caterpillars and geometrid moths that appear about once in a decade, defoliate vegetation, and for one or two successive years stir up a furore out of all proportion to their real significance. It is difficult to make people understand that the best thing to do about them is nothing. They carry their own inherent correctives, and there are reasons for believing that they represent biologically beneficent phenomena rather than otherwise. At any rate, they are followed by longer periods during which scarcely enough of the supposedly objectionable insects remain to remind us of their existence. The end of a so-called plague of native insects or rodents is rarely due to human effort or the money spent; it is usually merely the natural conclusion of the cycle.

Green and Evans[10] have given us only this year a statistical picture of a portion of the well-known snowshoe hare cycle of northern North America. They report that in the Lake Alexander area, Minnesota, these rodents reached in 1933 a maximum population of close to 500 hares per square mile. During the next two years there was a moderate decline. This was followed between 1935 and 1938 by the anticipated cataclysmic drop, until the population was only about 10 per cent. of the peak number. Recovery then began, and in 1939 it had about doubled the numbers of 1938.

The observations of Hewitt, Cabot, MacFarlane, Preble, Seton and others[11] on this general subject have been greatly extended by Elton. The long records of collection and sale of furs by the Hudson's Bay Company have proved a mine of priceless information for revealing plant and animal fluctuations in relation to climatic influences over more than a century. They have also enabled us to predict with considerable confidence the course of future events. Elton has assembled scattered historical references which help to trace the system back as far as the thirteenth century and, indeed, even far beyond that date to the occasion on which a great swarm of field mice ate the bowstrings of Sennacherib's army, when "the Assyrian came down like a wolf on the fold." It has been made easy for us to see that organisms that subsist principally upon the "interest" of plant and animal productivity, such as mice, rabbits, foxes and lynxes, show the sharpest periodicity. The beaver, on the other hand, which has few predatory enemies, and which eats bark and therefore lives on "capital" rather than interest, does not harmonize with the others; its fluctuations depend rather upon the man-made pressure

[10] R. G. Green and C. A. Evans, *Journal of Wildlife Management*, 4: 220–238, 1940.

[11] All cited in, C. G. Hewitt, "The Conservation of the Wild Life of Canada," 1921.

of trapping and the long-term changes in the water table. The curves based upon Hudson's Bay Company pelts also enable us to distinguish between scarcity due to persistent over-destruction by man and the purely temporary scarcity that results from a "crash" in the normal cycle of variability. Among the fur-bearers of Canada, for instance, the lynx and fox still exhibit the traditional cycles; but the marten, which has the extraordinarily long gestation period of nearly ten months, has been so heavily overtrapped that it is no longer able to increase rapidly in numbers at rhythmic intervals, as it formerly did.

We can do no better than to draw a moral from the customs of primitive peoples, who are almost never exterminators. It is known that in good years many mammals double the size of their poor-year broods. The Indians in western Canada count the embryos in the bodies of hares in order to obtain a clue to next year's rabbit crop. Civilized man now has plentiful data to justify him in looking much farther ahead and to comprehend the prospect for a broad range of natural resources. But he must remember that he is never dealing with discrete numbers or events, but rather with rates of waxing and waning. He must think not in terms of fixed but of constantly varying supply, and must regulate utilization of raw material according to a system of control that fluctuates no less than the natural cycles are bound to fluctuate. As long as the capital of animal numbers is destroyed to make the fortunes of a few men, the income that should accrue to future generations will be forfeited.

In short, we need to know much more than the current rate of exploitation in relation to supply, regardless of whether the latter at the moment seems to be decreasing, increasing or standing still. Petersen,[12] who has investigated the effect of fishing upon the stock of plaice in the Baltic, shows that between 1919 and 1924 the annual yield fell progressively from 2,997 to 1,280 tons. This has a highly familiar ring; the plaice, like so many other marine foodstuffs, were being overfished. But the author adds almost casually that the age of plaice has been determined to extend to 17 years, and that there is a long interval between years of plentiful fry. The last statement no doubt contains the kernel of the problem. You can't hope to regulate plaice fishing profitably until the cycle of the species has been worked out.

Variations in the supply of many other fishes, such as our own Atlantic haddock, are by no means entirely dependent upon the extent of market fishing. This was strikingly shown in a paper by Dr. Columbus Iselin, director of the Woods Hole Oceanographic Institution, given within the past fortnight before the New York Academy of Sciences. He reported that the strength of the Gulf Stream current varies about 15 per cent. from month to month, and that the pulsations are clearly correlated with tidal amplitudes along the Atlantic coast of the southern United States. At certain seasons the rhythms in the strength of the Gulf Stream are sufficient to form marginal eddies that suck most of the normal water off George's Bank, and thus drag the haddock fry into depths of 2,000 fathoms, instead of their customary 30 fathoms, resulting in the dispersal and loss of the whole generation. Forecasts of such calamities can be deduced from the tide gauges at Charleston and Miami, and such data will therefore have to be applied to any sound and lasting regulation of our local haddock fishery.

[12] C. G. J. Petersen, *Report of the Danish Biological Station*, 31: 7–11, 1925.

## V

Now we can all imagine, for the moment, a future in which the conception of steadily maintained returns from natural resources will be entirely eliminated from the point of view of the industries concerned and of the general public. Certain minor steps in this direction have already been taken. Shooting laws covering migratory waterfowl, for instance, are no longer reprinted as a matter of course from last year's texts. On the contrary, the President of the United States now issues an annual decree based upon a report on the contemporary status of the ducks and geese, derived by scientific methods and with more or less accuracy by the Fish and Wildlife Service. The most exemplary and hopeful change in popular response that could take place would be a cheerful acceptance of the mandate, instead of a howl of protest whenever the laws are tightened instead of liberalized. Since self-interest controls the decision, we should at least be able to accept it as calmly as a patient takes his prescribed diet. A gradual educational process may yet, however, pave the way for announcements that will some day refer to the probable Atlantic-coast oyster regulations twenty years in advance! Such distant forecasts would be the only means of preparing us for painless adjustment of our plans.

Now you may say that I have outlined a pretty prospect without offering any decent suggestions as to how it may come into being against the terrible force of prejudice and inertia. My answer is that in one part of the world the reality has been attained, and it works. The realm is that of the guano islands off the desert coast of Peru.

The history of Peruvian guano is the usual one of discovery, greed, erring faith in the inexhaustibility of free treasure, and then ruin; but, happily, the sequence can in this instance be continued through to a revival, due to the application of scientific principles while there was still time. The restoration of the

Peruvian guano industry or, rather, its conversion from a purely destructive exploitation into a true and lasting industry, represents one of the greatest examples of practical conservation that the world has yet seen.

On the biological side, the story is equally interesting and even more complicated. It involves a long, interacting series of cosmic phenomena, including the varying heat given off by the sun, the wind systems of the region, the circulation in the eastern part of the South Pacific Ocean and the maintenance of extraordinarily low water temperatures in tropical latitudes. On such foundations depends the existence of a teeming microscopic plant life which is the pasture of the sea. This in turn supports directly or indirectly the higher and larger living organisms, all the way from crustaceans and small fishes up to birds, seals and whales. There is no other littoral region where birds can be found in such overwhelming abundance. There is likewise no region in which wild birds, requiring no human care other than to be left sufficiently alone, are so closely associated in the popular mind with direct economic benefits to man himself. This also is true; guano is a commodity of commerce, worth millions of dollars annually to those who control its production and those who purchase it for the enrichment of their crops.

Birds of the present sorts, or birds which filled a similar ecologic niche, have probably occupied this coast for millions of years, or ever since the uplift of the Andes first established the fundamental geographic conditions that have continued to the present. Throughout short periods of years their numbers expand prodigiously, as a result of the bounty and surplus of food in the coastwise, northward-moving Humboldt Current. But at certain periods the oceanic circulation abruptly changes; warm surface water from the outlying tropical ocean flows toward the coast; conditions of life suddenly become unfavorable for the marine pasture, and the whole pyramided structure begins to topple like a house of cards. Dead fish line the beaches and the stench is carried miles inland. The birds, too, perish in quantities not to be measured by concrete numbers but rather by the hundreds of miles of their strewn corpses along the tide line. Their death is not usually due to starvation but to shock-disease and other maladies that overtake animals whose vitality has been sapped by the knocking from beneath their feet of the whole complex system upon which healthy existence depends.

On the west coast of South America the cycle, thus briefly described, appears to be one with a periodicity of about seven years. Some of the manifestations are much more severe than others, and there are indications of cycles within cycles, culminating at times in such extreme conditions as those of the early months of 1925. In any event, there is likely to be a gradual build-up during seven years toward a peak of population, to be followed successively by a more or less widespread dying-off, a period of readjustment and then a renewal of the upswing. A graph of the production of Peruvian guano during a long course of years shows very clearly the alternating peaks and depressions which are an index of the varying population of birds.

Between 1840 and the beginning of the present century, man aggravated the periodic reductions in population and hindered the recoveries. The birds were regarded not as everlasting capital but as a nuisance and an encumbrance on the thick and "inexhaustible" beds of fertilizer that their ancestors had laid down throughout thousands of years. By the time the last cargo of ancient guano had been transported from these islands, the future looked dark indeed for a country which required at least 70,000 tons a year to support its own essential agriculture.

But in due course it came to be realized in Peru that if the heedless human animal could act so adversely upon the world of life, not to mention his own interests, it should be equally plausible that by using his brain he might be able to bring himself into harmony with nature. That, fortunately, is what has been ultimately accomplished along the guano coast. In the present century the sea bird is king; it has been literally recognized as the goose that lays the golden egg. Out of the wreck of the past, a great civilized and beneficent system has evolved. The guano islands are now, first of all, bird sanctuaries, and by far the most impressive sanctuaries of their kind to be found anywhere on the face of the globe. Increase of a commercial product is their underlying object, but the crop removed in any one season is not allowed to exceed the limitations imposed by nature. The long view takes precedence over the immediate demand. It is fully realized that the guano output can never be expected to be equal each year, that operations must permanently be attuned to the seven-year periods, and that a watchful eye must always be kept upon exceptional circumstances affecting the wanderings and reproductive capacity of the sea fowl. In other words, the bird itself—the producer—has at last become the determiner of what man shall undertake. Human intelligence is now directed toward ameliorating the periodic and inevitable falling of the scales; human intelligence likewise endeavors to heighten the population peaks that as surely follow. By means of blasting and grading, the area of windward slopes on the islands, which are best suited to support dense aggregations of nesting birds, are being gradually increased. Wise laws, based upon fundamental ecological research, not only guard the birds themselves but also prevent any undue human competition for their food resources in the coastal ocean. The average yield of fertilizer, as figured by seven-year terms, has grown phenomenally during the past thirty years, yet it is believed that the maximum capacity of the islands still lies far ahead.

Here, at any rate, is one part of the world in which native wildlife will remain secure as long as such wisdom prevails. Here is scientific forecast in pragmatic operation. Here is a case in which a South American republic holds up a beacon for all other nations to admire and emulate.

# TOWARDS A NEW BIOCHEMISTRY?[1]

By Professor A. SZENT-GYÖRGYI

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THE atom consists of a nucleus surrounded by a system of electrons. By sharing one or more electrons, atoms can join to form molecules. In such a molecule, as a rule, every electron belongs to one or two atoms. This is our idea of a single small molecule, and this picture has hitherto unconsciously governed our thinking in biochemistry.

The study of crystals and metals, however, has revealed the existence of a different state of matter. If a great number of atoms is arranged with regularity in close proximity, as for instance, in a crystal lattice, the terms of the single valency electrons may fuse into common bands. The electrons in this band cease to belong to one or two atoms only, and belong to the whole system.

These bands or energy levels are separated from possibly higher levels by forbidden zones. Under ordinary conditions all electrons are within the lowest band. If this lowest band contains the maximum number of electrons ($2n$, if the number of atoms is $n$), as is the case with insulators, the electrons will be unable to transport energy. If, however, one of these electrons is raised by the absorption of energy to a higher level, and comes to be in what we call an excited state, where it will move and transport its energy freely, it will be impossible to say which is the atom to which the excited electron belongs, and the whole system can be looked upon as activated. By falling back to the lower level the electron will give off its excess energy and perform work in a place more or less distant from that of the absorption of energy. This is the case with certain phosphors, as has been shown lately by N. Riehl.[2] Here, as for instance in ZnS, the electron, raised to a higher level by a collision with an $\alpha$ particle, can travel relatively long distances and will fall back to a lower level, giving up its energy, where it meets a Cu atom, present as an impurity. Thus the absorption and emission of energy will proceed independently at different places.

The problem is whether this state of matter, *i.e.*, common energy levels, exists also in living systems. If it does it can not fail to influence profoundly our biological thinking and open new approaches to research and understanding. Protein molecules are systems built up of a great number of atoms, closely packed with great regularity. So theoretically the possibility exists that within these molecules analogous conditions to those in crystals prevail.

The first indication of the existence of such common energy levels was given by the study of photosynthesis, one of the most fundamental biological processes. Emerson and Arnold[3] found that 2,500 chlorophyl molecules form one functional unit. Warburg and Negelein[4] showed that four quanta are necessary for the reduction of one $CO_2$ molecule. There are observations to indicate that these four quanta must reach the $CO_2$ molecule simultaneously. Gaffron and Wohl[5] calculated how many chlorophyl molecules must interact to absorb four quanta simultaneously at the weakest optimal illumination. Their calculation showed that only one thousand molecules are capable of doing this. These observations indicate that the electrons, raised to a higher energy level by the absorbed light, can move and transport their energy freely through the system of chlorophyl molecules.

Kubowitz and Haas[6] have measured the inactivation-spectrum of urease, and P. Jordan[7] has pointed out that their results are in agreement with the idea that common energy levels exist within this protein molecule. At present K. Laki and M. Gerendás are engaged in my laboratory in the study of the inactivation-spectrum of fumarase, crystallized by Laki. Their results also indicate that the energy absorbed may leave the place of its absorption and cause a break of links at a different place, thus traveling at some distance through the molecule.[8]

1 Korányi Memorial Lecture, given in Budapest on March 21, 1941.

2 N. Riehl, *Naturwiss.*, 28: 601, 1940.

3 R. Emerson and W. Arnold, *Jour. gen. Physiol.*, 16: 191, 1930.

4 O. Warburg and E. Negelein, *Naturwiss.*, 13: 985, 1925.

5 H. Gaffron and K. Wohl, *Naturwiss.*, 24: 81, 1936.

6 F. Kubowitz and E. Haas, *Biochem. Zeits.*, 257: 337, 1933.

7 P. Jordan, *Naturwiss.*, 42: 693, 1938.