months, were placed, in the year 1888, in a millpond of flowing water, where the temperature, even in the hottest days of summer, did not exceed 16° Centigrade. In March, 1893, these fish were transferred to a shallow pool in which were living (and have been living ever since 1888) a number of fishes of the same brood, hatched at the same time. The newcomers and the old residents lived there healthily and contentedly until July, when the temperature reached 25° Centigrade; the newcomers began to die, but the old residents were not affected in the least. At 27°, all the newcomers were dead, but all of the old residents were quite alive and active, and they were not affected by the increase of temperature until 35° Centigrade was attained.

The presence or absence of moisture is another climatic condition of great importance. Countless numbers of tadpoles die annually from the drying of the shallow pools in which the eggs from which they hatched were deposited. Eggs of many marine animals cast up on the beach dry and die.

Observers in different parts of the world so widely separated as Illinois, France and Russia are agreed that humidity is a necessary condition to the existence and propagation of the Hessian fly, a dangerous enemy of wheat and other grains; while, on the other hand, the chinch bug (also an economic pest), only spreads when the temperature is high and moisture is absent.

Among climatic limitations are also to be included the effects of sediment in flowing streams or in ocean currents. For example, in the case of coral reefs, which parallel so many coasts, it is found that there is always a breach in the reef opposite the mouths of fresh water streams, and that the reason why the seabeaches occur seems to be that the sand and mud brought down by these streams into the ocean so cover up the coral polyps as to prevent their living in this space, and hence also prevents their forming coral.

Having briefly analyzed the effects produced by each of the four mentioned causes, we have now to attempt to understand how they act simultaneously. For it is true, in this aspect of nature, as in every other, that almost every phenomenon is not the result of one single cause, but the effect of many combined. Just as the movements of the planets, for example, are due to a composition of forces, so the struggle for existence is due to the combined action of these various causes which we have discussed.

The high, natural rate of increase in animals results, usually, in a large number of offspring. If all the offspring of a single parent begin their development in the same place, a competition is at once set up between them for the food which is available. If the food supply be large relatively to the number and needs of these offspring, then the fraternal competition is slight; but in many cases where other food is absolutely unobtainable, the severity of the struggle reaches its height in cannibalism. But the competition for food may not only be with one's fellows, but with other species having the same diet.

Gregariousness tempts enemies with the prospects of a large amount of food to be obtained with little labor; while, on the other hand, it may afford protection which numbers alone can give. It rarely happens that the structure and habits of a given species protect it equally well against all the adversities to which it is exposed. If, therefore, the food supply fail when the animal is unable to seek for it elsewhere, or an enemy appear when flight and fight are alike impossible, or a climatic change occur with a suddenness that admits of no adaptation thereto, then all of the successes of the previous life are lost, and the individual falls in the struggle.

It is extremely difficult to determine the rate of mortality among animals. Most of the data are based on individuals reared under conditions more or less artificial, and protected, to a considerable degree, from many adverse circumstances ordinarily existing in nature. The difficulty of obtaining information on this subject from animals in purely natural conditions is self-evident; since this would involve examinations of individuals scattered over considerable areas, and their identification for future record. Consequently our estimates of the proportion of those who, dying before maturity, fail in the struggle for existence, are little more than guesses. Nevertheless, we must use them in default of anything else.

From records of the number of half-grown oysters found in association with full-grown individuals, Moebius believes that only one newly hatched embryo in every 1,041,000 survives to reach the half-grown shelled condition. This is a death-rate of 99.99991 per cent. The figures are for the European species, in which the number of eggs is about one-ninth of that of the American species. For the Lepidoptera, Mr. C. S. Westcott, an associate of this society, who has paid much attention to rearing them in captivity, and to observing them under natural conditions, has kindly furnished me the following: "I have several times counted the eggs laid by a female to determine the number approximately, and have found *Aypanta cunia* to lay over 800. This species (which has two broods in this neighborhood), is about ten times as numerous in the second as in the first brood. Allowing each female to lay 800 eggs, this would mean that of the first brood one female to every 80 eggs completes its life, and in the fall brood, only one female to every 8,000 eggs. I once had a call for a large number of *Pyrameis huntera*, (a common butterfly of this region) and collected over 300 larvae. Every one of these larvae changed into pupæ; but out of the lot I got only one butterfly; every other chrysalis developed a parasite, these parasites being all of the same species. On another occasion I found about 75 larvae of *Melitæa phaton* butterfly, and nearly every one produced a perfect insect. The loss was very small."

Again, in the forest tent caterpillar, (which has been very destructive this last summer in the State of New York), the rate of mortality is estimated as about 41 per cent. Among fishes we note great mortality in the very early stages of their existence. Thus, Dr. J. P. Moore reports that in the eggs of the cunner collected at the surface of the sea during the summer of 1897, fully 30 per cent. had failed of being fertilized. Mr. Earl's opinion in regard to the cod is that probably but a very small number out of a million cod eggs are successfully hatched; and, of the young fish but very few reach maturity.

Probably every group of animals has many adversi-

ties to contend with. In the past, whole classes of animals have been exterminated, which means a rate of mortality of 100 per cent.; some species are even now passing away; yet, of the great majority of animals now living on the earth, after allowing for the annual variations of increase and decrease, it is probably true that they are holding their own.

How do they hold their own? The answer is to be found in a consideration of the means of defense—all those things that make for life.

Just as we have recognized four chief causes of the struggle for existence, so we propose to treat of the means of defense under four headings, corresponding to the defenses which exist against those four several causes. So we shall consider: firstly, the protection of the young; secondly, the protection of the food supply; thirdly, the protection against living enemies; and, fourthly, the protection against climatic changes.

THE SHRINKAGE OF LAKE NICARAGUA.

A QUESTION OF PERMANENCY OF THE PROPOSED NICARAGUA CANAL.

BY ANGELO HEILPRIN, F.R.G.S., F.G.S.A., late President of the Geographical Society and Professor of Geology at the Academy of Natural Sciences, Philadelphia.

A VERY serious aspect of the proposed Nicaragua Canal, and one that has so far escaped earnest consideration, is that which pertains to the permanency of the waters of Lake Nicaragua, the fountainhead of the San Juan River. The canal which intends to use the lake as the feeder to its high level must necessarily have this permanent, and if it cannot be held so, there can be no permanent canal. In a paper published in the SCIENTIFIC AMERICAN, of February 24, 1900, entitled "An Assumed Inconstancy in the Level of Lake Nicaragua," and further elaborated in the pages of the bulletin of the Geographical Society of Philadelphia for March, "The Nicaragua Canal in its Geographical and Geological Relations," I have given what appeared to me good reasons for believing that the level of the lake is inconstant, and that the waters had dropped from 15 to 20 feet in the period of little more than half a century or less. This conclusion is supported by the earlier determinations of altitude made by the Spanish engineer, Galisteo, in 1781, and the English engineer, Baily, in 1838, the results of which differ from those obtained more recently in the American surveys by some 20 to 30 feet. In a paper having the same title as my own, published in The National Geographical Magazine for April, Mr. C. Willard Hayes, of the U. S. Geological Survey, and geologist to the Nicaragua Canal Commission of 1897-99, attempts to refute my conclusions, and asserts that "notwithstanding these earlier determinations the level of Lake Nicaragua has remained constant except for slight seasonal fluctuations, at least for a period whose length has to be measured in centuries," and "that the geologic conditions in this portion of the Isthmus are such that they afford a promise of future stability, and that the region is, therefore, favorable for the construction and maintenance of a work such as the proposed Nicaragua Canal" (p. 161). Mr. Hayes concedes that a region subject to the change which I have indicated "would offer serious obstacles to the construction of a canal of the magnitude of the one proposed or to its permanency after construction" (p. 156).

A critical examination of Mr. Hayes premises shows them to be far from conclusive, while the data presented in the official report of Chief Engineer Wheeler, of the Nicaragua Canal Commission, effectually dispose of his contention as to the lake's stability, and confirm the argument which has been advanced for its instability. Mr. Hayes gives three causes, singly or in combination, "which might bring about a change in altitude of the lake surface: (1) A depression of the whole of this portion of the Isthmus without warping; (2) a depression of the lake basin by warping, the sea margins remaining constant; (3) a cutting down of the lake outlet" (pp. 156-7). Not finding direct evidences of these causes, the case is considered to have no standing.

To many geologists, other causes beside the three that have been brought forward will suggest themselves as being able to bring about the result which has been indicated, and in a way equally as simple and effective as those which Mr. Hayes names. Of such, one need hardly go beyond the very obvious one of a shrinkage in the supply of inflowing water.*

It is hardly necessary to traverse the arguments, based upon characteristics of flood-plains, the presence or absence of lake beaches and terraces, shore deformations, etc., upon which Mr. Hayes relies to prove the non-existence of his three causes; geologists know how illusory are "landmarks" of this kind in their negative condition. Nor need any particular weight be attached to the testimony of observations made or not made on the local phenomena by the inhabitants of a region, the particularly history involved in which dates to a period of fifty or sixty years back. When one realizes how many years were required to prove and disapprove the difference of level of the two oceans on the opposite sides of the Isthmus of Panama; to prove and disprove the rise and fall of the land on the northern shore of the Bay of Naples in the classic ground of the Temple of Serapis; to prove and disapprove that Mount Hood, a volcano standing almost on the outskirts of a populous town, was in energetic eruption in 1875; to prove or disprove that the famous Calaveras skull was found where it was found, etc., one need, perhaps, hardly assent to the proposition that in a region like Nicaragua some of its more pregnant phenomena "could not possibly escape notice"† and that lacking observational facts indicating an abatement of the waters of the lake, none such could have taken place. As a matter of fact, however, bearing upon the condition of Lake Nicaragua, emphatic testimony to the lowering of its waters is given by the

English engineer, Collinson, who ran a partial survey in the region in 1867; and in his report to the Royal Geographical Society, he further states that "even the least observant native, dwelling on the lake, will tell how its banks are rising year by year visibly before his eyes, etc.," and, thereby, whether accurately or inaccurately, supplements his own observations by an appeal to the observation of native sources. It is hardly necessary at this time to inquire into the credentials which Mr. Collinson bore as an engineer; suffice it to say, that there is enough evidence to show that in his day, whether his researches in Nicaragua were correctly or incorrectly made, he was considered a very competent observer; and his conclusions regarding the lake appear to be abundantly confirmed by the data furnished in the special report of the chief engineer, appended to the official report of the Nicaragua Canal Commission of 1897-99.

From this report it is made very plain that the intake of Lake Nicaragua, i. e., the rainfall on its surface, and the water that it receives from its full drainage basin, is for a run of years, and apparently for almost every year, less than the output, i. e., the loss due to evaporation and outflow. Indeed, in exceptionally dry years, the evaporation alone more than covers the entire intake.* From the observations made at a number of stations on the lake, it would appear that the annual rainfall over its surface is within about 28 per cent. of that at Rivas, while the inflow collected from the enclosing drainage basin is somewhat less than this amount, or 30 per cent. of the full rainfall over a region that has an area about three times that of the lake.† These data, with a knowledge of the amount of evaporation and the outflow, permit of an easy determination of the hydrodynamics of the lake. The evaporation from the surface of the lake is stated to be on an average of 6 inches per month during the dry season, and 4 inches in the wet. In 1898, the full evaporation for the year was 52 inches, but that year was considered to be "an abnormally wet one, and it is, therefore, probable that the evaporation was somewhat below the average. Mr. Davis (the hydrographer of the commission) estimates a normal annual aggregate at about 60 inches, or 5 feet."‡

The following absolute rise in the level of the lake as computed from a possible rainfall at Rivas is furnished by the engineers of the Canal Commission:

A rainfall of 30 inches would cause a rise, were there no evaporation or overflow, of.....	34 inches.
A rainfall of 40 inches " " " " " " " " " " " "	48 " "
" " " " " " " " " " " "	62 " "
" " " " " " " " " " " "	76 " "
" " " " " " " " " " " "	90 " "
" " " " " " " " " " " "	104 " "
" " " " " " " " " " " "	118 " "
" " " " " " " " " " " "	132 " "
" " " " " " " " " " " "	146 " "
" " " " " " " " " " " "	160 " "
" " " " " " " " " " " "	174 " "
" " " " " " " " " " " "	188 " "

From November 1, 1889, to June 1, 1891, a period of 19 months, the total rainfall at Rivas was 38.39 inches, which would have raised the level of the lake 45.75 inches. The evaporation alone during this time would have lowered it 95 inches, an absolute loss to the lake, beyond what would be entailed by the outflow through the San Juan River, of over 4 feet. This, it is true, was the driest period observed, but the condition is said to be "not at all anomalous." From the beginning of December, 1884, to the end of April, 1886, a period of 17 months, the total rainfall at Rivas was 37.43 inches, which amount would raise the level of the lake 44.4 inches. The evaporation for the same period is assumed to have been 84.25 inches, a net loss to the lake from this source alone of 3 feet 4 inches. From the beginning of November, 1894, to the end of April, 1896—19 months—the rainfall was 45.15 inches, which would put a credit of 55.72 inches to the lake. The evaporation for the same period was 95 inches, a loss to the lake again of 3 feet 4 inches. The loss to the lake during three dry spells, calculated from the excess of evaporation over rainfall and inflow, and without taking account of the natural outflow through the San Juan River, was, therefore, 10 feet 10 inches. The report judiciously and significantly adds: "The recurrence of such dry years shows that they are to be expected in the future and should be provided for."§

It is self-evident that unless there are special compensations to the lake for such losses, the losses must be perpetual; and the compensations sought for can only be found in years or periods of extraordinarily heavy rainfall. The problem of restoration, therefore, rests entirely with the question of such periods occurring or non-occurring. The reports of the Chief Engineer and Hydrographer of the Canal Commission plainly state that they have not occurred.

Despite the fact that following rapidly on excessive rains the surface of the lake has been known to rise as much as two feet in six weeks, the greatest net accession to the lake for an entire year, and throughout a period of 20 years, was considerably less than two feet. This was in the year 1897, when the rainfall at Rivas during the 164 days between May 17 and October 27, was 112.42 inches.—"the period of greatest rainfall shown in the Rivas records since 1879. . . . This then (148.58 inches) is the estimated amount of fluctuation that would have occurred during the period of greatest rainfall of the last 20 years, if there had been no evaporation on the lake or overflow from it."¶

The year 1898, when the rainfall at Rivas was 108 inches, was almost, or quite, as favorable as 1897, and the net rise in the lake was 18 inches. The evaporation from the lake was during that year 52 inches, and the outflow through the San Juan, 84 inches—the lake, therefore, throwing off 11 feet 4 inches. Had there been no evaporation or outflow, the lake would have risen that year 154 inches.** Taking the outflow of 84 inches to be about normal for the lake standing at or but little above, mean stage of water—elevation 104 to 106 feet—with a steady evaporation of from 50 to 60 inches, it is made impressively clear that many successive years of heaviest rainfall would be required to

* "During the dry season, the evaporation exceeds the inflow. During exceptionally dry years, exceeds the inflow for the entire year." Report Chief Engineer Wheeler, page 58.

† Report Nicaragua Canal Commission, page 18.

‡ Report Nicaragua Canal Commission, page 18.

§ Report Chief Engineer, page 66.

¶ Report Chief Engineer, page 66.

** Report Nicaragua Canal Commission, page 21.

Re ort Nicaragua Canal Commission, page 19.

make good the deficiency of a single exceedingly dry period; and, if such cannot be had, there must be steady, progressive and non-recuperative losses to the lake. This condition is, in fact, very plainly indicated in the report on rainfall by Mr. Arthur P. Davis, appended as the hydrographic report to the general report of the Nicaragua Canal Commission (1899). The following yearly record of rainfall at Rivas, noted by Dr. Earl Flint for the years 1880-1898, is there given (pp. 278-79):

1880.....	64 38	inches.
1881.....	79 21	"
1882.....	61 32	"
1883.....	49 77	"
1884.....	54 74	"
1885.....	34 59	"
1886.....	87 21	"
1887.....	74 89	"
1888.....	55 51	"
1889.....	84 36	"
1890.....	31 81	"
1891.....	66 03	"
1892.....	78 27	"
1893.....	106 13	"
1894.....	47 32	"
1895.....	47 68	"
1896.....	47 80	"
1897.....	123 43	"
1898.....	108 06	"

If with a rainfall of 108 inches, as before referred to in the year 1898, the net rise in the lake was only 18 inches, it becomes manifest from an examination of the above table and that before furnished for correspondent rises in the lake, that during 19 years of successive observations there were not more than three (or at the utmost four) periods, the years 1893, 1897 and 1898 (and 1886?) when the lake held its own; and during these years combined, the actual gains were less than five feet. On the other hand, in the single year of 1890, when the rainfall at Rivas was only 31.81 inches, the loss was as great as the gains for the entire 19 years!

Not knowing the amount of outflow through the San Juan River for the different years from 1880 to 1898, but assuming it, for a simple convenience of measure, to be on an average not more than one-half the amount,* 84 inches, that was found for the year 1898, and taking the annual evaporation at 55 inches, we arrive at the following interesting analysis of the table of rainfall:

In 1880 the lake lost.....	12 inches		
" 1881 " " gained.....	17 "	10 "	
" 1882 " " lost.....	34 "		
" 1883 " " ".....	27 "		
" 1884 " " ".....	55 "		
" 1885 " " ".....	21 "		
" 1886 " " gained.....	3 "		
" 1887 " " ".....	27 "		
" 1888 " " ".....	19 "		
" 1889 " " ".....	61 "		
" 1890 " " ".....	11 "		
" 1891 " " gained.....	8 "		
" 1892 " " ".....	11 "		
" 1893 " " ".....	40 "		
" 1894 " " ".....	40 "		
" 1895 " " ".....	39 "		
" 1896 " " ".....	21 (+) "	as determined)	
" 1897 " " gained.....	18 "		
" 1898 " " ".....			
363 inches 114 inches			

A loss of 363 inches as against a gain of 114 inches, or a net loss of 249 inches (20 feet 9 inches). The amount that I have allowed for outflow is probably fully 20 per cent. less than what was actually the case, if the data obtained by Childs in 1880, the Nicaragua Canal Board in 1895, and the Nicaragua Canal Commission in 1898-99, be assumed as the basis for computation, and I have taken the small measure merely to allow every advantage in favor of the argument for a maintenance of level. The evaporation assumed is also 5 inches less than what is assumed to be the amount for an average year by Mr. Davis.

It thus becomes apparent that for a long period of years Lake Nicaragua has undergone a very marked and progressive shrinkage; and there is nothing to indicate that the loss involved in this shrinkage can be made good for future years. If it is possible to assume other periods of years when the rainfall may be vastly in excess of what has been recorded for the past twenty years and more, and that a balance can be restored in this way, it can only be said that there is no evidence of such successive periods of excessive rainfall ever having taken place; and we may quote the words of Mr. C. Willard Hayes: "So far as known there is no evidence whatever that the rainfall has ever been greater in this region than it is at the present time; and further, 'it is, therefore, impossible for the level of the lake to reach the elevation given by Lieut. Bailly, merely by reason of heavy precipitation.'"

CONCLUSIONS.

The full conclusions, then, that must be drawn from the data furnished by the Nicaragua Canal Commission of 1897-99, and the special reports of the chief engineer and hydrographer appended thereto, are:

1. Lake Nicaragua has undergone marked shrinkage during the period of the last 25 to 50 years.
2. The shrinkage is a progressive one, and there are no known conditions by which the loss incurred can be made good.
3. The assumption is well founded that the earlier measurements of the altitude of the lake surface, made by Galisteo and Bailly, indicating an abatement of the waters by 20 to 30 feet, were accurate.

The relations of these conditions to canal construction become immediately apparent, and it may well be agreed that a region subject to the changes which have been indicated "would offer serious obstacles to the construction of a canal of the magnitude of the one proposed or to its permanency after construction."

The Steamboat on the Thames, plying from London to Richmond and Kew, will be discontinued this year. This is interesting, and brings to mind the accident which occurred twenty-two years ago by the sinking of the "Princess Alice," when seven hundred lives were lost.

* Except for the years 1893, 1897 and 1898.

† Official report, Nicaragua Canal Commission, page 145.

‡ National Geographic Magazine, April, 1900, page 161.

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