spectral emission was observable during Period A (*i.e.*, through opening *a*), there was no detectable emission during Period C. Since it is known from various lines of evidence that spectral emission is not appreciably the result of recombination of ions and electrons, but is the result of excitation, this proves conclusively that the post-arc currents are due to the neutralization of negative space charge by the persisting positive ions, and not to the ionization of excited atoms.

Furthermore, Kannenstine's results using a Braun tube were reproduced in all essential details, in very pure helium, in helium of ordinary purity (no impurity visible spectroscopically) and also in helium containing large amounts of mercury vapor. No quantitative difference greater than the limit of reproductibility under the same conditions was found.

Many of the peculiarities of the Braun tube figures were found to be produced by the resistance of the potentiometer and other elements of the circuit.

CARL ECKART

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THE SUCCESSIVE STIMULATION OF THE ARC LINES OF HELIUM BELOW THE IONIZATION POTENTIAL

RECENT experiments made in the research section of this laboratory have demonstrated photographically the successive stimulation of the arc lines of helium under increasing potential of electron bombardment between the resonance and ionization points.

The potentials necessary for the stimulation of the lines of the visible spectrum were calculated from the established term values of these lines and from a term value for the normal atom based on the assumption that the correct ionization point is 24.5 volts. The photographs show a concordance of observation with calculation to better than one tenth of a volt. The voltmeter corrections were made from ionization point curves taken under the same conditions in the same apparatus assuming the correct point to be at 24.5 volts. This correction amounted to 1.1 volts, a value also calculable by the usual methods by application of contact difference of potential and other corrections. A large Hilger quartz spectrograph was used with a plate setting to cover from about 5000A to 3000A. With this setting the spectrum at 22.9 volts consists of a single line, 3889A. This is the second line of the coplanar principal series, m = 2. The calculated voltage necessary to stimulate this line is 22.9 volts. At 23.5 volts three lines are found 5016 (calculated 23.00 volts), 4713 (23.51) and 3889. At 23.9 volts nine lines occur, 5048 (23.56), 5016, 4922 (23.65), 4713, 4472 (23.65), 4121 (23.88), 3965 (23.65), 3889 and 3188 (23.62). At 25 volts the full spectrum is obtained.

When viewed visually the lines appear and extinguish sharply in order. The disappearance of the line 5048 leaving 5016 adjacent to it furnishes a convenient method for establishing instrumental corrections if the calculated value for the appearance of the line is accepted as correct.

The experiments are an extension of work reported to the American Physical Society at its Washington meeting in April, 1924. The apparatus described at that time has been altered by the introduction of an equipotential lime cathode of a type similar to that suggested by G. Hertz (*Zeit. für Phys.*, 22, 24, 1924), but of a different shape, sharply peaked at its narrowed center to permit closer approach to the grid. The distance of electron acceleration did not exceed one half of a millimeter. Under these conditions both voltage and current were remarkably steady. No "kicks" or "hysteresis loops" were found in the current-voltage curves nor were there any evidences of oscillatory disturbances.

These results are a confirmation of the early observations of Rau (*Sitz. Ber. d. Phys. Med. Ges.*, Wurzburg, 1914) and of Richardson and Bazzoni (*Nature*, 98, 5, 1916) and of the recent publications of G. Hertz (*l. c.*).

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APRIL 15, 1925

THE NATIONAL ACADEMY OF SCIENCES

ABSTRACTS OF PAPERS PRESENTED AT THE WASHINGTON MEETING, APRIL 25 AND 26

Measurement of the circulation in man: DR. YANDELL HENDERSON and HOWARD W. HAGGARD, Sheffield Scientific School, Yale University. Ever since Harvey showed that the blood circulates, the determination of the volume of flow per minute has remained the outstanding, unsolved problem of the circulation. It is not merely general knowledge that is needed, but rather the means of determining the functional efficiency of the circulation in individuals in all conditions; in other words, a simple and fairly accurate method for measuring the circulation in man. The method based on absorption of nitrous oxide from the lungs is inaccurate and of limited applicability.

Investigations in this laboratory have led to the formulation of the principles controlling the absorption of any gas whatever by mere solution from the lung air into the blood. These principles show that the rate of absorption of a very soluble gas, such as ether or alcohol vapor, is dependent mainly on the volume of air breathed, that is, the respiration; while the rate

of absorption of a relatively slightly soluble gas is more nearly proportional to the volume of the blood stream through the lungs, that is, the circulation. Gases of about the proper solubility were therefore tried, one after another, until the vapor of ethyl iodide was tested. With this substance a simple, accurate and reliable method for measuring the circulation in man has been developed. It is applicable to practically all conditions.

A complete determination of the respiratory exchange, with the oxygen consumption as a basis for indirect calorimetry, is made with each measurement of the circulation. The whole process of inhalation, and the analyses for oxygen, CO_2 and ethyl iodide can be completed by one operator in half an hour.

Results have been obtained on a variety of persons from athletes to cardiac patients. For purposes of comparison and estimation of efficiency, the most significant features of the data reported are the stroke index, or volume in milliliters of blood per kilo body weight discharged by the heart at a beat, and the arterio-venous oxygen difference. The stroke index for normal persons during sitting rest ranges from 1.3 to 1.8. In some individuals it is much larger in the recumbent position —up to 2.0 or more; and much smaller in the standing position—down to 1.0 or less; these observations confirm those of Bock and Field. During vigorous exercise the stroke index may rise to about 3.5.

The arterio-venous oxygen difference in normal persons during rest is about 4 volumes per cent. This means that the circulation is normally so large in relation to the oxygen consumption of the body that the venous blood returning to the right heart contains on the average only 4 volumes per cent. less oxygen than the arterial blood. The blood stream pumped by the heart is thus about twice as large as was formerly supposed. During bodily rest its volume in liters per minute is about equal to the volume of air breathed per minute. During exercise respiration may increase 8 or 10 fold, and the circulation 4 or 5 fold.

Hot baths quicken the circulation without greatly increasing the oxygen consumption. Thus they further reduce the oxygen difference and raise the pressure of oxygen in the tissues. On the other hand during muscular exertion, which is vigorous but such as can be sustained for a considerable time, involving an oxygen consumption of about 2 liters per minute, the circulation increases from a resting value of 7 or 8 liters per minute for a man of 70 or 80 kilos, up to a flow of 30 liters or more per minute. Under such conditions the arterio-venous oxygen difference also increases, reaching 8 volumes per cent., or 40 per cent. utilization, or more. During greater exertion the oxygen difference increases, because the circulation does not.

In cardiac patients the inefficiency of the circulation shows itself in the increase of the arterio-venous oxygen difference above the normal value. The capacity of the circulation to keep the oxygen difference down, and thus to keep the pressure of oxygen in the tissues up, appears to be the limiting factor in the maximum power that can be sustained by athletes at one end of the scale, and by cardiac patients at the other.

Cell respiration: DR. F. G. NOVY and DR. M. H. SOULE, University of Michigan. This paper presents some of the results obtained in investigations on the respiration of micro-organisms. A compensation manometer has made it possible to observe the pressure changes which take place within a culture tube or jar, and to remove samples of the contained gas for analysis. The gas exchange of an organism can thus be followed, whether grown in air, or in varying concentrations of oxygen, carbonic acid or other gases.

Cylinders of sterile raw potato consume all of the oxygen in a tube and return a corresponding amount of carbonic acid, the respiratory quotient being 1.0. When the oxygen is consumed, or if it is replaced by nitrogen, the potato respires as an anaerobe. It is known that anaerobic bacteria will grow, apparently in the presence of air, provided a piece of raw potato is added to the broth. In such case, the favoring action of the potato is due to the removal of the dissolved oxygen.

The study of the respiration of certain pathogenic protozoa, Trypanosomes and Leishmanias, showed that they required oxygen and that the gas exchange was much the same as in the case of bacteria. When grown in tubes, with an air capacity of about 100 cc., all of the oxygen was removed in 6 to 10 days and more than 15 per cent. of carbon dioxide was returned. When cultivated on blood agar, the respiratory quotient was found to average 0.82 to 0.87; in the presence of glucose, the quotients were 0.94–0.95. Increased concentrations of oxygen inhibited the growth. Carbon dioxide, in 20–30 per cent. concentration, was also inhibitive.

The average respiratory quotient of the human tubercle bacillus, when grown on glycerine agar, was 0.84; on glucose agar, 0.99. The bovine bacillus gave slightly higher values. These results closely approximate theory and show that the glycerine and glucose are utilized as sources of energy for the growth of these organisms.

When grown on glycerine agar, a single tube culture can consume all of the oxygen in 700–1000 cc. of air. On glucose agar the oxygen consumption is less. The human type can be grown in concentrations of oxygen up to 100 per cent., whereas the bovine type is inhibited by 80 per cent. Carbon dioxide, in excess of 60 per cent., shows some inhibition.

The tubercle bacillus must have oxygen, but it can grow in an atmosphere which contains 0.5 per cent. or less of oxygen. The slow and poor growth, obtained under these conditions, is not due to lack of oxygen but to the low tension of this gas. This fact explains the slow growth of the organism within the human body since the oxygen tension in the tissues is low.

The anti-sterility vitamin, fat soluble E: HERBERT M. EVANS and GEORGE O. BURR, University of California. When rats are reared on various "synthetic" food mixtures consisting of fat, carbohydrate and protein in separate and relatively pure form together with an appropriate salt mixture and the vitamins A and B, they grow well and have every appearance of health.

Depending somewhat on the exact character and the proportions of the constituents of the food, they sooner or later exhibit complete sterility. The sterility is a dietary deficiency disease for it can be cured or prevented by a change in dietary régime, a change involving the addition of certain single natural foods high in a new food factor or the addition of very much smaller amounts of extracts of those foods.

The sterility disease affects males and females differently. In the male it eventually leads to destruction of the germ cells (eventually the entire seminiferous epithelium) but this is not the case with the female, where the ovary and ovulation are unimpaired throughout life but where a highly characteristic disturbance occurs in gestation, the death and resorption of the developing young. It is necessary to insist on the peculiar character of dietary sterility, thus produced in the female through lack of vitamin E, for it is only by ascertaining the existence of typical "resorption gestations" that one may be assured that he is dealing with deficiency in the specific substance E. Many other dietary delinquencies cause sterility in the female, but they all do so by interference with other steps in the reproductive mechanism than those involved in lack of E, usually by preventing oestrus, ovulation, fertilization or implantation but not by resorption after implantation has occurred.

In gestations where E is low or absent, the embryos seem at first normal, but sooner or later, often by the eighth day, retardation in development can be substantiated. Evident abnormality, especially monstrosity, does not occur. At some time between the twelfth and twentieth day, foetal death occurs.

Large numbers of females have been reared on various "pure" food régimes and bred shortly after the sixtieth day of life. Only those exhibiting a typical resorption were now employed to trace the distribution and abundance of the new food factor E in natural foods. Shortly after the failed or resorption gestation a small amount of a single natural food stuff was now added to the ration or fed separately from it and the fate of the next gestation followed with similar care. In many instances a normal sized litter of vigorous young resulted. In others, no alteration of the sterility was secured. We have thus charted the considerable and inconsiderable possession of E on the part of common foods. It is present but never highly concentrated in a great variety of animal tissues, musculature, fat and viscera, included in the latter being pancreas, spleen, liver, heart, hypophysis and placenta. One of the most remarkable things about the content of E in animal tissues is the fact that the vitamin is low in the viscera. It is lower in the liver than in the musculature. A daily feeding of half the total liver of rats reared on natural foods will not invoke fertility. There is failure also when the entire heart, spleen, brain, kidney or testes are fed daily. The musculature and fat, on the other hand, while not a concentrated source of E, contain in their totality several times the minimum requirement for a successful gestation. E is present but extremely low in milk fat.

Cod liver oil, though high in vitamins A and D, is notably lacking in E. Throughout the life of animals, 9 per cent. by weight of the ration may be constituted by cod liver oil, a single drop of which daily is adequate for A requirements and yet sterility results. In contrast with the paucity of E, even in its most abundant depots in animal tissues, is its concentration in the organs of certain plants, especially in seeds and green leaves. It can be demonstrated to be unhurt after careful desiccation of such leaves (lettuce, alfalfa, pea, tea). Thus in a series of experiments, one and one half, one half and finally one fourth gram daily of the lettuce leaf powder proved efficacious in cures. E is high in some cereals. We have found it in oats, corn and especially wheat, where it is low in the endosperm, but concentrated in the embryo. The richness of wheat germ in E is extraordinary. We have found no other naturally desiccated substance comparable to it in value; 250 mg. daily evokes cures. In the case of both wheat germ and lettuce leaf, ether extraction of the carefully desiccated substance removes E quantitatively and secures for us oils which are efficacious in *daily*, single drop (25 mg.) administrations. E is probably present in most commercial oils so that when the latter constitute a high proportion of the diet, for instance, when fed as 15 per cent., displacing lard, fertility results.

We have completed a series of cannibal experiments. Sterile females reared upon "pure" food régimes were sacrificed daily and their tissues (liver, musculature and fat) fed to other females reared in an identical fashion and likewise of proven sterility. At the same time, normal females of proved fertility were similarly sacrificed and fed to other sterile "pure" food females. In all instances, the tissues of rats reared on a natural food régime were able to invoke fertility in their sterile sisters. Of even greater significance would seem the demonstration that in no instance could a cure be obtained by the administration of the same tissues from sterile females.

If animals are reared on a diet of natural food stuffs and after their fertility is established, shifted to a pure food ration, they preserve their fertility for three or four months, when they lose it. Similarly, when sterile animals are cured with foods possessing the new vitamin, not only is the next gestation normal, but in some circumstances, the next two or three gestations.

Vitamin E is transferred from mother to offspring during intra-uterine life, for the tissue of new born rats acts as a cure of female dietary sterility.

An excess of E can not increase fertility beyond normal limits. The administration to sterile animals of foods or extracts of foods known to be twice to twenty times as rich in vitamin E as is required for the birth of living young does not increase litter size or weight or in other ways improve the performance of the reproductive mechanism beyond the normal limits.

The symbiosis between termites and their intestinal protozoa, and the toxicity of oxygen for protozoa: DR. L. R. CLEVELAND, National Research Fellow, at the Johns Hopkins University. The intestines of all wood-feeding termites are teeming with countless millions of large

flagellate protozoa, which digest wood for themselves and for their hosts, the termites in which they live, move and have their being. This protozoal horde may be removed from the termites by incubation, by starvation and by oxygenation, and neither method of removing the protozoa kills the termites, but they are not able to live more than three to four weeks after their protozoa have been taken from them. Give the protozoa back, and they will live indefinitely. The protozoa can not live outside of termites. The termite intestine is their gastronomical paradise. Here, then, is an ideal partnership; it is impossible for one partner to live without the other.

Cockroaches harbor two kinds of ciliate and two kinds of flagellate protozoa, all of which may be removed by confining the cockroaches in oxygen, and the confinement does not injure them at all. But cockroaches, unlike termites, are able to live indefinitely after their protozoa are taken from them. The protozoa of many other, probably all, insects may be removed by oxygenation. Oxygenation, then, will be of great value in working out the exact rôle that insects play in the transmission of protozoa from man to man, from animal to man, from animal to animal, from plant to plant, and from plant to animal.

All the protozoa of earthworms, salamanders and fish may be removed by oxygenation, and without injury to the earthworms, salamanders and fish. There are many protozoan diseases of fish which oxygenation will very probably cure.

Frogs harbor many different kinds of intestinal protozoa (often seven different genera are present in a single host), all of which are killed when the frogs are confined in oxygen, and, as in the case of other animals, without injury to the frogs.

It is highly probable that all intestinal protozoa may be removed from all invertebrates and from all cold-blooded vertebrates by oxygenation, and that none of these hosts will be injured. Pure oxygen is toxic for all forms of life and especially so under pressure, but at 3.5 atmospheres it is very much more toxic for the protozoa of these animals (invertebrates and cold-blooded vertebrates) than for the animals themselves; in some instances the protozoa are all killed in less than one hundredth the time required to kill the animal in which they live. In other words, oxygen is more than one hundred times as toxic for the parasites as for the hosts. Why is this true? It is very probably due to the fact that the protozoa have acclimatized themselves to an environment with a small amount of oxygen, very much smaller than that of their host, and when placed in an environment (*i.e.*, when oxygenated) with much more oxygen they are unable to stand the change, because the change for them is far greater proportionally than for their host, and they die, while their host is unaffected.

Such a physiological difference between hosts and parasites is taken advantage of here for the first time to free animals of their protozoan parasites, and it may be possible to take advantage of it to a still greater extent and free animals and plants of other parasites, inclusions, bodies and agents by oxygenation.

Some concurrent changes involving the newer aspect of the sex problem: DR. OSCAR RIDDLE, Carnegie Institution's Department of Genetics. Investigations conducted during recent years provide a considerable body of data—obtained particularly on frogs and birds—which indicate that the normal chromosomal control of sex may be completely reversed by special conditions; and that the several special means employed to effect such sex-reversal really become effective through pronounced and prolonged changes of metabolic rate in the developing organism. This is designated the "newer aspect" of the sex problem; the facts concerning the usual or normal control of sex by the sex chromosome mechanism may be regarded as the older and now well-established aspect of the sex problem. Facts of the latter kind lie wholly within the field of genetics; but the available data on the newer aspect of sex are principally facts of biochemistry, physiology and embryology, and only in small part are they genetic data. One object of this presentation is to supply evidence that a newer aspect of the sex problem now exists.

If metabolic distinctions of sex are even more fundamental than are chromosomal differences it might be possible, in specially suitable material, to associate seasonal changes in sex ratios and other sex phenomena—as these have earlier been found in pigeons—with parallel seasonal changes in the metabolism of the parent animals. Besides the nervous system the organs now believed to be chiefly responsible for effecting variations in metabolic rate are the thyroids and suprarenals. Data showing the monthly and seasonal size changes in the thyroids of three kinds of pigeons have now been obtained. Curves constructed from these data show that the thyroids are notably larger during autumn and winter and become reduced in spring and are lowest in summer. Three kinds of sex data previously obtained—and earlier partially described as indicating a relation of metabolic rate to sex—have now been classified according to the seasonal changes in thyroid size. This grouping of those earlier results shows:

(1) As obtained under the breeding methods practiced by us the sex ratio varies with the seasonal fluctuations in thyroid size. The highest proportion of males corresponds to the period of largest thyroids; the highest proportion of females to the period of small or smallest thyroid size. (2) Seasonal changes in the storage metabolism within pigeon ova, as measured by burning the yolks in a bomb calorimeter, also parallel the changes in thyroid size. Least storage is found in winter; most in summer and early autumn. (3) A small seasonal difference is found for the percentage of alcohol-soluble material stored in the ova of pigeons. The lower percentage of fat corresponds to periods of larger thyroid size; higher storage values are associated with smaller thyroid size.

Concurrent changes are thus found in four kinds of data concerning metabolism on the one hand and sex on the other. Some deviations from the above stated rules are found, these chiefly and rather consistently concern the autumn period. It is suggested that this discrepancy may result from the prolonged hypertrophy of

the suprarenals which has earlier been shown to accompany continuous egg-production in pigeons. It is not considered probable, however, that the seasonal fluctuations of thyroid size which doubtless occur in higher animals generally have any influence on the sex ratio under normal conditions. These results have been observed only under special experimental conditions, and even here the relation of thyroid size of parent to sexuality in the offspring is not regarded as simple or direct.

These data demonstrate the practicability of dealing with the sex problem by biochemical and physiological methods. They bring the results obtained on the pigeon and the frog into clearer harmony—Adler having ascribed a male-determining action to the strongly acting thyroid in tadpoles arising from "over-ripe" eggs. The results appear to provide new information on the intimate nature of sex. They also probably permit a closer view of the way in which the sex chromosomes perform their normal function.

Experimental chemical and bacteriological pollution of wells via the ground water route: PROFESSOR C. W. STILES, U. S. Public Health Service. In the prevention of hookworm disease, excreta-disposal is of fundamental importance, especially in connection with the possibility of infecting water supplies. The views sanitarians have held on this subject have been so divergent that an extensive series of experiments were undertaken in order to uncover the underlying principles involved. The experimental field, with about 500 experimental wells, is isolated far from habitations so that the danger of spreading infection has been eliminated. In these experiments, pollution, both chemical and bacterial, was placed in the ground. The chemical pollution has been recovered in wells up to a distance of 414 feet, and the bacterial infection 232 feet, away from the point it was placed in the ground. These results effectively dispose of the claim that bacteria can be carried only a few feet under ground. It has been proved that the pollution extends only in one direction, namely, in the direction of the ground water flow; it floats in a shallow band at the top of the ground water table. During dry weather, when the water level falls, the bacteria tend to filter out into the soil; during wet weather the water level rises, picks up the bacteria, and carries them further; if dry weather continues sufficiently long, the bacteria die. Under favorable conditions, however, the bacteria have lived under ground up to 2 years and 8 months, and chemical pollution put in the ground 2 years and 9 months ago is still being recovered from the wells. Thus, the rise of the ground water, due to rain fall, results in spreading underground pollution to the wells while the fall of ground water, due to continued dry weather, results in purifying the ground water supply. The principles uncovered by this investigation have their practical application in sanitation, not only as respects the distance but also the location of wells from possible sources of pollution. Further they show that the circular type of sanitary devices is safer than the almost universally adopted quadrangular type.

A banana in the Tertiary of South America: EDWARD W. BERRY, The Johns Hopkins University. The original home of the banana (Musa) has always been a disputed problem, most authors inclining to the belief that it was in the southeastern Asiatic region, since there are so many cultivated varieties as well as wild forms in that region at the present time, and since the equivalent word occurs in the Sanscrit, Arabic, etc.

More particularly botanists have, almost without exception, disputed that the genus Musa was indigenous in the Western Hemisphere, or was cultivated here prior to its introduction into Hispaniola from the Canary Islands in 1516, as related by Oviedo in 1556.

Alexander von Humbolt was the first to question this belief and to maintain that the banana was probably a native of America in pre-Spanish times, and in recent years O. F. Cook has argued that it was an aboriginal American crop-plant, originally cultivated as a root crop, the valuable pulpy fruits, normally seedless, being a result of hybridization, since the so-called wild seed-bearing species have non-edible fruits more or less similar to the capsular fruits of all the other genera of the family.

I have received the fossil seeds of a species of Musa from Dr. Maurice A. Rollot, who collected them from the coal measures of the Cerros de Guadalupe and Montserrate which form a part of the eastern upland border of the Sabana of Bogota in Colombia. The altitude is about 9,000 feet and the geological horizon is probably Oligocene, although there is some doubt as to its precise age.

These more or less compressed and highly lignified fossil seeds are larger than those of any of the existing Malaysian species known to me, but may be matched by the seeds of several existing African species, among which they most resemble those of the so-called Abyssinian banana, *Musa ensete* Gmelin.

Banana-like leaves, described as Musophyllum by paleobotanists, have long been known from the Tertiary of the United States, Europe, Central and South America, but it is altogether impossible to distinguish the leaves of Musa from those of the exclusively American genus Heliconia. In the case of the seeds, however, this uncertainty disappears, since the seeds of Musa are perfectly characteristic and strikingly different from those of all the other genera of the family.

The present discovery shows that Musa was a member of American Tertiary floras and although it does not necessarily prove that the banana was brought into cultivation by the aborigines of the western hemisphere, it lends probability to such a belief, and in a measure serves to substantiate statements to this effect made by Garcillaso de la Vega and Montesinos in the early part of the sixteenth century.

Outlines of the history of the recent fauna of Palearctic Asia: PROFESSOR PETER P. SUSHKIN, Russian Academy of Sciences. I wish to thank the local committee of the academy for the opportunity of presenting to you my views concerning the history of the recent fauna of Siberia and High Asia. These views are the result of studies based in part on my field work in the

Kirghiz Steppe, in southern Siberia, and in N. W. Mongolia. At present, most zoogeographers adopt the divisions of Palearctic Asia into two subregions; the northern, which extends across the Eurasian continent from the Pacific to the Atlantic, and the more southern, or High Asian.

Starting with the study of birds, I have found that nearly one half of the fauna of every locality in Palearctic Asia consists of species which may be termed Transpalearctic, since they extend from ocean to ocean: some of them are also widely distributed from north to south, whereas others are restricted to one of the zonal provinces. The remainder consists of groups of more restricted distribution. For Siberia, leaving out the Transpalearctic elements, the important groups are: on the east, the Transyenissean, or East-Siberian, group with its subdivisions, and on the west, the West-Palearctic and West-Siberian groups. The demarcation line between them runs, roughly speaking, along the Yenissei River and then sweeps westward round the Altai highland. I have found that the Transyenissean species are strongly characterized, some presenting characters of relatively high antiquity; moreover, this group is intimately connected with the fauna of High Asia, many species reaching southward as far as the southern limits of the Palearctic; some of the Transyenissean forms are surely of southern origin. On the other hand, the fauna of western Siberia is in the main common with that of Europe; its distinctive forms are not numerous and are feebly characterized.

These facts find no explanation in recent conditions, but they are in full harmony with the paleogeography of these regions. The Transyenissean elements, strongly characterized, with features of antiquity and presenting relations to the fauna of High Asia—in spite of present differences of physical geography—correspond to the territory of that part of the Eurasian dry land which is known as the Angara continent. Western Siberia is a new dry land which emerged only at the beginning of the second half of the tertiary, and underwent considerable restriction of its area in later times. With this corresponds the paucity and prevailingly youthful character of its endemic forms. The transpalearctic distributions which prevail now are features of a later time, and for some of the animals involved traces of their Angaran, or western, origin may be found.

The fauna of High Asia is also strongly characterized, harmonizing well with the old age of this dry land. Prevalent in the fauna are biological types characteristic of desert, of mountain, and especially of dry highland. Sharp characteristics, and in some cases geographical distribution, of these biological types tell of a long duration of recent conditions. But at the same time the distribution of the fauna presents many gaps and many isolated remnants, these isolated colonies often having failed, as yet, to develop local characters. And all species which present an interrupted distribution are types characteristic of a more fertile landscape. These facts tell clearly of the extensive devastations to which the fauna has been recently subjected.

My interpretation is that present ecological types and corresponding environment are of an old origin, but that their present dominance is a new fact. I deny completely the theory of a large inland basin within the territory of High Asia in the Tertiary, and I consider the country as having presented the conditions of a continental climate, the land being more fertile, though with patches of desert here and there, and the rainfall more abundant than now.

M. Severtzoff and Professor Nassonov, after studying the distribution and structure of the wild sheep, have both come to the conclusion that this genus migrated from High Asia to America before the last glaciation; that in America they were driven south by the glaciation, that afterwards the American stock spread again to the north and gave origin to another group; and finally that this new group spread back into the Asian continent and occupied eastern Siberia, so that the present Siberian sheep stand, geographically and structurally, in no close relation with the sheep of High Asia. It may be mentioned that a similar course of migration is now admitted for certain human tribes.

The origin of species as revealed by vertebrate paleontology: A rejoinder to William Bateson: DR. HENRY FAIRFIELD OSBORN, American Museum of Natural History. This is a paleontological rejoinder to Bateson's Toronto address of 1921 in which he stated as the result of twenty-five years of genetic research: "Variations of many kinds, often considerable, we daily witness, but no origin of species. . . . That particular and essential bit of the theory of evolution which is concerned with the origin and nature of *species* remains utterly mysterious." Bateson and his school have been endeavoring to interpret the past by the present; the time has now come in biology to reverse this doctrine and *interpret the present by the past.* In paleontology we observe secular evolution and the adaptive action and reaction of the heredity germ to physical environment, to living environment, and to habit, under Osborn's principle of tetraplasy in form, tetrakinesis in function.

In biomechanical adaptation as observed in continuous genetic phyla of both invertebrate and vertebrate animals, the evolution of the germ-plasm can be continuously traced and is found to conform to nine chief biomechanical adaptations. Five of these principles have been discovered between the time of Aristotle and the present among living animals and confirmed among extinct animals. These are as follows: (1) Motion or function invariably precedes form; change of motion or function precedes change of form, just as in the inorganic world energy directs matter, not matter energy, as first observed by Aristotle. (2) The principle of compensation or economy of growth as defined by Aristotle and later by Geoffroy St. Hilaire. (3) The principle of biomechanical continuity discovered by the invertebrate paleontologist Waagen and confirmed by Osborn in the Titanothere Monograph. (4) The principle of germinal trend in a definite direction implied by Waagen and expressed by the Austrian paleontologist Neumayr in the term "mutationsrichtung." (5) The principle of acceleration and retardation observed by Von Baer in

embryology and elaborated in paleontology by Alpheus Hyatt. (6) The principle of allometry or change of proportion, the chief source of the origin of genera and of species, observed by Lamarck and Darwin and elaborated by Osborn in the Titanothere Monograph. (7) The principle of rectigradation of adaptive organs observed by Cope and elaborated by Osborn, confirmed in the primates, the horses, the rhinoceroses, the titanotheres, and the proboscideans; the second source of the origin of species. (8) The principle of experimental adaptation observed in the lower organisms in zoology, confirmed in the higher organisms like the primates and ungulates in paleontology; this principle accounts in part for the extraordinary divergence and diversity of the mammalian kingdom. (9) The principle of adaptive radiation, an elaboration by Osborn of Lamarck's *ébranchement* and of Darwin's "divergence." Under this principle as developed by Dollo and Osborn fall the biomechanical processes of homoplasy of Lamarck, of convergence, of alternating habitat elaborated by Dollo.

Four of these nine biomechanical principles are observed in paleontology only, which reveals the secular evolution of the germ-plasm, and could never be discovered in zoology, which reveals only the transitory fluctuations of saltations of the germ-plasm. These nine principles include exactly the modes by which new mutations, new species, new genera, new families and new orders of vertebrates arise. These principles of the origin of species are not theories or hypotheses, they are facts so clearly and repeatedly revealed that we can safely predict not only what the origin of the next species and genus will be like, but where this species or genus is likely to be found and in what stage of evolution it will be found. What really happens in the natural biomechanical origin of species is this: Whenever all the four energetic conditions of heredity, of environment, of biota, of habit or ontogeny, and the non-energetic condition of the struggle for existence (selection) are the same, we observe that there arises similar ascending mutations, species, genera, families, whether in France, in central Mongolia or in our own western territories. New similar species will arise at approximately, if not at precisely, the same rate, whether we observe them in France, Mongolia or our Rocky Mountain region.

Thirty-six years of intensive paleontological research have solved the question of the biomechanical origin of species and there is little to be added by discovery. Whether or not biophysical and biochemical specific characters arise according to similar principles remains to be demonstrated.

Method of determining and measuring the associative relations of species: PROFESSOR S. A. FORBES, University of Illinois. It is the object of this paper to describe and illustrate a method by which ecological affiliations and groupings may be accurately shown of species whose powers of locomotion and habits of migration make it impossible to study them by simple local inspection as may be done with stationary plants.

The materials necessary are numerous collections (as of fishes or insects), as nearly alike as possible, or observations (as of birds) so made and recorded as to show the numbers per square mile or other unit of area of each species in each habitat.

The method proposed is based on the obvious idea that the frequency with which species are found together in collections or by observations may be made a measure of their ecological affiliation, provided that joint occurrences due to mere chance or random distribution are distinguished and separated from those having an ecological origin. This requires for each pair of species studied a computation of the number of chance joint occurrences to be expected in each situation and a comparison with the number of actual joint occurrences observed. If these numbers are approximately equal no ecological affiliation of the species is indicated. If the actual is larger than the chance number, the difference is a measure of such affiliation and if it is smaller the species are being drawn apart into different environments.

By the use of the calculus of probabilities a coefficient of association is readily found for any two species which is a measure of the degree of ecological affiliation between them. This coefficient is expressed by the formula $\frac{ad}{bc}$; a being the total number of collections or observations made, b the number containing the more abundant, and c the less abundant species, and d the actual number of joint occurrences of the two species in the same collection or observation. Under the notation $\frac{bc}{a}$ = the number of chance joint occurrences to be expected and $\frac{d}{\frac{bc}{a}}$ or $\frac{ad}{bc}$ is the ratio of this number to the actual number of joint occurrences.

Such a coefficient taken by itself is unsatisfactory as a measure of ecological affinity unless the length of the series is known of which it is a part, and for this an expression for complete association of two species is necessary such that wherever one occurs the other may be expected also. This maximum possible number of joint occurrences in any case is the number of occurrences of the less abundant species (c), and $c - \frac{bc}{a}$ is an expression for the largest possible number of ecological joint occurrences in the case given, $d - \frac{bc}{a}$ represents the *actual* number of ecological joint occurrences and the quotient of the former divided by the latter is the ratio of the actual to the maximal number. The working formula consequently is not $\frac{ad}{bc}$ but $\frac{d - \frac{bc}{a}}{c - \frac{bc}{a}}$ by the use of which the ecological affiliation of pairs of species can be accurately expressed; and by a systematic tabulation of such ratios the affiliations of a group of species may be completely shown. Examples of such tables for collections of fishes and birds and of their use in forming ecological groups are given as illustrations of the method and of its product.