SCIENCE

VOL. LXXI FRIDAY, JANUARY 3, 1930 No. 1827

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal
Lancaster, Pa. Garrison, N. Y.
Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

THE DISCOVERY OF TERTIARY MAN[1]

By Dr. HENRY FAIRFIELD OSBORN

RESEARCH PROFESSOR OF ZOOLOGY, COLUMBIA UNIVERSITY, HONORARY CURATOR OF VERTEBRATE PALEONTOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

THE discovery of Quaternary man was the central biological achievement of the nineteenth century. For twenty-four centuries the largely speculative idea of a natural rather than a supernatural origin of man had been slowly developing through the observations of zoologists and the dissections of comparative anatomists. From the time of Anaximander (547 B. C.), of Galen (131 A. D.), of Leibnitz (1700), of Buffon (1755), of Goethe (1790), of Erasmus Darwin (1794), of Lamarck (1809), of Chambers (1844), of Leidy (1847–1873) to that of Charles Darwin (1859–1871), one bit of evidence after another was added from comparative anatomy, until in the sixteenth century comparative zoology contributed the strong likeness to man of the anthropoid apes—the chimpanzee and gorilla of Africa, the gibbon and orang of eastern Asia. The most significant and prophetic observations in comparative anatomy were those of Goethe in the discovery of a separate intermaxillary bone in the upper jaw of man which both he and Leidy rightly interpreted as linking men with the apes and other primates in which the upper jaw is composed of two bones. Up to 1859 the relatively new science of paleontology had contributed nothing, because the female Neanderthal skull of Gibraltar in 1848 and the male Neanderthal calvarium of Germany in 1856 were misinterpreted by Virchow, Huxley and other anatomists.

I emphasize comparative anatomy and zoology, for as regards *direct* evidence our speculative position toward Tertiary man in 1929 is very much the same as Lamarck's and Darwin's speculative position toward Quaternary man between 1809 and 1871, because we are still largely dependent upon the facts afforded by

[1] Address of the retiring president of the American Association for the Advancement of Science, Des Moines, December 27, 1929.

comparative anatomy and comparative zoology, in the absence of direct paleontologic evidence in Middle and Lower Tertiary time. This statement is not true as regards *indirect* evidence, for human paleontology is now in a very strong position even to the very base of Quaternary time, a period estimated by geologists at 1,250,000 years. Fossil human remains of over 100 Quaternary individuals have been found including: *Palaeanthropus neanderthalensis* of Neanderthal, 48+; *Homo sapiens* of Cro-Magnon and Chancellade, 42; 2 of the Trinil race of Java, *Pithecanthropus erectus;* 2 of the Piltdown race, *Eoanthropus dawsoni;* 1 of the Heidelberg race, *Palaeanthropus heidelbergensis,* also 1 and possibly 2 more individuals recently reported by Freudenberg under the name *Hemianthropus;* 27 of the recently discovered Chinese *Sinanthropus pekinensis* (Schlosser, 1903; Zdansky, 1926; Black, 1927–1928). All these human fossils constitute a firm and broad human paleontology for Quaternary time and the close of Tertiary time. Each generic name, *e.g., Palaeanthropus, Pithecanthropus, Eoanthropus, Sinanthropus* and *Homo,* demonstrates an entirely distinct branch of the fossil human families of Quaternary time; each branch is known to paleontologists as a *phylum,* and the special scientific analysis of these several branches is termed *phylogeny.* Phylogeny is a relatively new and very important branch of biology, the principles of which were entirely unknown to Darwin (1859–1871) and only in part known to Huxley, as they are now revealed by the brilliant and world-wide discoveries by invertebrate and vertebrate paleontologists. My forecast of the Tertiary anatomy and habits of the "dawn-man" is greatly influenced by our direct knowledge of the phylogeny of other mammals.

As Quaternary fossil man was the central biological contribution of the nineteenth century, so Tertiary man constitutes the goal and peak of biological discovery in the twentieth century. Thus far I have been dealing with well-known facts because these Quaternary fossil men have become household words all over the world. On the other hand, the discussion of Tertiary man carries us into the unknown, into one of the most interesting fields of human speculation and anatomical controversy, into several divergent camps of human opinion and interpretation, along several great lines of comparative anatomy of the principal organs concerned, namely, the brain, the skull and jaws, the limbs, the hands and feet. Both with Lamarck and Darwin the "ape-man" descent was never more than a working hypothesis based upon the closer approach of the anthropoid apes to man than that observed in any other group, for want of any positive data. Both Lamarck and Darwin postulated a *reversible* evolution in function and structure whereby an animal with all the psychical and anatomical adaptations of arboreal apes could secondarily take on a gradual change of habit and function and gradually enter a new erect career with radical changes in habit and in mind as well as in the anatomy of limbs, hands and feet. Darwin's starting-point (1871), after picturing as our ancestor a hypothetical ape not far from a primitive Miocene chimpanzee, concluded with the following all-important sentence both as to habit and habitat:

The foot was then prehensile, judging from the condition of the great toe in the foetus; and our progenitors, no doubt, were arboreal in their habits, and frequented some warm, forest-clad land.

Quite recently (August, 1927), before the British Association, President Keith summed up this hypothesis as follows:

DATE OF MAN'S EMERGENCE. It is useless to go to strata still older than the Miocene in search of man's emergence; in such strata we have found only fossil traces of emerging anthropoids. All the evidence now at our disposal supports the conclusion that man has arisen, as Lamarck and Darwin suspected, from an anthropoid ape not higher in the zoological scale than a chimpanzee, and that the date at which human and anthropoid lines of descent began to diverge lies near the beginning of the Miocene period. On our modest scale of reckoning, that gives man the respectable antiquity of about one million years.

This Lamarck-Darwin working hypothesis has been greatly strengthened and in large measure adopted by an army of human and comparative anatomists including all the leading and most brilliant men of our time such as Sir Arthur Keith (1927), Dr. G. Elliot Smith (1926–1929), Professors William King Gregory, Dudley J. Morton and Robert M. Yerkes, as well as by a host of other able but less widely known anatomists. So great has been the force of nearly unanimous adherence to the Lamarck-Darwin hypothesis that it has gained world-wide acceptance even among the most intelligent scientists, as may be seen in passages in two outstanding works of the present decade, Eddington's "The Nature of the Physical World" (1928) and Jeans's "The Universe Around Us" (1929). A parallel instance of the world-wide assumption of a working hypothesis is that of Lamarck's hypothesis of the inheritance of acquired characters as the prime cause of evolution. Although never demonstrated, the Lamarckian hypothesis was universally accepted until Weismann gave it a death blow in 1880. Such may be the fate of the "ape-man" hypothesis.

I was myself rather suddenly converted to the opposite "dawn-man" hypothesis in a roundabout manner. When in 1919 after years of search the American Mu-

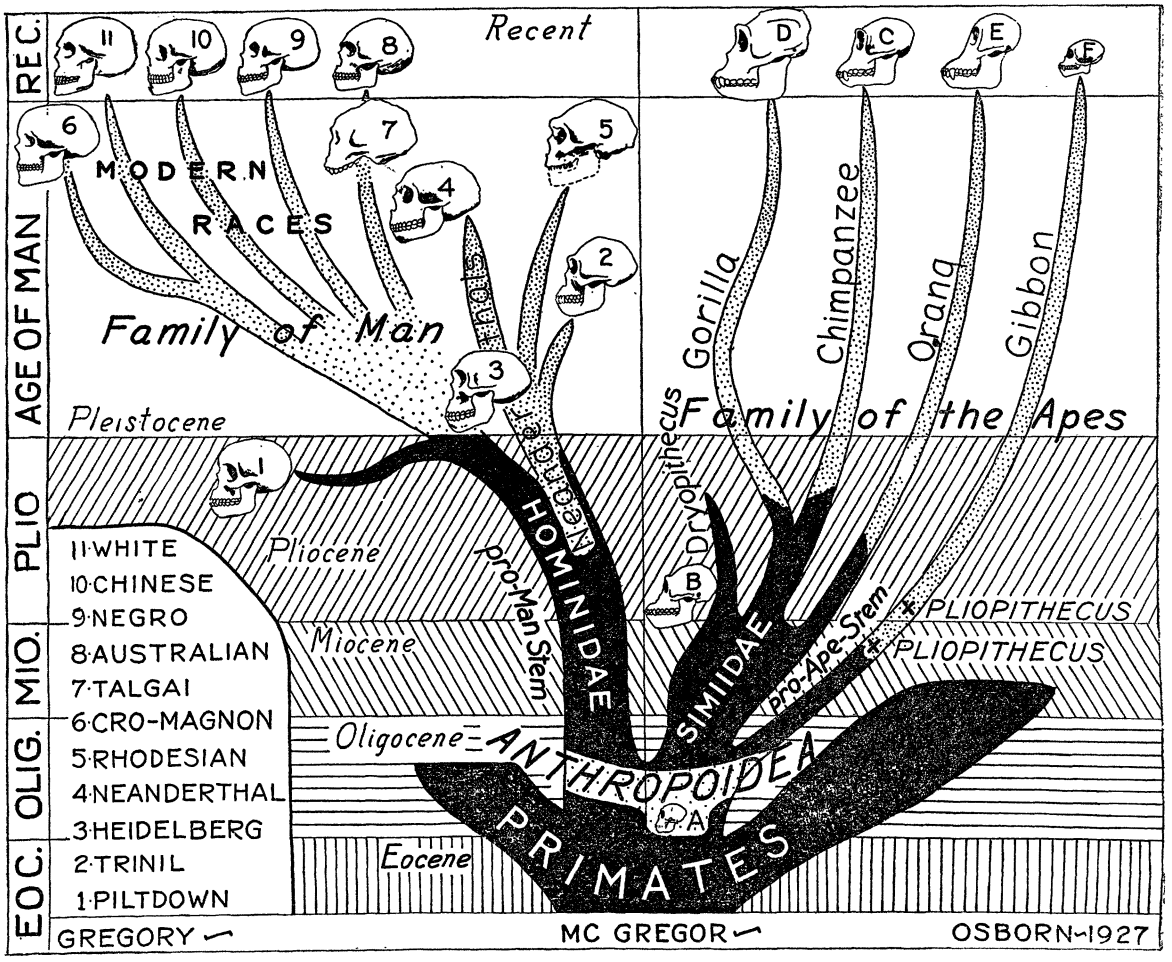

FIG. 1. OSBORN'S PRESENT THEORY OF THE ASCENT AND PHYLOGENY OF MAN.

Left: Family of Man (*Hominidae*), dividing into the Neanderthaloid and modern racial stocks; present geologic location of the Piltdown, Heidelberg, Trinil, Neanderthal and Rhodesian fossil races. Right: Family of the Apes (*Simiidae*), including the Pliocene and Miocene dryopithecoids nearest the ancestral stock of the Anthropoidea, also the lines leading to the gorilla, orang, chimpanzee and gibbon. Below: Anthropoidea, the common Oligocene ancestors of the *Hominidae* and of the *Simiidae*.

seum discovered in Middle Pliocene time the complete skeleton of a horse, named *Pliohippus leidyanus,* a perfect horse in all except name and perhaps color, the bearing of this case of precocious adaptation on human descent flashed across my mind, and before a meeting of the National Academy of Sciences I predicted that the greatest surprise in store for twentieth-century science would be in the discovery of a large-brained Tertiary man! This anatomical prophecy has unexpectedly been confirmed by recent paleontologic evidence that *Eoanthropus,* the "dawn-man" of Sussex, is of Upper Pliocene or Tertiary age.

The large brain of *Eoanthropus* suggests as our first quota of counter-evidence a review of our greatly enriched knowledge of the Quaternary fossil brain.

BRAIN SURPRISES OF QUATERNARY DISCOVERY

These surprises arise from the profound researches and independent discoveries of Dubois, Smith Woodward, Boule, Keith, McGregor, Black, Economo and Leboucq, to which honor roll we should add Frederick Tilney's "The Brain from Ape to Man" (1928). The six outstanding points as to the brain are as follows: (1) that certain races of fossil man of the last 1,250,000 years had a brain cube equal to or greater than that of modern man; (2) that the much-despised cave man (*Palaeanthropus*) was inferior to ourselves neither in brain cube nor in hand ability, although far inferior to ourselves in civilization; (3) that certain of the cave men (*Homo sapiens,* Cro-Magnon) were our superiors both in average brain capacity and in average artistic ability; (4) that at the close of Tertiary time there lived a race (*Eoanthropus dawsoni*) with a brain cube equal to the minimum of that of the living Veddahs, Papuans and native Australians; (5) that the ratio of human brain weight to body weight in Quaternary time was apparently the same as it is to-day, namely, 1:50

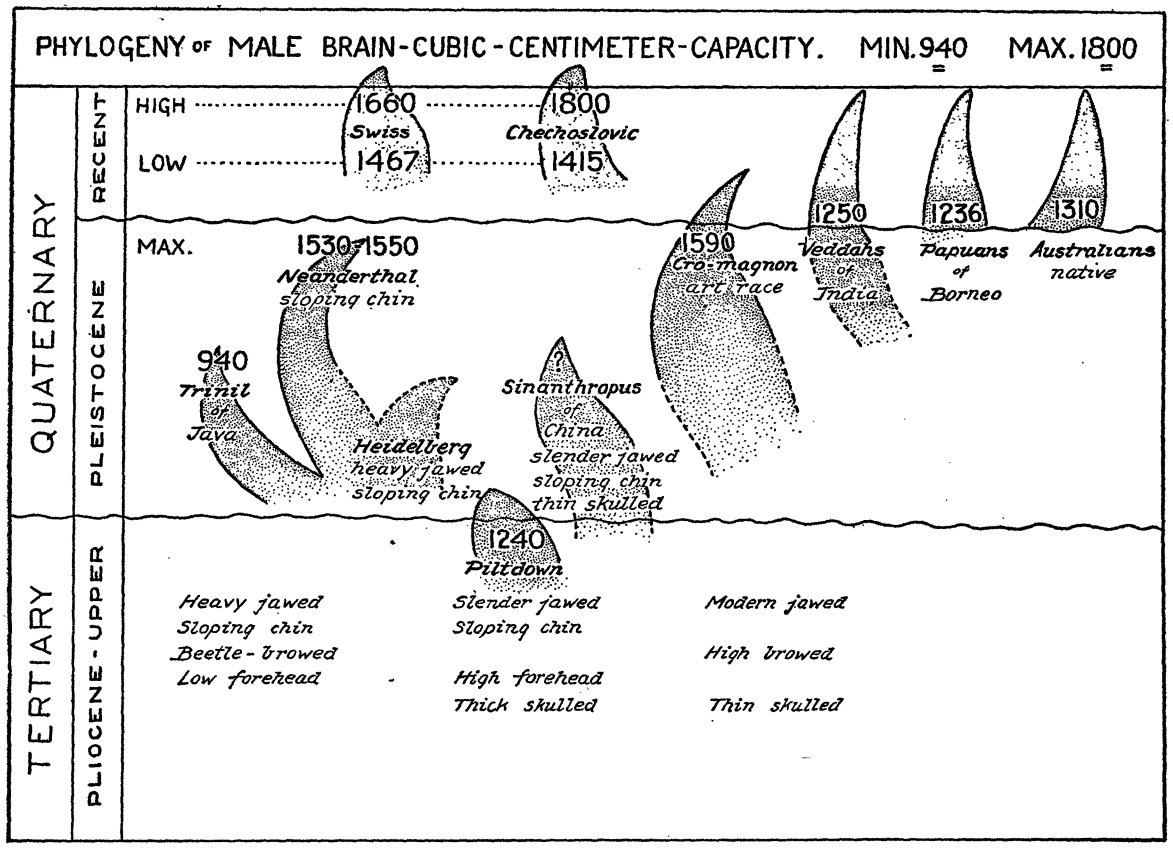

FIG. 2

(Weber, 1896), in contrast to the anthropoid apes, in which it is as follows:

	Brain to body weight ratio
Super-arboreal Gibbon of southeast Asia (130 gr.)	1: 66 or 1: 73
Arboreal Chimpanzee of west Africa (412 gr.)	1: 51 or 1: 61
Super-arboreal Orang of Borneo (400 gr.)	1: 183 or 1: 194
Terrestrial-arboreal Gorilla of central and west Africa (565 gr.)	1: 150 or 1: 200

(6) as Dietrich has shown, *Pithecanthropus*, the Trinil race of Java, is not an ancestral Pliocene type, as was formerly supposed, but a surviving mid-Pleistocene branch, the companion of a stegodont elephant; the Trinil brain is a case of arrested development.

The conclusion is inevitable that *the main cubic evolution of the human brain took place during antecedent Tertiary time and not, as we formerly thought, during the Quaternary Age of Man or Glacial period.*

These six points are supported by the following comparison:

	Brain cube in cc
Summit of Quaternary and *Modern* time:	
Homo sapiens, Cro-Magnon of Mentone	1550
Palaeanthropus, Neanderthal Caveman, La Chapelle-aux-Saints	1530
Homo sapiens, average modern Swiss	1467
" " average modern European	1450
" " Alpine race of Czechoslovakia	1415
Homo sapiens, fossil Alpine race of Ofnet	1400
Homo sapiens, native Australian race	1310
" " native Indian Veddahs	1250
Mid-Quaternary:	
Pithecanthropus erectus (Trinil man of Java)	940
Summit of Tertiary:	
Eoanthropus dawsoni (Piltdown Dawn Man)	1240
Living Papuans of New Guinea	1236

It is well known that the *brain cube* is not a reliable test of brain power or capacity, as Leboucq has recently pointed out in striking examples from recent times:

	Brain weight in grams
Tourgenieff, Russian novelist	2,012
Cuvier, founder of paleontology	1,829
Byron, poet	1,807
Gambetta, statesman	1,246
Anatole France, littérateur	1,017 (to 1,317)

Doubtless this *cube-versus-intelligence* disparity in brain function also prevailed during the Quaternary Age of Man, although in the few fossil cases where comparison is possible we note a similar disparity between male and female brain weight.

We must therefore adduce collateral and very substantial proof that Upper Tertiary man, whom we may provisionally designate "the dawn man" after Smith Woodward's well-chosen term *Eoanthropus,* made highly intelligent use of his 1,240–1,300 cubic brain measurement.

This brings us to the most startling discovery of the twentieth century, the full significance of which we have only recently learned to estimate.

The First Positive Discoveries of Tertiary Man

Archeologists are still divided as to the human origin of *eoliths,* so that we can not class these rude flints as positive evidence.

One of the most striking coincidences in the history of human paleontology is that indubitable flint implements of Tertiary men were discovered by J. Reid Moir on the east coast of Anglia in the year 1909 and that in 1911, only two years later, an indubitable human skull and jaw of what proves to be Tertiary man were found in Piltdown, Sussex, by Charles Dawson. It has required eighteen years of research by Moir and Smith Woodward, aided by the most able archeologists and anatomists of the world, to establish the full significance of these epoch-making discoveries of 1909–11. By adding year by year implement after implement from two strata of Upper Pliocene time, J. Reid Moir, originally an amateur collector of Ipswich, has finally overcome all incredulity and even hostility and has thoroughly established the Red Crag and sub-Red Crag strata of the Upper Pliocene coast of Anglia as the site of a widespread and highly varied flint and bone industry, including the "eagle's beak" (rostro-carinate), "skin cutter," "side scrapper," "push plane," "borer" and "chopper" and "piercing tool," all indicating a race of hunters highly adept at flint flaking; finally, for killing purposes, a perfected "sling-stone," ranking as a work of Paleolithic art. All these artifacts have been confirmed and recently embodied in the Stone Age chronology of Abbé Henri Breuil (December, 1929). Breuil not only accepts the Tertiary age, but in his latest paper (December, 1929) shifts the entire pre-Chellean and Chellean flint industries from mid-Quaternary down into the base of Quaternary time, namely, into the first Interglacial or Mindel-Riss stage; this obviously shifts the pre-Chellean and Chellean flint-making design and intelligence down close to Tertiary time—in fact, some of Reid Moir's flints are identical with the Chellean artifacts.

Meanwhile Osborn, by world-wide study of fossil elephants and mastodonts, has firmly established these Reid Moir flint beds as of Upper Pliocene or close of Tertiary time, against the contention of the late Ray Lankester that these flints were early Pleistocene. Hardly less positive is Osborn's determination, with the aid of Reid Moir, Freudenberg, of Heidelberg, Matsumoto, and Bather and Hopwood, of the British Museum, that the Piltdown race—*Eoanthropus dawsoni* of Smith Woodward—is of Upper Pliocene Tertiary age rather than of Quaternary age as formerly supposed.

Both the Red Crag of Suffolk and the Piltdown beds of Sussex yield a very primitive species of elephant generally known as *Elephas planifrons* (first discovered, 1858, by Falconer in the upper Siwaliks of India), whose migrations are now traced from the Vaal River of South Africa (Broom) northward into Italy and England, far eastward into India, with absolutely definite measurement and form of the enameled ridge-plates of the grinding teeth which in the elephants and mammoths give us *a new and quite dependable means of dating all the fossil man discoveries of Upper Tertiary to Recent time.* Upper Tertiary man is thereby shown to have been an elephant hunter, probably for bone and ivory as well as for flesh, over a million years ago. This discovery also paves the way for the great intercontinental migration routes and the African-Eurasian dispersal of man even in as remote a period as the Upper Pliocene.

In view of the fact now established that even in the Upper Pliocene man was an extremely adept flint worker, with deft hands and fingers guided by an imaginative and intelligent forebrain, it seems probable that Upper Pliocene man, like his companion the Upper Pliocene elephant, was already a nomad and needed long and agile lower limbs as his only means of distant transportation. We are thereby forced to reconsider Darwin's concept of the primitive ape-man as inhabiting a "warm, forest-clad land."

Traveling Limbs and Tool-making Hands of Tertiary Man

Fifty-eight years of incessant zoological and comparative anatomical research have been focused upon

the anatomy and embryology of the apes and man to find out the bearing of the recapitulation or biogenetic principle of Haeckel on the ancestral Tertiary hands and feet of man. Recently Morton (1927), Schultze (1925–29), Straus (1927), Gregory (1925–29), Hrdlička (1928), have devoted special memoirs to this problem, Straus summing up in the paraphrased words: The foot of embryonic man is of a structure unfitted for an upright terrestrial existence. It is in most characters not unlike that of an adult gorilla, although in some respects even more primitive than that of the largest anthropoid apes. The chief point of embryonic resemblance is in what Darwin termed "the prehensile big toe," but the paleontologist Matthew (1928) has pointed out that all primitive Eocene mammals, both arboreal and terrestrial, had the big toe well set apart from the others. This stronghold of "prehensile big toe" evidence, therefore, carries man far back of the highly specialized anthropoid ape big-toe stage and tends to sustain the "dawn man" contention that even the embryonic foot of man may date back to the more remote Upper Eocene time.

This contention is even more strongly borne out by the embryonic human hand, in which there is no evidence whatever of having passed through an anthropoid ape limb-grasping stage. While the newest analysis of the embryonic hind limbs may leave us in doubt as to a possible case of reversed evolution from the Miocene ape leg to the human stage, the human hand and the human brain, especially in the light of *Eoanthropus* discoveries, seem to dissipate some of the doubts raised by the feet and strengthen the new "dawn man" hypothesis of a very remote separation of our running and tool-making ancestors of the plateaus and savannas from the same great stock (Anthropoidea) which independently gave rise to the tree-loving anthropoids of the tropics.

No one should misunderstand the "dawn man" hypothesis I have been advocating in a series of papers and addresses since April 7, 1927. I am not ignoring the strong evidence for an Eocene arboreal stage in our ancestry; I am not ignoring the overwhelming evidence of a remote community origin between man and the anthropoid apes; I am combating the special feature of the Lamarck-Darwin hypothesis that man once passed into highly specialized arboreal adaptations attained by the Miocene apes; finally, I am inclined to separate the human stock at a geologically earlier pre-Miocene period of anthropoid evolution. In the geologic remoteness of this momentous separation of the "dawn man" stock we are aided by a mass of collateral evidence utterly unknown in the time of Darwin.

This brings us back to the sub-science of phylogeny spoken of above, which, in popular terms, aims at the reconstruction of the family tree of man by principles recently discovered in the family trees of other mammals.

NEW PRINCIPLES OF PHYLOGENY APPLIED TO MAN

First, we have discovered that the geologic period of separation of the adaptively radiating branches in many families of mammals is of an antiquity undreamt of even a few decades ago. Even in Lower Eocene time all the existing families of hoofed mammals, such as the horses, tapirs, rhinoceroses and titanotheres, had widely separated from each other in tooth, limb, hand and foot structure. Before the close of Eocene time these branches were further subdivided into forest-loving and plateau-loving types; in every branch the forest-loving types were stationary or regressive. Similarly, by the close of Eocene time the mastodont and elephant families are found widely separated into five greater branches (in Oligocene time there were numerous sub-branches and in Miocene time eighteen distinct branches). In the succeeding Oligocene time we discover a sharp and world-wide division between plateau-loving and forest-loving types: in the forests remain all the backward conservative types; on the plateaus and uplands are found the alert, progressive, forward-looking types, including all the long-hind-limbed bipedal animals adapted to rapid progression in an open or partly forested country. It is no exaggeration to say that at the dawn of Oligocene time all the plateau-loving animals are distinctly modernized both in habits and in bodily proportions.

Is it likely that the primates alone escaped this divorce between backward, forest-loving life and forward, plateau, savanna and upland life, especially as Eocene forest areas in every continent began to contract and upland open plains and plateaus began to expand?

A second principle of modern phylogeny is that every ancestral stage, whether of horse, rhinoceros or elephant (the three kinds of animals I have most intensively studied for the past thirty years), preserves the hundred per cent. *structural equipment* for giving rise to its more recent or modernized descendants; each branch has the potentiality of the remotest twigs of descent. Through change of function nature may transform an organ but it can never restore a single lost part, whether it be a lost tooth, a lost digit, a lost ankle bone or rib, a lost tendon or nerve. This is Dollo's principle that *the evolution of anatomical organs is never reversible even though the evolution of functions and habits is frequently reversible.* On this principle the human hand could never reacquire the nerves, muscles, functions, freedom, flexibility and separate innervation lost in the

highly specialized arboreal ape hand; the opposable human thumb could not spring back from the partly atrophied anthropoid ape thumb. Our quadrupedal ancestors certainly had a forefoot capable of developing into the human hand with its long flexible fingers separately innervated and its thumb which, as Erasmus Darwin postulated, could reach the tip of each finger in turn, all depending upon separate innervation from special cell centers in the spinal cord and brain. Primitive man is not only a tool-making animal, he is a music-making animal; consider "Blind Tom," the negro musical genius of his day, who not only possessed an excellent finger technique but a marvelous musical memory that enabled him after a single hearing to repeat elaborate piano compositions. In this human hand connection let us recall also the researches of Sir Richard Paget in advocating the gesture origin of human speech, as gesture demands flexible fingers.

Third, to this hundred per cent. structural equipment of our remote ancestors phylogeny adds a hitherto unperceived germinal potentiality of specialization along certain pre-determined directions rather than others in adaptive reactions to changes of environment; this *teleogenesis* rests upon thousands of observations among primates, horses, titanotheres and elephants which prove that parallel anatomical and psychical progress is traceable to germinal community of origin. The psychic resemblances of the apes to man are partly parallelisms, partly common inheritance (Yerkes). Teleogenesis is not to be confused with the old "teleology," nor is it a revival of a hypothetical vitalism or internal perfecting tendency.

Finally, and perhaps from glandular impulses (Keith), phylogeny proves that independent of selection, of environment, of habit, certain phyla exhibit rapid or accelerated physical and mental adaptation, while others are held back. The creative brain, the tool-making hand, the fleet hind limb of man apparently combine in accelerated adaptation, while forest-loving primates advance much more slowly.

Does not this unbiased survey of recent discoveries in archeology, human and comparative paleontology and human and comparative anatomy, compel us to reconsider the classic Darwin-Lamarck hypothesis and to substitute a new hypothesis? The new hypothesis carries us into a geologic antiquity hitherto undreamt of. Anthropology is forced to share with chemistry and physics entirely new notions of space and time. To my mind the human brain is the most marvelous and mysterious object in the whole universe and no geologic period seems too long to allow for its natural evolution.

OBITUARY

KARL VON DEN STEINEN

THROUGH the sudden death of Karl von den Steinen, which occurred on the fourth of November, 1929, anthropology has lost one of its most eminent representatives.

Born in 1855 at Mühlheim a./d. Ruhr, he attended the Gymnasium of Düsseldorf, from which he graduated in 1871. He studied medicine at the Universities of Zurich, Bonn and Strassburg, devoting himself particularly to psychiatry. He was assistant at the Charité in Berlin, but soon he gave up this position and took a journey around the world which lasted from 1879 to 1881. On this journey he met Adolf Bastian in Hawaii and accompanied him on his visits to the natives. Bastian's enthusiasm for ethnological problems, the varied experiences of the long journey and contact with many foreign cultures were probably the causes that determined von den Steinen's ever-increasing devotion to the problems of anthropology.

At that time, however, geographical problems were nearer to his mind. In 1882 he was a member of the German party in charge of the meteorological station in South Georgia—one of the series of stations that were to observe for a year the meteorological and magnetic conditions in both circumpolar regions. Later on he published his observations, made during this year, on the life of the seals and birds of South Georgia. Immediately upon his return in 1884 he organized an expedition through Central Brazil and explored the Xingú, one of the southern tributaries of the Amazon, which up to that time was entirely unknown. This journey yielded important geographical results and at the same time brought him into close contact with the primitive natives of this area who were at that time still almost entirely untouched by European civilization. His account "Durch Zentral Brasilien" gave the results of his observations. Not satisfied with the completeness of his studies, he returned to Brazil in 1887 and devoted himself entirely to the study of the natives of the Xingú region. For several years after his return he was occupied with work on the results of this expedition which was finally published in 1894 under the title, "Unter den Naturvölkern Zentral Brasiliens," a book which has become one of the classics of ethnological literature. He published his linguistic observations in 1892 as a grammar of the Bakairí language.

Meanwhile he had accepted a chair at the Univer-