key to the present seems hardly to be appreciated. Even the scanty allusions of the subject are not altogether reliable. In Shull's chapter IV, dealing with fossils, we are informed that bees, wasps, ants and butterflies are known from the Jurassic. This is not at all the case. We read that fossil insects of the Cenozoic era "are not very numerous," in spite of the readily accessible literature describing thousands of species. The statement about the ants of the Sicilian amber in Robson and Richards (p. 131) is wrong, and appears to result from confusion with the Baltic amber.

The real appeal of these books must be to the rising generation. The young naturalists of to-day have an enormous advantage over their predecessors. Much of the necessary taxonomic work, preliminary to everything else, has been done. The science of genetics has been made over, and its contributions illuminate every biological problem. Paleontology, the description, classification and discussion of fossils, has shown astonishing progress. Morphology and physiology are escaping from their traditional isolation, and becoming more and more part of general biology. Chemistry and physics have made their rich contributions, in spite of the little appreciation of biological problems shown by the majority of specialists in these subjects. The museums have piled up vast quantities of materials, waiting to be studied by those who have the time and the skill. Expeditions go all over the earth, and travel to many formerly inaccessible regions is now easy. What an opportunity to go to work and, instead of arguing as I have done in this review, reveal the actual facts of nature in all their wonderful and beautiful complexity!

T. D. A. COCKERELL

UNIVERSITY OF COLORADO

SPECIAL ARTICLES

THE PRODUCTION OF COSMIC RAY SHOWERS

THE evidence derived from experiments on small bursts[1] indicates that a shower is produced at a single act. A plausible explanation of this result is the following: a high energy electron produces at a nuclear encounter a large number of photons simultaneously. Each of these photons subsequently gives rise to a pair or a Compton electron. Now the classical electrodynamics of point charges is unable to predict anywhere near the number of sprays of photons that is actually observed. Thus either the theory of electrodynamics is wrong or the concept of point charges is so restricted in its scope that it excludes this phenomenon.

In a paper on the annihilation of the proton,[2] the writer introduced the idea that a proton does not exist at all times as a point charge but has a finite probability of dissolving into a positron, a neutrino and a neutron. (That paper then dealt with the problem of the excitation of the β field in a collision with another nucleus.) We know now, however, that the ordinary interaction of the β ray theory is inadequate to explain fully the properties of the β field in the neighborhood of the nucleus. Some new assumption must be made concerning this fictitious charge distribution. Since the properties of the Born system of electrodynamics are similar to those derived from the Dirac-Heisenberg theory of the negative energy states, it is of interest to develop the consequences of the Born theory in this connection. In the close collision of an electron with a nucleus of atomic number Z, there appears in addition to the charge distribution of the electron and nucleus a new distribution of charge density. This polarization of the medium arises as a consequence of the non-linearity of the Born system of electrodynamical equations. If we now make the additional assumption which is explicitly contained in the theory, that the polarization charge scatters radiation with the same probability as the true charge density, then we find that the ratio of the probability of the emission of $n+1$ photons at one collision to the probability of the emission of n photons is of the order of 1 to 12 on the average. This result only holds when the energy of the colliding electron $\varepsilon m c^2$ is such that ε lies within the limits $2 \times 10^3/Z$ to $2 \times 10^4/Z$. Outside of this energy range, shower production on the Born theory should be absent.[3]

It is the purpose of this paper to present a semi-empirical formulation of the β field which leads to a similar result. From studies of the interaction of protons and neutrons and from the endeavor of physicists to explain the magnetic moment of the proton in terms of the β field, the following empirical distribution of the field has been advanced.[4] On the average the proton is dissolved into a neutron, a positron and a neutrino during 1/10 of the time. During its brief life the positron has an energy of the order of 100 M.E.V. On the basis of this assumption it is possible to develop a theory of shower formation. If a high energy electron $\varepsilon > 137$ collides with this system during the time that the proton is dissolved into a neutron,

[1] C. G. and D. D. Montgomery, *Phys. Rev.*, Abstracts, Rochester meeting, 1936.

[2] Bramley, *Phys. Rev.*, 46: 438, 1934.

[3] Bramley, SCIENCE, November 8, 1935.

[4] Bethe and Bacher, *Rev. of Mod. Phys.*, 8: 205, 1936.

positron and neutrino, then there exists a finite probability that the positron will be excited to a higher level of the energy continuum. In this excited state the positron can either escape from the neutron or drop to its original energy state with the emission of radiation. In its ground state it is again possible for the positron to reunite with the neutron to form a proton. Now it is quite possible for the radiation process to take place in either one or many steps. On this picture it is this multiple process which is the origin of the spray of photons found in showers. A calculation of the ratio of the probability of the emission of $n+1$ photons to that of n photons during the descent of the positron from its excited state to the ground state has been carried out. This ratio is $\left(\frac{2}{137\,\pi}\right)\frac{(\log W)^2}{n+1}$, where W is the ratio of the energy of the electron after the $n+1^{\text{th}}$ transition to $m\,c^2$. Now this ratio is greater than the classical value 1/137 for those values of the energy ratio W which are greater than $\exp.\sqrt{\frac{(n+1)\pi}{2}}$. For electrons with a smaller amount of energy in the final state the reverse is true. It is the possibility of a value, larger than 1/137, for this ratio, which is the significant feature of this explanation of shower production.

An estimate of the energy of the photons can be determined from the expression for the probability of emission of a single photon. If ν is the frequency of the photon emitted then an approximate value of this probability is $\left(\frac{2}{137\,\pi}\right)\frac{c^2 \log W}{\nu}$; here c is the velocity of light. According to this expression the emission of a relatively soft photon is the most probable event. Thus a shower should be composed of a spray of low energy photons $2\,m\,c^2$.

Besides the production of showers of photons, this process should be accompanied by the emission of a single positron. This production of a positron by the dissolution of a proton is quite a different process from that in which it appears as one member of a pair.

Finally, if the Oppenheimer conditions are applied to this process, an upper limit for the energy $\varepsilon\,m\,c^2$ of the electron capable of producing showers is found again just as in the Born theory, ε max. $(137)^2/Z^{1/3}$.

ARTHUR BRAMLEY

SWARTHMORE, PA.

NERVE CELLS WITHOUT CENTRAL PROCESSES IN THE FOURTH SPINAL GANGLION OF THE BULLFROG

THE frog is favorable material for a neurological study of visceral innervation and particularly the relation of sympathetic to spinal nerves because its vertebral column is so shortened that only ten spinal nerves exist and thus the elements contributing to the celiac plexus reveal an exaggerated concentration into a limited locus. The fourth spinal nerve (fifth in early development) carries over half the fibers contributing to the celiac nerve. The two conclusions of particular interest and significance which have come out of this study are, (1) that practically all the neurons whose fibers pass out the communicating ramus to the celiac nerve have their cells of origin in the dorsal root ganglion and (2) that nearly all these neurons lack central processes extending to the spinal cord by way of the dorsal root.

The evidence upon which these conclusions are founded is derived from serial sections of the fourth spinal nerve, roots, ganglion, adjacent sympathetic trunks, rami and celiac nerve stained by silver and osmic methods.

In osmic preparations the myelinated fibers were counted on several nerves and the counts from a representative example are given in Fig. 1. The dorsal

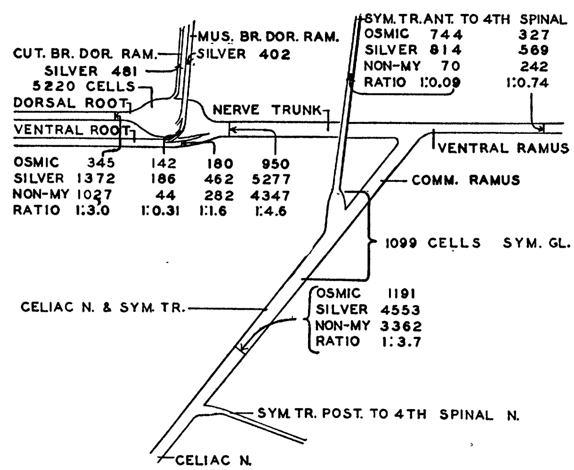

FIG. 1. Fourth spinal nerve of the bullfrog; cut. br. dor. ram. and mus. br. dor. ram., cutaneous and muscular branches of the dorsal ramus; sym. tr. ant. to 4th spinal n., sympathetic trunk anterior to 4th spinal nerve; other abbreviations are self-evident.

root contains 345 fibers and the ventral root (combining dorsal ramus and spinal nerve portions), 322. The total in the two roots is 667 myelinated fibers, of which it is estimated at least 259 are distributed to the dorsal rami, leaving 408 fibers for the spinal nerve distal to the ganglion. In the spinal nerve trunk, however, there are 950 myelinated fibers. The existence of more myelinated fibers in the spinal nerve than in both roots has previously been described by Hardesty[1,2] in *Rana virescens*. The "additional"

[1] I. Hardesty, *Jour. Comp. Neurol.*, 9: 64–112, 1899.
[2] I. Hardesty, *Jour. Comp. Neurol.*, 10: 323–354, 1900.