Fig. 1. Comparison between the reflectance of the parent's bill (filled symbols and unbroken line, left ordinate) and the response of the chick (unfilled symbols and broken line, right ordinate). The reflectance has no secondary blue maximum matching that of the chick's response. Filled symbols connected by unbroken lines indicate the composite sample; other filled symbols indicate masked samples.

24 June for reflectance measurements in a DU spectrophotometer with a diffuse reflection attachment. For the first of two methods, which measured the reflectance of single mandible pieces, it was necessary to mask the large aperture of the apparatus and to correct for the effects of masking. In the second method the full apparatus opening and a composite of several mandible pieces were used. The three lower mandible specimens were bisected in the midsagittal plane to form six halves; five of these six were placed in the full sample holder (2.5 cm in diameter) to cover about 96 percent of the viewing area.

The results (Fig. 1) rule out the hypothesis that the blue-preference of the begging chick corresponds to a blue peak of reflectance in the parent's bill. Measurements on one mandible were taken from 300 nm in the ultraviolet to 1200 nm in the infrared. The ultraviolet curve remains at its blue level in Fig. 1, and the infrared curve continues to rise with about the same slope as shown between 600 and 700 nm. Similarities in absorption spectra suggest that the pigment responsible for reflectance might be a form of melanin (4).

Why does the chick respond to red and blue, when the parent's bill is just red and there are no really blue objects in the chick's environment? Two of many possible interpretations of this mismatch are worth considering (5).

The first is that the chick's pecking preference may be primarily adapted to avoid green grass surrounding the nest, and only secondarily adapted to the red bill of the parent (6). A "green-avoidance" in pecking leaves a remaining high responsiveness to the spectral extremes, red and blue. In this case, the parent's bill would not even have to be

colored (although a neutral color would reflect some green); or the bill could be either red or blue, or both. For example, the related skuas and jaegers (Family Sterocorariidae) feed their young in a like manner as gulls, but the bills of the adults have no bright coloration; the color preferences of skua chicks are unknown. Thus, the color of the parent gull's bill could have arisen under other selection pressures, such as for courtship displays. In fact, the laughing gull's bill appears much brighter red during earlier courtship than later during the chick-rearing phase.

The second possible interpretation is that there are certain receptor-neural constraints in the coding of color information in the chick's visual system, and that a "red-preference, green-avoidance" cannot be coded without a secondary "blue-preference." Despite the fact that there are no blue objects in this species' natural breeding habitat, secondary blue peaks have also been found in the adult's spectral response curves both to retrieving eggs and to removing eggshell fragments (7). If the color-coding system is under certain constraints, the neural-receptor processing may be rather simple (1–3) —more simple than, for example, that which underlies hue perception in man —and thus may be amenable to physiological analysis.

JACK P. HAILMAN

Department of Zoology, University of
Maryland, College Park 20742

References and Notes

1. J. P. Hailman, *Behaviour Supplement 15*, (Brill, Leiden, 1967).
2. ———, *Nature* 204, 710 (1964).
3. ———, *Experientia* 22, 257 (1966).
4. J. M. Bowness, R. A. Morton, M. H. Shakir, A. L. Stubbs, *Biochem. J.* 51, 521 (1952); M. S. Mason, D. J. E. Ingram, B. Allen, *Arch. Biochem. Biophys.* 86, 225 (1960); B. Schmidli, *Helvet. Chim. Acta* 38, 1078 (1955); L. E. Arnow, *Biochem. J.* 32, 1281 (1938); R. H. Hackman, *ibid.* 54, 371 (1953).
5. Ethology has uncovered many examples of behavior patterns that can be elicited more readily by an artifically constructed stimulus than by the usual stimulus-object in nature; such artificial stimuli are termed "supernorma"; see N. Tinbergen, *The Study of Instinct* (Oxford Univ. Press, London, 1951).
6. This possibility was raised by D. A. Quine and J. M. Cullen [*Ibis* 106, 164 (1964)] with respect to pecking in young arctic terns *Sterna macrura*.
7. J. P. Hailman, *Amer. Zool.* 6, 568 (1966).
8. Supported in part by PHS-NINBM grant 07075 and a biomedical sciences support grant from the University of Maryland. I thank Drs. M. Impekoven, W. M. Schleidt, and C. G. Beer for comments on the manuscript and A. Segre and S. Hoyt for the specimens, taken at the Brigantine Field Station of the Institute of Animal Behavior at Brigantine, N.J. Details of masking procedure available from author upon request. Contribution No. 7 from the Brigantine Field Station of the Rutgers University Institute of Animal Behavior.

5 June 1968

Evolutionary Effects of Cosmic Radiation

One of the earliest discoveries of paleontology and stratigraphy was that there have been episodes of marked biotic change in the history of the earth. The most radical, or at least most apparent, of these have been taken as major dividing lines in geochronology: times of apparent great organic diversification (such as Precambrian-Cambrian), of apparent great extinction (such as Pleistocene-Recent), or both (Permian-Triassic and Cretaceous-Tertiary, for example). Since the discovery that various kinds of radiation have strong effects on organisms, not only somatic damage but also increased mutation rates, it has been suggested repeatedly that major biohistorical episodes of extinction or proliferation, or both, have been related to episodes of heightened radiation. Some relatively crude and easily refuted hypotheses have supposed the relevant radiation to be telluric (1). At least as early as 1950, however, a hypothesis implicating cosmic radiation, of one sort or another, was clearly expressed (2). In view of later proposals of the same idea, it is interesting that Schindewolf had then already explicitly suggested that the relevant radiation might come from supernovae. Russian scientists, who have shown special interest in this subject, had also advanced the supernova hypothesis (3).

To make the causation of biohistorical episodes by cosmic radiation plausible, it must be supposed that impact of such radiation on the earth was exceptionally intense at a few widely spaced times in the past. After apparent reversal of the geomagnetic field was deduced from remanent rock magnetism, it was suggested that during reversal there could be a relatively brief time of near zero field intensity and that during that time impacts of cosmic rays on the earth would be greater than usual. That was then advanced as a possible mechanism behind the biohistorical episodes in question (4). It was, however, soon argued that increased radiation due to that cause alone would be so slight that appreciable effects on the evolution of any organisms would be inconceivable (5). Shortly thereafter, and quite recently, the already old idea of increased radiation from explosion of a supernova was again advanced (6). Serious doubts as to the efficacy of that mechanism were also soon raised (7).

It seems that recent discussion and

arguments both pro and con have taken insufficient account of the actual features of the known fossil record that proponents of these hypotheses seek to explain. The following considerations are pertinent.

1) Evolutionary rates of origination and of extinction of taxa of organisms have been greater at some times than at others, but they have been perceptible continuously throughout the whole history of life. Intensifications of causes or contributory factors at various times must be assumed, but there is no impelling evidence that distinct factors, acting only at defined times separated by long intervals, are involved.

2) Correlation between extinctions and geomagnetic reversals has been indicated for only a few organic taxa, and for them it rarely amounts to exact coincidence. Since some taxa were becoming extinct at almost every geologically definable time point in the past, it is plausible that no cause and effect is indicated by the low degree of coincidence established objectively. There is no evidence, even of this loose kind, for the supernova hypothesis, because no specific arrivals of radiation from supernovae at past geologic times have been demonstrated.

3) Both kinds of hypotheses involve the assumption that major episodes of extinction and of the beginning of unusual diversification affected numerous taxa over spans of time geologically short or virtually instantaneous. Disagreement (6, 7) about whether significantly intensified radiation lasted for a few days or a few centuries is irrelevant to the record, because in the present state of the art geochronologists can rarely discriminate between an instant, a few days, and a few centuries; but the record shows the biohistorical episodes under consideration to have extended over geologically recognizable and even geologically long spans of time. Some proponents have shown mass extinction of many and major taxa as if they occurred just at the end of the Permian or the Cretaceous, for example, but last actually known occurrences of those groups are spread over millions, even tens of millions, of years. For Pleistocene extinctions the spread is less, but closer dating is possible and shows the major extinctions, in diverse areas, spread over at least thousands, and up to tens and hundreds of thousands of years. Records of appearances of new major groups after mass extinctions, notable in the Triassic and the Tertiary, are spread over tens of millions of years. The Cambrian record of diversification is also spread over tens of millions of years.

4) In some major episodes, at least, the record shows that animals that were equally affected lived under conditions that probably could have made the impact of radiation on them quite different. It is, for example, most unlikely that ammonites habituated to zones of widely different marine depths, pelagic ichthyosaurs, and terrestrial dinosaurs would be affected similarly, but all these and many other taxa under still more diverse conditions became extinct during the long span of the late Cretaceous. [That Schindewolf (2), for example, shows all as dying out exactly at the end of the Cretaceous is the sort of misrepresentation previously mentioned.]

5) On the other hand, organisms living together under the same conditions in regard to probable radiation exposure reacted differently, some becoming extinct and others not. During the late Cretaceous most marine reptiles, including many marine turtles, became extinct, but other marine turtles did not; amphibious dinosaurs became extinct, but amphibious crocodilians associated with them did not. During and shortly after the Pleistocene most proboscidians became extinct, but two genera did not. Examples could be multiplied.

Some of these matters of record might be discounted by appeals to ignorance (such as incompleteness of the record) or by unsupported *ad hoc* postulates (for example, that a geologically instantaneous exposure to intense radiation might have geologically prolonged effects). However, it is the record in hand that the hypotheses purport to explain, and neither the supernova hypothesis nor the geomagnetic reversal hypothesis is in agreement with that record.

In addition to those discrepancies of record, there is the more theoretical question whether fluctations in radiation up to intensities invoked by these hypotheses are either necessary or sufficient to account for observed or probable changes in overall rates of extinction and origination. In my opinion they are neither necessary nor sufficient, but some qualified students disagree.

G. G. SIMPSON
Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, and Department of Geology, University of Arizona, Tucson

References

1. For example, F. M. Dyssa, P. G. Nesterenko, M. V. Stobas, A. Z. Shirokov, *Dokl. Akad. Nauk SSSR* 131, 185 (1960).
2. O. H. Schindewolf, *Der Zeitfaktor in Geologie und Paläontologie* (Schweitzerbart, Stuttgart, 1950); *Z. Deut. Geol. Ges.* 114, 430 (1963).
3. Especially, V. I. Krasovskiy and I. S. Shklovskiy, *Dokl. Akad. Nauk SSSR* 116, 197 (1957).
4. N. D. Opdyke, B. Glass, J. D. Hays, J. Foster, *Science* 154, 349 (1966).
5. C. J. Waddington, *ibid.* 158, 913 (1967).
6. K. D. Terry and W. H. Tucker, *ibid.* 159, 421 (1968); W. H. Tucker and K. D. Terry, *ibid.* 160, 1138 (1968).
7. H. Laster, *ibid.* 160, 1138 (1968).

5 July 1968

Science

Evolutionary Effects of Cosmic Radiation

G. G. Simpson

ARTICLE TOOLS	http://science.sciencemag.org/content/162/3849/140
REFERENCES	This article cites 8 articles, 5 of which you can access for free http://science.sciencemag.org/content/162/3849/140#BIBL
PERMISSIONS	http://www.sciencemag.org/help/reprints-and-permissions