movements; (2) the production of positive record of sufficient magnification for easy reading; (3) readily adaptable to various types of eye-movement problems other than reading; (4) low cost of construction and operation.

The problems for which this camera is now being used are: (1) The study of binocular coordination in convergence and divergence movements of alternate fixation on near and far points of light; (2) the analysis of eye movements of good and poor readers who have the same intelligence rating; (3) the determination of the attention value of different types of advertisements and of different items in a single advertisement; (4) analysis of changes that take place in eye-movement habits of poor readers who have been subjected to intensive remedial training; (5) binocular coordination of stutterers *versus* that of normal speakers, and (6) dysintegration of eye-movements during stuttering spasms.

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SPECIAL ARTICLES

THE GREAT GLACIAL CYCLE

IT is fairly well known that the present Ice Age, or the cycle of ice ages in an interglacial period of which we now live, was preceded by other ages or cycles of ages, leading as far back as we can see in geological history.[1] Some of these have been limited in extent, both of time and area, but others have involved large areas of the earth for millions of years. If we consider the greater cycles that are most recent and most certainly identified, and compare them with the absolute dates which have been obtained from radioactive changes,[2] we find that they occurred at intervals of some 200,000,000 years. Thus we may make the following comparisons, giving the periods in millions of years. I have used a unit of 210 millions, as it seems to fit a little better than the even 200, especially at the Cobalt glaciation, but the uncertainty of the data makes the difference trivial.

210. *Permocarboniferous Glaciation*

204. Joachimstal pitchblende, supposed Permocarboniferous.

239. North Carolina uraninite, supposed late Carboniferous.

A very long and widely distributed glacial period, mainly in the southern hemisphere and lasting through the later Carboniferous and much of the Permian, with its climax at the beginning of the Permian.

420. *Late Ordovician Glaciation*

374. Branchville, Ct., uraninite; Silurian or Devonian.

443. Lake Superior coracite; early or middle Ordovician.

This cycle is not so well defined, but seems to cover larger area in Quebec, and is also represented in Europe.

630. *Early Cambrian or late Precambrian Glaciation*

573. Katanga pitchblende; late Precambrian.

587. Ceylon thorianite; late Precambrian.

673. Morogoro, Tanganyika; late Precambrian.

This shows a very large area of glaciation in the world, but much of it is of uncertain date and may belong to the following period; back from this time fossil dating is no longer possible, and it becomes difficult to join up dated igneous rocks with the corresponding glacial deposits, except where, as at Cobalt, they are directly associated.

840. *Keweenawan*

No dated radioactive rocks; Reeds gives this as the date for the Keweenawan, which shows doubtful glacial remains about Lake Superior.

1050. *Cobalt (Huronian)*

987. Olary, S. Australia; Animikian.

1024. Ontario uraninite; Animikian.

1056. Arendal, Norway, cleveite; Cobaltian.

1087. Llano Co., Texas, uraninite and Douglas Co., Col. Samarskite; Cobaltian.

This is evidently a major glaciation at least in Canada, where the Cobaltian radioactive dated rocks and glacial remains are directly associated. Coleman discusses the Animikian as Precambrian and the Cobaltian as Huronian, but the radioactive dating suggests a single cycle. Extensive glacial traces elsewhere may belong to this cycle.

1260. *Algoman*

No dated glacial remains.

1470. *Timiskamian*

1465. Keystone, South Dakota, uraninite, Timiskaming.

Extensive glacial traces in Canada, doubtful elsewhere.

1680. *Keewatin*

Doré conglomerate of Canada a possible representative of this or an earlier cycle. No radioactive dating, so far as I know.

Plaskett[3] has just estimated that it takes the solar system 230,000,000 years to make the great circle around the system of the Milky Way. The rough agreement suggests a connection. It is well known that at present the dense center of the Milky Way

[1] A. P. Coleman, "Ice Ages, Recent and Ancient," New York, Macmillan, 1926.

[2] Holmes and Lawson: *Am. Jour. Sci.* (5) 13: 327, 1927, brought up to date and diagrammatically presented by C. A. Reeds, *Nat. Hist.* 31: 129, 1931.

[3] *Proc.* Am. Phil. Soc., 69: 417, 1931.

is obscured behind a cloud of opaque matter. It may be suggested that this center radiates a small but substantial amount of heat, sufficient to raise the temperature of the earth a few degrees. If this is the case, during the periods when the earth does not lie behind the obscuring cloud, it will be a few degrees warmer, and when the cloud passes in front, the temperature will drop a corresponding small amount. Such a small difference in temperature may well make the difference between a stretch of time when glacial periods are frequent and wide-spread, and one when they are rare and mainly limited to mountain areas.

As the obscuring cloud is nearer to the center of the Milky Way than ourselves, the obvious assumption is that it is revolving about the center more rapidly than ourselves (obviously in the same direction). We can calculate what its period would have to be, to occult the center every 210 million years, and it works out at 110 million years. Assuming that most of the mass of the Milky Way is concentrated at its center (Plaskett suggests 80 per cent.), this would make the radius of its orbit of the order of 5,000 light-years.

If this is the case we have gone about the center of the Milky Way some eight times, and the obscuring mass about 17 times, since the oldest visible rocks were laid down, some 1,850 million years ago.

This scheme is presented as a suggestive hypothesis, rather than a full-fledged theory. Its chief weaknesses are two: one due to the uncertain dating of the geological deposits, especially as glacial deposits and datable radioactive ones (igneous) are rarely found in close association; the other, which Dr. Boothroyd would emphasize, that the amount of radiation possible from the center of the galaxy would not be able to raise the temperature of the solar system even the few degrees necessary. A systematic error in the radioactive datings might change the figures involved somewhat, but could hardly be large enough to interfere seriously.

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EGGS OF FRESH-WATER FISHES SUITABLE FOR PHYSIOLOGICAL RESEARCH[1]

Fundulus heteroclitus, a marine Poeciliidae commonly called the killifish, or marine minnow, has been used for many years as the standard fish for various types of physiological research. Their eggs are especially well adapted for experimental studies due to the fact that they can be easily fertilized in the laboratory and their embryos can be observed during development through the transparent shell membrane.

It is not always possible or desirable, however, for the investigator to conduct his research at a marine biological station but since several of the fresh-water laboratories are now equipped for fundamental physiological research as well as for ecology, life-history and taxonomic studies, it may be of interest to call attention to a few species of fresh-water fishes, the eggs of which have been found to be very satisfactory for research on the beat of the embryonic heart. By the use of these eggs it is often possible for the inland investigator to conduct his research in or near his own laboratory.

The log-perch (*Percina caprodes*)[2] is one of the larger and more abundant of the darters belonging to the family Percidae. It occurs in all the Great Lakes, in Lake Champlain, in the St. Lawrence and the various tributaries of this system and ranges south to Virginia, Alabama and throughout the Ohio basin, westward to Kansas, and southwestward to Texas. An excellent colored plate and description of this species is contained in Forbes and Richardson's "Fishes of Illinois." The plate is opposite page 282.

The adults are found in schools of several hundred at spawning time. The spawning beds are found along the shallow windswept shores of lakes, usually where sand is abundant. When the water is quiet the schools move to the very edge of the lake and spawn in a few inches of water. Spawning takes place during the day time on quiet days. The males remain in a group while the females rest on the sand at the edge of the spawning area. At intervals the individual females move toward the group of males, one of which starts spawning with her, during the progress of which the eggs and sperm are emitted while the tails vibrate in such a way as to dig a pit in the sand and cover many of the eggs. Reighard[3] has described the spawning and method of sex recognition of this species in excellent detail. Spawning takes place from as early as June 15th and may continue as late as July 20th at the University of Michigan Biological Station on Douglas Lake in Northern Michigan.

During the spawning season log-perch are easily collected with a twenty-five or thirty foot minnow net. The fish can be stripped immediately and the eggs fertilized in finger bowls or syracuse watch-glasses or fishes may be kept in an aquarium with the water at a cool temperature and stripped when desired. A 70 to 80 per cent. fertilization is usually secured if the eggs are fertilized by the dry method. The eggs are collected in the dry watch-glasses and

[1] Contributions from the University of Michigan Biological Station, North Dakota State College, and The College of the City of Detroit.

[2] For a discussion of the taxonomy of this species see Hubbs and Brown, *Trans.* Roy. Can. Inst., 17: 1–56, 1929.

[3] Reighard, Papers of Mich. Acad. Sci., p. 104–105, 1913.