600 r, but the response, unlike females irradiated on the day of metestrus, remained fairly uniform in the groups that received 200 to 500 r. In animals irradiated on the 2d day after metestrus, only those receiving 200 and 300 r had significantly more implants. Numbers of implantations in females irradiated on the 2d day after metestrus were significantly below controls after exposure to 300, 500, and 600 r, while the value at 400 r remained at control levels and reflects the significant increase in numbers of ova shed at this dose.

There was no discernible increase in abnormally developed fetuses in irradiated females. Also the incidence of fetal death was extremely low during the latter trimester of pregnancy. In females irradiated on the day of metestrus there was, like ovulations and implantations, a significant increase in the number of living fetuses following 100 to 600 r (Fig. 1). The response paralleled the linear increase in implantations, reaching a maximum of 15.5 fetuses per female after 500 r, then declining to 13.0 per female after 600 r. Females irradiated on the day after metestrus responded with significantly more living fetuses following doses of 200 to 500 r. The maximum responses were observed after 200 and 300 r, followed by a slight decline after 400 and 500 r and a significant decrease to 7.7 fetuses after 600 r. Number of fetuses in females irradiated on the 2nd day after metestrus remained at control levels for all doses except 600 r when the number was significantly reduced to an average of 5.4 fetuses. Average number of fetuses found in females irradiated on the 3rd day after metestrus decreased in a linear fashion from 100 to 600 r with a range of 5.8 after 100 r to 0.9 after 600 r.

The data obtained from females irradiated during metestrus indicate that there exists a clear-cut dose-response relationship for ovulations, implantations, and numbers of fetuses. On the other hand, females irradiated on the day after metestrus (M+1) exhibit a biphasic response. At lower doses M+1 females actually have a greater response than do M females; for example, ovulations at 200 and 300 r for M+1 females are higher than for M females at the same doses. Likewise the number of implantations for M+1 females reach 15.2 after 200 r and remain essentially the same for 300, 400, and 500 r. Numbers of fetuses reach a maximum of 14.1 and 14.4 after 200 and 300 r for M+1 females while a comparable value in M females is not reached until 300 and 400 r (13.8 and 14.5). On the other hand, after 600 r the numbers of fetuses are 13.0 for M females, while they are significantly reduced to 7.7 for M+1 females.

The significant though uniform increase in ovulation rate obtained in M+2 females at doses of 200 to 600 r suggests that only those follicles that survived follicular atresia and attained a particular stage of development were affected by the irradiation. The maximum number of ovulations obtained for M females after exposure to 500 and 600 r (30.1 and 31.1) appears to be the upper limit of response. These numbers coincide with the 30 to 35 developing follicles, 250 μ or greater in diameter, found during metestrus (*7*).

Exposure to 50 r had no effect on the reproductive factors studied, regardless of the time of exposure.

Exogenous sources of gonadotrophins will also cause an increase in the number of ova shed with subsequent implantation, but the end result is generally a decrease in average litter size. This has been attributed to uterine overcrowding (*8*) and to hormonal inadequacy (*9*). The increase in litter size found in females irradiated during metestrus or the day after parallels the implantation rate and clearly suggests that a radiation-induced euhormonal balance exists.

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10. This paper is based on work performed under contract with the U.S. Atomic Energy Commission at the University of Rochester Atomic Energy Project, and has been assigned publication No. UR-49-733. We thank F. Van Slyke and C. Gale for carrying out the irradiation of the animals.

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Pteridinium and the Precambrian-Cambrian Boundary

Cloud and Nelson (*1*) have discussed the vexed question of the Precambrian-Cambrian boundary (or the Phanerozoic-Cryptozoic boundary, as they seem to prefer) in the light of the discovery of a *Pteridinium* impression in the Deep Spring Formation of California. While remaining unconvinced that their interpretation of the impression is correct, I do not wish to carry this further. In their discussion of the philosophical aspects of the boundary problem they have overlooked the fact that the Ediacara and Nama Beds have been correlated by Glaessner (*2*) with the Precambrian rocks of Charnwood Forest, in Leicestershire, England. This area of Precambrian rocks is separated from the overlying Lower Cambrian by a major unconformity, representing a phase of orogeny during which the Charnian rocks were folded, cleaved, intruded by porphyry and diorite masses, and deeply eroded (*3*). A date of 684 ± 29 million years on one of the latter intrusives has been obtained by Meinesy and Miller (*4*), which indicates that the age of the sediments surrounding the diorite must be considerably older. If Cloud and Nelson's interpretation of Palaeozoic pre-Cambrian (or Phanerozoic) time is to be extended back to include all metazoan fossils it must thus be extended to include far more than the 2000 feet (600 m) of the Deep Spring Formation, to include from Charnwood Forest what is generally regarded as part of Precambrian time more than 680 million years ago. An alternative explanation of the occurrence of their *Pteridinium* in the Deep Spring Formation, which does not seem to have occurred to Cloud and Nelson, is that the chronological range of *Pteridinium* extends upward from the Precambrian well into the Cambrian, possibly much later. Indeed, the whole correlation of the Ediacara, Nama, and Charnwood beds by their fossil faunas is dubious, as what has really been correlated is their unusual state of preservation, and until the chronological range of the faunas is known, no more than a very broad Late Precambrian date can be accepted. Cloud and Nelson's discovery simply adds a range up into the Cambrian.

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22 March 1967

Ford challenges our interpretation of evidence relating to a crucial question in geology: how, and on what grounds, shall the last one-eighth of earth history, characterized by abundant multicelled animal life (the Phanerozoic Eon), be separated from the first seven-eighths, in which fossils representing such life are absent or doubtfully represented (the Cryptozoic or Precambrian Eon). We approve of this challenge and the manner in which it is stated. We readily admit that the proposition we support is, on current evidence, debatable, as is the one we oppose. What is important is that discussion and the search for critical evidence continue until a rational and broadly acceptable solution of the problem is reached. We will not here elaborate on the specifics of this problem. They are briefly stated in the paper which Ford criticizes (*1*) and are considered in detail in a paper in press by Cloud (*2*). The discussion below is confined to points raised by Ford.

To begin with, let us reiterate what we stated in the report criticized, namely, that we also have reservations about the identification of the California "*Pteridinium*," indicated by the use in that paper of the conventional prefix *cf*., for "compare with" (although this was confused by editorial revision beyond our control). More specimens are needed to confirm or discredit our provisional interpretation. Nevertheless, at this time there is a reasonable likelihood that this identification is correct, and, while expressing his own reservations, Ford does not quarrel with us on that score.

Rather he observes (i) that we overlooked Glaessner's correlation of the Ediacara and Nama beds with strata of the Charnwood Forest in England, (ii) that it seems not to have occurred to us that *Pteridinium* might have a long chronological range, and (iii) that the Charnwood Forest beds are intruded by, and therefore older than, rocks whose radiometric ages strongly imply a Precambrian age.

Mindreading, of course, is hazardous, and the fact is that neither (i) nor (ii) is true. We are well aware of suggestions by Glaessner and others about the possible correlation of the Ediacara beds not only with strata in the Charnwood Forest, but also in the U.S.S.R., as stated at the end of the first paragraph of our paper (*1*). As for an extended range for *Pteridinium*, that, of course, is a possibility no thoughtful paleontologist would fail to consider for any fossil. It may be, as Ford intimates, that what has been correlated with the Ediacara fauna outside of South Australia is merely an unusual state of preservation. Nevertheless, we are persuaded by the arguments that have been advanced for the approximate contemporaneity of the principal records that the burden of proof lies on those who might prefer a broad temporal transgression. If substantial grounds can be found to question such approximate contemporaneity, then, of course, even if the *cf*. notation is removed from our *cf. Pteridinium*, its bearing on the boundary problem would be seriously weakened.

There remains to consider the position in the geologic column of the Charnian beds, which we do in fact accept as probably correlative with the Ediacaran. Points of evidence that bear on this include (i) the numerical age of the oldest rocks of demonstrably Paleozoic (hence Phanerozoic) age anywhere, (ii) the stratigraphic equivalence of the oldest rocks above the Charnian, and (iii) the dating of the igneous rocks that intrude the Charnian sediments and place a minimal limit on their age. Radiometric ages for the oldest Paleozoic rocks leave much to be desired. The age taken by Davidson (*3*) as most nearly tying down the base of the Paleozoic is a K^{40}/Ca^{40} age on sylvite from Lower Cambrian potash deposits of the Irkutsk region, which gives a figure of 620 ± 20 m.y. (million years) for a point *within* the Lower Cambrian. On this evidence a figure of 650 m.y. before the present for the base of the Paleozoic (and Phanerozoic) is a reasonable working estimate, although it might eventually be found to range down to 700 m.y.

As for the stratigraphic position of the oldest rocks above the Charnian, this is not clear to us. Information available to us until receipt of Ford's comment above has indicated correlation of different immediately post-Charnian rocks with Triassic, Carboniferous, and Ordovician, but nothing as old as Cambrian. If the Charnian rocks are indeed separated from overlying rocks of demonstrably Lower Cambrian age by a major unconformity, as Ford reports (referring to a work in press), then the chances of the Charnian being of Precambrian age are greatly improved—although Ford would probably be among the first to agree that unconformities are not the primary grounds for worldwide geologic time division.

A Precambrian age for the Charnian would be required if igneous rocks that definitely crosscut it could be shown to be chronologically so ancient as to put them clearly within the Precambrian. Unfortunately the conclusion that such intrusives, and therefore the Charnian, are Precambrian rests on potassium-argon age determinations on whole rock samples of porphyroids. Ages of 574 ± 26 m.y. and 684 ± 29 m.y. were obtained, and the latter was chosen as fixing the minimal age of intrusion (*4*). Inasmuch, however, as a satisfactory basis has not yet been established for evaluation of K/Ar ages on whole rock systems, any such numbers proposed contain the possibility of bias for excessive as well as minimal age. Indeed, Ford himself had earlier quoted an age of greater than a billion years for the same rocks (*5*).

In this state of uncertainty we find no reason at this time to emend the propositions set forth in our earlier paper (*1*).

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Magnesium Pemoline and Human Performance

Ronald G. Smith's report on magnesium pemoline and its relation to learning and memory in man [*Science* **155**, 603 (1967)] contains certain errors. He bases his conclusions on test-