times the mass of our sun and our sun, the interval is $7 \cdot 5 \times 10^{12}$ years. These two figures do not differ greatly, for a star squanders its mass at a great rate during its highly luminous giant state; it is the last part of the journey that takes the time. Both figures are of course enormously large in comparison with any estimates heretofore made on the ages of the stars.

If nothing unexpected intervenes in the next $6 \cdot 4 \times 10^{12}$ years—and it must be admitted that there is time enough for the unforeseen to occur—Sirius will at the end of that period be similar to our present sun. We cannot, however, assert that $6 \cdot 4 \times 10^{12}$ years ago our sun was in the state of the present Sirius. The old-fashioned astronomer believes that the whole universe was created only some 10^9 or 10^{10} years ago, and until the contrary is proved he has a right to his opinion.

The geologist insists that life on our earth must have existed for millions of years because fossil bones occur under deposits which, he estimates, must have taken millions of years to accumulate. A similar method of reasoning is available to the cosmogonist, who has the advantage over the geologist that he can calculate, instead of estimating, his periods of time.

All calculations in cosmogony have hitherto been made on the supposition that stellar masses remained constant. The conception of diminishing masses brings new features into almost every problem of cosmogony. For example, the orbit of a particle about a gravitating mass is no longer an endlessly repeated ellipse; it is an ellipse of ever-increasing size, the major axis of which varies inversely as the mass of the attracting body. After 1,500,000 millions of years, when our sun will only have nine-tenths of its present mass, the radius of the earth's orbit will be ten-ninths of its present size and the year will have lengthened to 451 days. The whole universe of stars is expanding for the same reason and in the same way as the solar system. When, if ever, in the past the average star had four times its present mass, the stars must have been 64 times as closely packed as now, and stars must have interfered with their neighbours 64 times as much as they now do. When due allowance has been made for this, it is found that features are shown by the stars which could be produced by the influence of neighbouring stars in periods just about equal to those we have had under consideration, say six or seven millions of millions of years. These features are the fossil bones of cosmogony.

Foremost among such features must be placed the orbits of binary stars. A newly formed binary star has generally a period of a few hours and an almost circular orbit of radius of the order 5×10^{11} cm. Old binaries show much longer periods, orbits which are frequently highly eccentric and of radius much greater than those of new stars. Statistically, the orbits tend towards conformity with what may be called the "equipartition law"—the law which would be obeyed exactly if the binaries were pushed and pulled about by their neighbours for an unlimited time. Calculation shows that the observed partial conformity to this law indicates a knocking about for a period of the order of that just mentioned, say six million million years.

The same period is indicated by the velocities of the stars in space. Statistically, the most massive stars have the lowest velocities, and there is a pronounced tendency to obey an "equipartition law" under which the velocity varies inversely as the square-root of the mass. This would be obeyed perfectly if the stars had influenced one another for ever; the partial extent to which it is obeyed again indicates a period of the order of six million million years.

A somewhat less convincing "fossil-bone" is provided by a study of the ratios of the masses of the two components of binary stars. As a binary gets older, its components become more equal in mass. According to Aitken,[3] 20 spectroscopic binaries of early type (B to B8) show an average mass-ratio 0·70, while 7 of late type (F to G) show an average mass ratio of 0·89. Calculation shows that to pass from a mass-ratio 0·70 to one of 0·89 would require a period of 4·5 million million years. The numerical result is entirely satisfactory, but it must be admitted that it is based on scanty material.

Finally, it may be remarked that the extension of the time scale which is now proposed increases enormously the chance of solar systems being formed by tidal action. With a time scale of 10^9 years, we had to think of systems of planets such as our own as being of necessity extremely rare. With the longer time-scale and the recognition that our system of stars must have been more closely packed in the past than now, we can think of planetary systems as being, if not quite the normal accompaniment of a sun, at least fairly freely distributed in space.

[3] "The Binary Stars," pp. 206, 207.

The Ages of Peat Deposits.

By Dr. W. H. PEARSALL.

RECENT work on the Yorkshire peat has raised some very interesting problems as to the ages of various types of peat deposit in the British Isles. One of the striking features of the Pennine peat is the normal absence of any marked differences in composition, such, for example, as the definite forest layers observed in the Scotch deposits by Prof. Lewis. Typical Pennine peat is usually composed entirely of cotton-grass remains, though here and there the remains of heather or birch point to local desiccation, which can usually be traced to drainage. In the Ingleborough district, Messrs. Cheetham and Burrell find the basal vegetation to differ very slightly from that of the main peat, though rushes are often present. Birch scrub with local pine and oak is also very widely distributed up to 1900 ft. The presence of oak is suggestive, since this tree is not known from deposits older than Neolithic, either in England or Scandinavia.

Mr. J. Holmes first pointed out that neolithic flints occurred about the base of the peat, and now further information is accumulating, largely through the efforts of Mr. F. Buckley and Dr. T. W. Woodhead. They have found among the trees at the base of the peat, a horn of *Bos primigenius* and a triangular arrow-head of the Neolithic Dolmen period. At a somewhat higher level, a piece of bronze and a barbed arrow-head suggest the Bronze Age horizon. Added to this, are previous discoveries of two horizons in the sand underlying this peat. The lower layers of sand contain flint implements of the Belgian Tardenois culture, while similar traces of the later Tardenois period are found in the upper layers of sand.

If the facts so far ascertained are completely substantiated, they form a very valuable chronological sequence. The question then arises as to their relation to the Scottish peat deposits studied by Lewis. These show fairly definite horizons roughly corresponding to Geikie's well-known climatic periods, namely, from below upwards, a Sub-arctic or Tundra zone, a Lower Forest, a Lower Turbarian or peat layer with some arctic plants in places, an Upper Forest, and finally an Upper Turbarian or deep peat layer.

Now, tree layers in peat are not *necessarily* an indication of climatic change. There is, for example, at present a general tendency for woodlands on poor soils (owing to the progressive leaching of the soil) to be replaced by moorland types of vegetation. Wood layers at the base of the peat may indicate a similar natural succession of vegetation. The study of plant successions on lowland peat also indicates that stages of woodland may alternate with stages in which peat is formed more rapidly, without the intervention of climatic change. It is obvious that extreme caution is necessary in interpreting the wood layers in peat deposits. The validity of the assumption made by Lewis that the Scottish peats show evidence of climatic change, largely rests on two facts. In the first place, the peats studied were mostly from high levels, where the general conditions are unfavourable to tree growth. Secondly, Lewis lays emphasis on the continuity of the main horizons almost all over Scotland. The Scottish wood layers are thus, apparently, signs of widespread changes. Samuelsson has reinvestigated the Scottish deposits and his main conclusions agree with those of Lewis.

So far as it can be ascertained, there is at present little evidence as to the archæological age of the main horizons. We can, however, obtain a rough correlation with the English results by indirect methods. According to Clement Reid, the submerged forests round the English coast are apparently of Neolithic age. Reid also estimated the period of coast depression to occur between 3500 and 1500 B.C., since when the coast has remained fairly stable. He pointed out that as no arctic or tundra species occur in these forests, they were probably formed a long time after the last considerable glaciation. The submerged forests apparently approximate to the tree layer at the base of the Pennine peat and the period of its replacement by moorland. Now along the Scottish coasts, the submerged forests are replaced by the 40-50 foot beaches, also of Neolithic date, and these beaches correspond in time to the Lower Turbarian stage of Lewis. If this approximation is correct, we then obtain the suggestion that the destruction of the Pennine forest coincides with the colder climate assumed for the Lower Turbarian. It would also indicate the Scottish Upper Forest to be approximately Bronze Age, while the Palæolithic horizons might lie below the Lower Forest. It is of interest to compare this approximate sequence with that obtained from the very detailed studies of Scandinavian peats. The following summary, taken chiefly from von Post, avoids most of the controversial points.

VEGETATION-CLIMATIC PERIODS.

1. Sub-Atlantic—Colder and moist.	Recent.	
2. Sub-Boreal—Drier: the warmest part of the post-glacial period	Bronze Age	*circa* 2000 to 1000 B.C.
	Stone Cists Passage Graves Dolmens	Neolithic. English submerged forests are later than Littorina depression.
3. Atlantic—Warm and moist	First Swedish Stage	
	Transition — including Tardenoisien	Maximum extent of Littorina Sea.
4. Boreal—warmer	Ending about 6000 B.C.	
5. Sub-Arctic	End of Palæolithic—beginning about 10,000 B.C. (De Geer).	

The warm Sub-boreal period in Scandinavia could scarcely fail to exert some influence in Scotland. Hence the estimate of the Upper Forest as being approximately of Bronze Age would receive some justification. The Neolithic Dolmen period apparently indicated at the base of the Pennine peat lies at the beginning of the Scandinavian Sub-boreal period, and we are apparently faced with the difficulty that the Scandinavian climate was becoming drier and more favourable to woodland vegetation while British climate was becoming colder (and moister ?). The evidence clearly suggests that either the Scandinavian and British culture periods were reached at different times or else that the climatic sequences were actually somewhat different. Much would depend, therefore, on the determination of cultural horizons in the Scottish peat. To these problems, one must in honesty add one more. The Pennine upland peats, as a whole, show few, if any, traces of Lewis's Upper Forest layer, although this is supposed to represent a time when the forest limit was very greatly raised both in Britain and Scandinavia. Further, in the Danish and Swedish lowland moors, this horizon is marked by a definite layer of "horizon peat"—the Sub-boreal surface.

A similar surface presents the only strikingly uniform horizon in the upper peat of the North Lancashire "mosses." It occurs about 3 to 4 feet below the surface, and below the peat is brown and partly decayed remains of Sphagnum and Eriophorum. Above this horizon, the peat is "white" and undecayed Sphagnum peat. Dr. Osvald, to whom I showed this, considered that it coincided with the Swedish Sub-boreal horizon. It certainly corresponds with a long period when the development of all the North Lancashire moors was arrested and when, according to Mr. Rankine, the surface was sufficiently firm to allow a corduroy road to be laid on it. Why is this horizon and that of the Scottish Upper Forest so conspicuously absent from the typical Pennine peats ? It must be confessed that these problems suggest that the climatic theories of peat succession are not nearly so firmly anchored in Great Britain as in Scandinavia. The further investigation of peats is likely to assume great importance and, in particular, the establishment of cultural horizons in the Scottish peats. The present indications clearly raise more problems than they solve.