Bull. Mater. Sci., Vol. 4, No. 3, May 1982, pp. 317–319. © Printed in India

Some remarks concerning near-zero *g* experiments on living systems

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MS received 23 January 1980

Abstract. In the case of animal systems, gravity probably plays an important role only during early development ; this has to do with the determination of embryonic polarity. At other times in the life of an animal, gravity is a hindrance. If animals are to be sent into space, it is clearly necessary to study the effect of zero *g* on their physiology and behaviour. This apart, there seems to be no basis for thinking that biological experiments conducted in outer space might yield interesting insights into how living systems work.

Keywords. Zero *g*; early development.

The purpose of this short article is to look at experiments done at near-zero *g*, basically, in outer space, from the point of view of fundamental biological principles. The available literature indicates that work done so far has really not succeeded in illuminating the working of a living system in any such manner; probably not surprisingly, since most of the experiments have a 'because it is there' air about them. If plants or animals are to survive extraterrestrial life, it is of undoubted interest to investigate the effects of space travel on living systems, much for the same sort of reason that it is of interest to examine what happens to materials in outer space. One might expect effects of increased cosmic radiation, of reduced gravitational acceleration, and of changes from the usual day-night cycle. In what follows, it is indicated why it is the present author's opinion that as things stand it is unlikely that in such experiments one can expect non-trivial effects; next, brief mention is made of some of the work that has been done; and finally, speculation is made on what might be interesting things to look for in the future.

As far as life on earth is concerned, the force of gravity is a hindrance. The investment in elaborate musculature that the higher animals have gone in for is probably due in large part to an effort to overcome its effects. It is true that practically all of terrestrial life as we know it is dependent on a certain partial pressure of oxygen in the atmosphere, which in turn is contingent on a sufficiently strong gravitational field; but within the duration of a life-time, few biological processes are affected by the gravitational field as such. To put it in a different way, in the development of living systems chemical potentials are of overwhelming importance in comparison with gravitational potentials. The qualification 'few' made earlier refers to the obvious instance of plants, which in general grow in an upward direction relative to the earth, and in fact have evolved gravity sensors to help in process. However the most plausible explanation of even this is that the primary selective force making plants move in such a manner was not gravity but the amount of light received by them, of course, subject to constraints like competition between plants, predation, etc. and so on, Summing up, it seems fairly unlikely that a very low gravitational acceleration by itself can lead to effects on a living system which might be useful in understanding some basic principle of the system's working.

As regards the kind of investigations that have been carried out so far, Chakravarty and Rao (1979) have given a detailed listing to which the reader is requested to refer. These deal with a variety of phenomena including physiological effects on humans and animals, rates of cell division, the pattern of cell division, and the effect of high radiation levels on growing cells and adult organisms. Apart from physiological effects like nausea, changes in red blood cell mass, and so on, which are interesting on their own in the sense mentioned earlier, none of the experimental results excite particularly strong notice. There are two reasons for saying this. Firstly, the results of some of the experiments are not interesting when considered from a mundane, terrestrial point of view. This includes cases in which the phenomenon at near-zero *g* is similar to that on earth, as well as cases in which the phenomenon is just what one observes on simulating weightlessness on earth. Secondly, and quite in a different class, there are experiments with striking results—but as far as one can see, incapable of interpretation at present. For example, there is the reported developmental abnormality in fruit fly eggs laid during satellite flight : adults had a missing wing and deformed thorax.

Now we shall make two remarks which are very speculative and have to do with the possible role of gravity in influencing form or pattern (i) during embryonic development and (ii) during the course of many generations. Most animals have two characteristic features: one is a graded difference in cell types from anterior to posterior (in simpler terms, head to tail), and the other is bilateral or left-right symmetry. The anterior-posterior differences are known to be correlated, at least in a gross sense, with concentration differences of particulate matter in the roughly spherical unfertilised egg (Ebert and Sussex 1970). For instance, yolk being heavier than anything else inside a frog's egg, settles to the bottom of the egg; this bottom is the future posterior region. Given this anterior-posterior axis, it is likely, but unproven, that the point of sperm entry at the egg surface defines the plane of bilateral symmetry. On earth, the gravitational potential difference between the ends of a 1 mm egg is about 10^2 $(cm/sec)^2$. To transport 10,000 molecules across the egg, each of molecular weight 10,000 Daltons, needs, therefore, between 0·1 eV and 1 eV of energy. As against this, the chemical-free energy available from the hydrolysis of a single molecule of adenosine triphosphate, the usual reservoir of energy in cells, is of the same order (Lehninger 1970). The question that one wishes to raise is the following: is a fixed direction of the gravity vector an essential prerequisite of the symmetry-breaking processes in early embryonic development? Or are other factors like mechanical pressure from within the mother, or polarised chemical reactions, sufficient? It must be emphasised that to guarantee that development occurs under near-zero *g* conditions one needs to begin the experiment at least one generation in advance, so to speak. This is in order to be certain that gravitational effects on egg development are also eliminated.

The second remark is concerned with the fact that the evolution of living systems has of necessity taken place under conditions of finite *g*. This has led to all sorts of adaptations, as for example those concerned with flight. What sort of adaptations would selection lead to under zero *g* conditions? This is a blind-alley experiment, but at the same time one potentially capable of giving rise to a very interesting outcome. In order to notice a trend of change within a reasonable time one would need to pick an organism which (a) has evolved quite special techniques to beat gravity, (b) breeds sufficiently rapidly, and (c) generates a large amount of genetic variability within each generation. Since spontaneous rates of mutation are normally quite small, one might want to accelerate (c) artificially—say by making use of ionising radiations. An interesting candidate for such an experiment would be the fruit fly *Drosophila*, particularly since among the advanced organisms its genetics has been studied more than that of any other.

In conclusion, the author wishes to stress that in no way does he regard the speculative ideas mentioned here as even partial justification for an experimental programme in outer space, particularly one in which our country has to bear much of the cost. As far as the problem of a fundamental understanding of living systems goes, there is no compelling need at the present time to seek answers in outer space. Besides, to return to an earlier point with a different emphasis, it is unlikely that such work will in any way be more worth doing than equivalent but inexpensive—and perhaps more ingenious—experiments performed on earth.

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