Reports

Nonexistence of Gravity Shields

Electric forces exhibit sign reversals that can be associated with plus and minus signs for elementary charges. In considering gravitational effects upon antimatter, it is essential to know whether a similar sign change occurs for gravitational forces. This note gives an elementary argument for a negative conclusion—namely, the dominant gravitational force between matter and antimatter is attractive, just as between matter and matter. This conclusion may be of significance for cosmological speculation involving antimatter (*1*).

The following discussion involves two approximations: the gravitational field is considered as weak, so that distortion of space-time can be neglected; and relative velocities are supposed to be small, so that only the static interaction terms need be included. Both approximations are appropriate to most practical applications of gravitation. Under these approximations, the electromagnetic and gravitational interactions between two systems assume identical forms:

$$V = -\int\int d^3r_1\rho_1(r_1)\,\varphi(1r_1 - r_21)\rho_2(r_2)\,d^3r_2 \quad (1)$$

Here φ is a function exclusively determined by the properties of the gravitational or electromagnetic field transmitting the interaction from r_1 to r_2, and ρ_j is an appropriate density junction for system j. In the static approximation $\varphi(x) = x^{-1}$ for both gravitational and electromagnetic fields, since both are massless. The quantities ρ_j are different for the two cases, however: the charge density is the fourth component of a 4-vector, while the matter density is the double-fourth component of a second-order tensor.

In the weak-field approximation, the interaction between gross aggregates of matter is the sum of the interactions between their constituent elementary particles (nucleons and electrons). Thus the behavior of V for gross matter is determined by its behavior for elementary particles. In quantum mechanics, the essential step in transforming from a particle to an antiparticle is the operation of complex conjugation, where the associated conventional coordinate system is (x, y, z, ict). Thus complex conjugation is also associated with reversal of the sign of t and of all 4-components; the charge density ρ_j will hence change sign upon substitution of antimatter for matter, while the matter density will not, having the signature $(-1)^2 = +1$.

Another statement of this conclusion is that "gravitational charge" has only one sign. This immediately negates the possibility of a shield for gravitational forces: the action of an electric shield depends on the separability of two types of charge with opposite sign. This result may be limited by the approximations stated but should certainly be valid for all terrestrial applications.

This argument obviously extends to fields of any intrinsic multipolarity: if two particles interact through the mediation of an nth order tensor field (*2*), the associated static potential will or will not suffer sign changes for antiparticles, according as n is odd or even. Association of the imaginary factor i with the time coordinate characterizes a second alternation of sign between even and odd n. For like charges, $(\rho_1\,\rho_2)$ has a factor $(i)^{2n} = (-1)^n$; with the additional minus sign in Eq. 1, like charges are repulsive for odd n, attractive for even n. Hence attractive static potentials are possible for any n, but repulsive potentials occur only for odd n.

D. C. PEASLEE

Department of Physics,
Purdue University, Lafayette, Indiana

References and Notes

1. For example, M. Goldhaber, *Science* **124**, 218 (1956).
2. Pseudotensor fields are excluded from consideration, for they yield a vanishing interaction in the static approximation.

19 November 1956

Sulfhydryl Groups and Cell Division

The idea has long been held that sulfhydryl groups are particularly important in cell division. Support for this idea has come from three lines of evidence, all established by early investigators (*1, 2*): the strong nitroprusside reaction of a number of proliferating tissues; the inhibition of division by thiol poisons and its reversal by cysteine, glutathione, or thioglycollate; and the fall and rise in concentration of soluble thiols prior to first cleavage in the fertilized sea-urchin egg.

On the basis of these observations, Rapkine (*1*) proposed a theory of division in which a reversible denaturation of protein and a reduction of oxidized glutathione were the key mechanisms. In Rapkine's scheme, protein denaturation was the primary event that had to precede division since it was by the resultant exposure of the —SH radicals that the intracellular store of oxidized glutathione was reduced. The glutathione thus formed altered the oxidation-reduction level of the cell so as to effect a fermentative metabolism leading to division.

Later, Brachet (*3*) pointed out that the oxidation of protein —SH to the disulfide could be given in addition a structural function by relating the disulfide linkage to the formation of the mitotic spindle. Recently, Mazia (*4*) dismissed the idea that the changes in soluble sulfhydryl concentration were related to metabolic shifts in the dividing cell. Instead, he interpreted the fall and rise in soluble sulfhydryl concentration as resulting from the formation and dissolution of the spindle elements. To support this interpretation, he presented preliminary data showing that at the time of spindle formation in the fertilized sea-urchin egg, protein —SH was at its lowest and soluble thiol at its highest concentration, and that throughout the cycle from fertilization to first cleavage, protein —SH and soluble —SH were in reciprocal concentrations.

It is the purpose of this communication (*5, 6*) to report briefly some analytic results that have a bearing on these speculations. Developing anthers of a lily (*Lilium longiflorum* var. Croft) were analyzed for their content of soluble and protein sulfhydryl during an 11-day interval surrounding the mitosis of the microspores. It is possible to determine the interval easily because of Erickson's demonstration that the length of a flower bud is correlated with the synchronous divisions of the germinal cells in the anther (*7*). At 41 mm, these cells are all present as young microspores; at 62 to 63 mm, the mid-point of the interval studied, they undergo mitosis to yield binucleate pollen cells, the only quick and marked change between 41 and 180 mm, the time of anthesis.

During this interval, the microspores and pollen are the principal components of the anthers. They differ from the much studied sea-urchin egg in at least two important respects: (i) they do not have the extraordinarily low nucleo-cytoplasmic ratio of the newly fertilized egg in which cytoplasmic changes (the growth and disappearance of the spermaster, for example) could well obscure changes directly related to nuclear division and (ii) they do not undergo cytoplasmic cleavage. Since such cleavage is

generally accompanied by sol-gel transformations, the possibility that the measured changes in protein —SH are due to this purely cytoplasmic event is eliminated in analyses of the anther.

The cycles of thiol concentrations associated with microspore mitosis are illustrated in Fig. 1. The solid line represents the total acid-soluble —SH and —SS— as determined by amperometric titration after electrolytic reduction of the extracts. It can be seen from the values for —SH alone (determined on the same extracts before reduction) that there is no conversion of —SS— to —SH preceding mitosis such as is postulated by Rapkine. Parallel determination of glutathione content of the extracts by the glyoxalase technique revealed the same cycle of variation as that found by the amperometric method. The soluble —SH was largely, though not entirely, glutathione.

The results are thus in agreement with the generalization of Rapkine that soluble thiol compounds increase prior to cell division. The source of such thiol is not, however, in a reservoir of soluble disulfide. On the contrary, there is an absolute increase in the concentration of glutathione preceding mitosis, and this high concentration persists until well after mitosis is completed. Variations of a smaller order of magnitude have been noted during the mitotic period, but because they have not yet been satisfactorily established they are omitted from the figure. Since formation and dissolution of the spindle occurs during mitosis and, since the high concentration of —SH extends well on both sides of the mitotic cycle, the idea that the concentration of glutathione varies directly as the degree of gelation of the spindle body cannot have general application. Indeed, by comparing the curves for protein and soluble —SH, respectively, it can be seen that in lily microspores the two components do not bear a reciprocal relationship to one another.

In one respect, the results obtained are consistent with earlier studies on marine eggs and protozoans: the association of an intense nitroprusside reactivity with the process of cell division. To this we can only add that the reactivity is, in fact, largely due to glutathione. There is no indication from the data concerning how the increase in soluble sulfhydryl occurs. The most probable explanation is that there is a synthesis of the compounds in question. Neither Rapkine's idea of protein as an —SS— reducing agent, nor Mazia's idea of the spindle as a glutathione-releasing agent can account for the behavior of the microscopes.

With respect to *function,* there are at least a few facts that point in the direction of a metabolic role for the glutathione. It has already been found in lily anthers that ascorbic acid concentration increases during microspore mitosis; by contrast, oxygen consumption falls (*7*, *8*). The twin occurrence of ascorbic acid and glutathione where the normal channels of terminal oxidation are interrupted may have some significance. Glutathione and ascorbic acid appear to play an important role in the respiration of embryonic plant tissues in which cell divisions are presumably frequent (*9*). In a number of animal tissues, ascorbic acid and glutathione have been found in isolated nuclei; possibly they are associated in some ways with nuclear metabolism (*8*). Thus, whether or not Rapkine was correct in picturing glutathione as effecting a fermentation in the cell to stimulate division, his idea that glutathione plays a metabolic role in the process of cell division certainly finds support in the behavior of lily microspores.

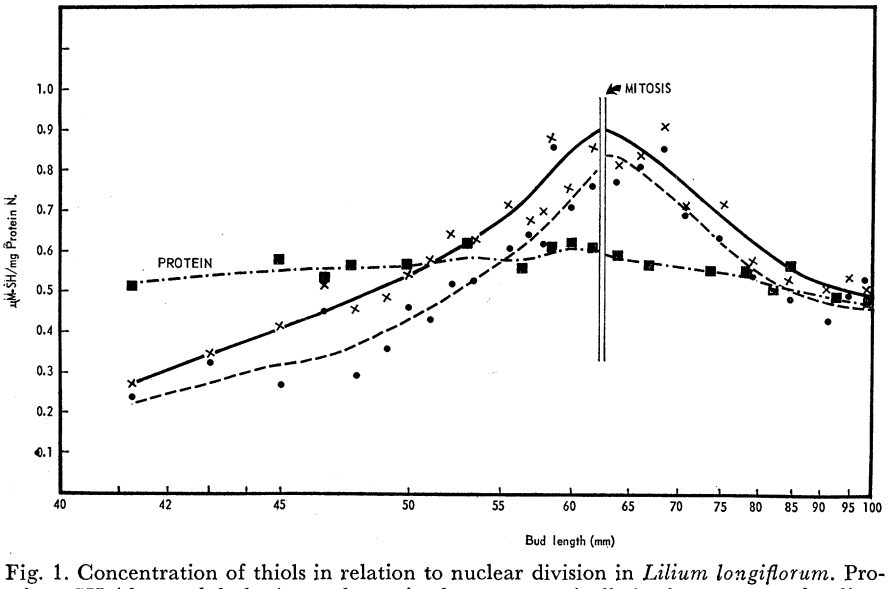

Fig. 1. Concentration of thiols in relation to nuclear division in *Lilium longiflorum.* Protein —SH (dots and dashes) was determined amperometrically in the presence of sodium lauryl sulfate after the protein had been washed twice with sulfosalicylic acid. The solid line represents total soluble thiols; the broken line, reduced soluble thiols. The use of bud length as an index of cell development has already been established (*7*).

HERBERT STERN

Chemistry Division, Science Service, Canada Department of Agriculture, Ottawa, Ontario

References and Notes

1. L. Rapkine, *Ann. physiol. physicochim. biol.* 7, 382 (1931).
2. F. S. Hammett, *Protoplasma* 7, 297 (1929).
3. J. Brachet, *Chemical Embryology* (Interscience, New York, 1950).
4. D. Mazia, *Glutathione* (Academic, New York, 1954).
5. This article is contribution No. 327, Chemistry Division, Science Service, Canada Department of Agriculture.
6. I wish to express my thanks to B. Rheaume for his helpful technical assistance in these experiments.
7. R. O. Erickson, *Nature* 159, 275 (1947).
8. H. Stern and S. Timonen, *J. Gen. Physiol.* 37, 483 (1954).
9. L. W. Mapson and E. M. Moustafa, *Biochem. J. (London)* 62, 248 (1956).

16 November 1956

Preparation and Properties of Growth Hormone from Human and Monkey Pituitary Glands

Following the isolation of growth hormone (somatotropin) in pure form from beef pituitaries (*1*), many attempts have been made to determine its effectiveness in man, but without success (*2*). Similarly, it has been shown that while growth hormone prepared from fish pituitaries is active in fish, it is not active in rats (*3*). Likewise, somatotropin concentrate from monkey pituitaries is active in the monkey, whereas the beef hormone is not (*4*). One of the obvious explanations for the failure of the beef somatotropin to act in man is that the beef somatotropin is chemically different from the hormone derived from man. We wish to report (*5*) that the human and monkey growth hormones are indeed different from the beef hormone.

From 0.8 g of lyophilized human pituitaries (*6*) extracted with CaO solution, an active concentrate was obtained by precipitation with 1.9*M* $(NH_4)_2SO_4$ as previously described (*7*). The $(NH_4)_2SO_4$ precipitate was extracted with phosphate buffer of *p*H 5.1, containing 0.057*M* Na^+ and 0.45 *M* $(NH_4)_2SO_4$. The clear extract was chromatographed on the polycarboxylic acid resin Amberlite IRC-50 (XE-97) under the conditions shown in Fig. 1. The contents of tubes 99 to 127 were combined, and the active component was precipitated by adding an equal volume of 5.0*M* $(NH_4)_2SO_4$. The precipitate was dissolved and dialyzed. The dialyzed solution was brought first to *p*H 4.5 and