to $10^{50}$ gms, we find as an upper limit for the density $10^{-16}$ gms per ccm.

It might be mentioned incidentally that we arrive at the same value for the mass of the universe as does Sir Arthur Eddington if we simply start from the following two hypotheses:

(1) That the sum of the proper energies of all particles contained in the universe equals the amount of the gravitational energy of the universe (either exactly or at least in the order of magnitude);

(2) That the sum of the spheres of action of all the electrons contained in the universe is as great as the surface of a sphere which would include a volume equal to the total volume of the universe.[2]

It might also be mentioned that Sir Arthur Eddington's wave-mechanical considerations make it probable that a purely arithmetical relation connects the masses of the hydrogen-atom and the electron, that is

$$(5) \qquad \frac{m_H}{m} = 4\,\pi \times 137 \times \sqrt{\frac{17}{15}}$$

The ratio 17/15 is the same as 136/120, whereas the whole number 137 is, according to Sir Arthur Eddington, the reciprocal of the Sommerfeld constant of fine structure of the hydrogen-spectrum. The arithmetical relation (5) yields the value 1,833, whereas the empirical value is 1,835.[3]

The elementary quantum of action may be represented, as is well known, either as a product of energy and time or as a product of length and momentum. If we, therefore, divide the elementary quantum of action by cosmic constants of the dimensions of time, energy, length and momentum, respectively, we obtain four "subatomic" constants (about $10^{-43}$ ergs, $10^{-103}$ sec, $10^{-93}$ cm, and $10^{-54}$ gm cm $sec^{-1}$). The subatomic energy constant, which might be called the primordial energy-element, seems to find a simple interpretation. As is well known, the red-shift in the line-spectra of extra-galactic nebulae can be described by the formula

$$(6) \qquad \frac{\Delta\nu}{\nu} = \frac{s}{c\,t^*}$$

Here $\Delta\nu$ means the diminution in frequency of a photon emitted by an object in the distance $s$, and $c\,t^*$ is a distance of 1,700 million light years, and therefore

$$(7) \qquad 1/t^* = 1.8 \times 10^{-17}\ \text{sec}^{-1}.$$

The primordial energy-element ($w$) is given by the relation

$$(8) \qquad w = \frac{h}{t^*} = 1.2 \times 10^{-43}\ \text{ergs},$$

$h$ denoting the elementary quantum of action.

[2] *Cf.* A. Haas, *Phys. Rev.*, 49: 411, 1936.
[3] *Cf.* A. Haas, *Phys. Rev.*, 49: 636, 1936.

If we denote the energy of the photon by $\varepsilon$ (where $\varepsilon = h\nu$), we may write equation (6) in the following form

$$\Delta\varepsilon = h\,\nu\,t/t^*$$

where $t$ denotes the time during which the photon has been traveling, or

$$(9) \qquad \Delta\varepsilon = w \times \nu \times t$$

We now recognize at once the significance of the constant $w$ if we put $t$ equal to a period of a single oscillation, that is, equal to the reciprocal of $\nu$. In this special case the loss in energy becomes equal to $w$. This means that every photon, irrespective of its wave-length, gives off a primordial energy-element during each vibration or in traveling one wave-length.

The number of primordial energy elements which are given off in a definite time depends on the frequency, but the relative diminution in energy in this time is independent of the frequency. A violet photon, *e.g.*, loses twice as many primordial energy elements per second as a red photon, but, on the other hand, the violet photon contains twice as much energy as the red photon.

We have in the universe, on the average, a quantity of radiant energy of about $3 \times 10^{15}$ ergs, referred to one gram of matter.[4] The loss in radiant energy which is the consequence of the continual "reddening" would, therefore be, according to equation (6)

$$3 \times 10^{15} \times 1.8 \times 10^{-17}$$

or about 0.1 ergs per gram and second.

On the other hand, the energy production by the stars and star-systems amounts to about one tenth of an erg per gram and second.[5] The energy which is given off in the form of primordial energy elements might, therefore, be compensated by the energy production of the stars. Perhaps we might consider the energy which is liberated in the form of primordial energy elements, as the source of the radiation of the star-systems.

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## TYPE SPECIFIC ANTIPNEUMOCOCCUS RABBIT SERUM

BOTH horses and rabbits may be immunized against pneumococci of the various types, and the sera of these animals not only react specifically *in vitro* with the homologous micro-organisms and their products, but also afford protection against infection in laboratory animals. The sera from these two species of animals,

[4] *Cf.* A. Haas, "Kosmologische Probleme der Physik," Leipzig, 1934, Chapter IV.
[5] *Cf.* A. Haas, *Anzeiger Akad. Wiss. Vienna*, 70: 265, 1933.

however, differ in a number of properties. The antibodies of the two species differ in size, solubility and degree of specificity.[1, 2] The optimum physical conditions for the interaction between antigen and antibody are different for sera of the two species and the immune precipitates formed with the polysaccharides are distinctive in appearance. Evidence has been presented indicating that the antibody in horse serum is a lecithoprotein, while that in immune rabbit serum is a cephaloprotein.[2] Indeed, sera from the two species have been found to differ in their immunological properties in at least thirty respects.

Some of these differences suggest that antipneumococcus rabbit serum may possess certain advantages over horse serum in the treatment of lobar pneumonia.

(1) Immune rabbit sera confer a greater degree of protection on mice in proportion to the content of specifically precipitable protein than do antipneumococcus horse sera, as is shown in Table I. This is probably related to the fact that the antibodies in immune rabbit serum are of smaller size than are those in horse serum. The latter fact also suggests that diffusion of the immune substance into infected foci may occur with greater readiness in the case of rabbit serum than with horse serum.

TABLE I

MOUSE PROTECTIVE POTENCY WITH REFERENCE TO AMOUNT OF SPECIFICALLY PRECIPITABLE NITROGEN

| Serum | Mouse protective units per cc | Maximal amount of specifically precipitable nitrogen | Protective units per mg specifically precipitable nitrogen |
|---|---|---|---|
| Horse A concentrated.. | 3,000 | 5.80 mg | 520 |
| Horse B unconcentrated | 750 | 1.51 " | 500 |
| Rabbit A unconcentrated | 1,700 | 1.51 " | 1,120 |
| Rabbit B unconcentrated | 1,400 | 0.67 " | 2,090 |

Protective units of sera determined by method of Kirkbride, Hendry and Murdick.[3] Specifically precipitable nitrogen determined by the method of Heidelberger and Kendall.[4]

(2) In mice, small amounts of cholesterol, cephalin or materials rich in these lipids block the protective action of antipneumococcus horse serum but are without effect in the case of rabbit serum.[5]

(3) In massive infections in laboratory animals there are optimal amounts of antipneumococcus horse sera which must be used in order to obtain successful results. Larger amounts are less efficacious and still larger amounts may have no protective action whatever. This "prozone" effect is not observed with antipneumococcus rabbit serum.[6]

(4) Although it is still a moot question as to whether complement may be involved in the protective action of immune serum against pneumococcus infection in animals, it may be pointed out that *in vitro* complement fixation does not occur when pneumococcus polysaccharides are mixed with immune horse serum, while it does take place when they are mixed with immune rabbit serum.[7]

(5) As compared with horses, rabbits almost invariably respond to pneumococcus immunization with the production of serum of good titer. If serum treatment is to be carried out in all cases due to any one of the thirty or more types, the production of these sera would be greatly simplified by employing small animals rather than horses.

(6) In our hands the cost of producing immune rabbit serum is definitely less than the cost of producing concentrated antipneumococcus horse serum. The increased cost of handling small animals is more than offset by the fact that concentration of rabbit serum is less necessary in view of its high potency.

(7) Owing to the present wide-spread use of immune horse serum in a variety of conditions, the number of individuals artificially sensitized to rabbit serum is probably much less than the number of persons sensitized to horse serum and the danger of anaphylactic reactions may therefore be less if rabbit rather than horse serum be employed in treatment.

In view of these considerations and the fact that there appeared to be no contraindications to its use, antipneumococcus rabbit serum was first employed in this hospital in the treatment of Type I lobar pneumonia in man in April, 1936. Subsequently similar preparations have been used in the treatment of cases due to pneumococci of certain of the other types as well.

The series of cases in which rabbit serum has been used is as yet not sufficiently extensive to permit conclusions to be drawn concerning its efficacy as compared with horse serum, and the clinical results obtained will form the subject of a subsequent communication. In Type I pneumonia, however, in which a large experience in treatment with horse serum has already been gained in this hospital, treatment with immune rabbit serum in the few cases in which it has been employed has apparently been very efficacious. The experience so far obtained indicates that rabbit

[1] K. Goodner, F. L. Horsfall, Jr., and J. H. Bauer, *Proc. Soc. Exp. Biol. and Med.*, 34: 617, 1936.

[2] F. L. Horsfall, Jr., and K. Goodner, *Jour. Exp. Med.*, 62: 485, 1935.

[3] M. B. Kirkbride, J. L. Hendry and P. P. Murdick, *Amer. Jour. Hygiene*, 23: 187, 1936.

[4] M. Heidelberger and F. E. Kendall, *Jour. Exp. Med.*, 61: 559, 1935.

[5] K. Goodner and F. L. Horsfall, Jr., *Jour. Exp. Med.*, 64: 377, 1936.

[6] Goodner, K. and F. L. Horsfall, Jr., *Jour. Exp. Med.*, 62: 359, 1935; and 64: 369, 1936.

[7] H. Zinsser and J. T. Parker, *Jour. Immunol.*, 8: 151, 1923.

serum is no more toxic for man than is horse serum; immediate reactions do not occur with any greater frequency. Serum sickness has been infrequent and of a mild character.

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## IDENTICAL TWINS IN A MOUSE CROSS

IN 1934 the late Dr. C. V. Green[1] published statistical evidence that there occur occasionally in mice uniovular twins, since pairs of individuals with identical color characters and of like sex occur more frequently than chance alone would indicate to be probable. Miss Bodemann[2] has also described and figured two mouse embryos in the primitive streak stage found enclosed within a common yolk sac endoderm layer, among the progeny of x-rayed mice, evidence which points to the same conclusion as that reached by Green.

We are able to support Green's conclusion with observational evidence of the occurrence of a pair of identical twins under conditions which render their identification all but unmistakable.

The genes for two recessive mutant characters (dilution (d) and short ear (se)) are borne in the same mouse autosome at closely adjacent loci. Gates (1928), who made a "repulsion" cross, observed no crossovers in an $F_2$ population of 426 individuals involving a test of 852 chromosomes. Snell (1928), however, in a similar but more extensive search for cross-overs reported the occurrence of one crossover in 1,158 cases; later in data hitherto unpublished he observed two crossovers in 890 cases. In backcross populations, Miss Copeland in 1931 reported the occurrence of one crossover in 106 cases, an observation confirmed by Snell, though he himself observed no crossovers among 1,034 backcross young. Combining these various observations, the indicated occurrence of crossovers up to 1931 was 4 in 4,040, or roughly 1 in 1,000 cases.

Subsequently, Castle, Gates, Reed and Law[3] made a cross in which short ear and dilution were introduced in the coupling relationship, reciprocal backcrosses being later made to the double recessive (d se) race. The observed recombinations and their respective frequencies were as follows:

| | D Se | d Se | D se | d se |
|---|---|---|---|---|
| ♀ $F_1$ × ♂ d se .... | 827 | 2 | 0 | 792 |
| ♂ $F_1$ × ♀ d se .... | 67 | 0 | 1 | 68 |
| Totals ...... | **894** | **2** | **1** | **860** |

Three crossovers were thus observed in 1,757 cases, or about 1.75 to a thousand, a frequency somewhat greater than that previously reported, but based chiefly on the behavior of heterozygous females in which crossing over is known to be more frequent than in males. We may then safely conclude that the normal amount of crossing over between the loci for dilution and short ear is not over one or two for a thousand cases.

Besides the three crossover cases already reported, there was observed, in a backcross between a doubly heterozygous female and a double recessive male, a pair of dilute brown males having long ears and so belonging in the crossover class, d Se. Since a crossover has a probability of occurrence of only one or two in a thousand, the odds against the occurrence simultaneously in the same litter of two independent crossovers identical in sex and three independent color characters would be about 332 to 1, according to calculations made by Snell, the details of which need not be reported here.

We accordingly regard the conclusion as justified that the pair of long-eared dilute brown male individuals which occurred in the same backcross litter were in reality *identical twins* derived from the fertilization of a single egg in which a rare crossover had occurred between the loci for dilution and short ear.

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# SCIENTIFIC APPARATUS AND LABORATORY METHODS

## A NEW APPARATUS FOR CONSTANT TEMPERATURE

THE continuous maintenance of precise temperatures by the use of heating units is now a relatively simple matter, but the available temperatures dependent upon the controlled application of heat are necessarily above the temperature of the room in which the apparatus is kept. There is also equipment for maintaining fixed temperatures below room temperature by the use of refrigerating units. In connection with experimental work by the senior author, it was desired to have several chambers in which constant temperature could be maintained independently of room temperature, the temperature of one chamber would be independent of that of any other, and there would be complete flexibility within a wide range of low and high temperatures.

We have designed and had in satisfactory use for

[1] SCIENCE, 80: 616, December 28, 1934.
[2] *Anat. Record*, 62: 291–294, 1935.
[3] *Genetics*, 21: 310–323, July, 1936.