tion of a magnetic field. The shapes and sizes of the paths of electrons in the metal, which reflect the size and shape of the Fermi surface, are then probed by various techniques, and parts of the surfaces can be deduced. Perhaps the most powerful technique makes use of the de Haas–van Alphen effect. This effect depends upon a restriction in the number of allowed corkscrew orbits in a magnetic field, similar to the restriction in number of allowed orbits in the atom, or in the metal with no magnetic field. This gives rise to fluctuations in many properties at high magnetic fields, notably in magnetic susceptibility, and these fluctuations are related directly to cross-sectional areas of the Fermi surface.

None of these experimental techniques could have been used without extremely pure samples of metals. The presence of impurities, as mentioned earlier, causes electron collisions. If these collisions become so frequent that an electron never completes a full path in the magnetic field without a collision, the paths become ill-defined and measurements become smeared-out and useless. Rapid advances in the understanding of Fermi surfaces have been possible only during the past few years, when extremely pure metals have been available. The requirement for long electron paths between collisions also makes it necessary to conduct these experiments at extremely low temperatures, so that the thermal vibrations, with their concomitant electron scattering, are minimized.

For the same reasons that experimental studies of the Fermi surface have only recently been possible, it is only recently that a need for this knowledge has been strongly felt. The cruder experiments could be explained by the cruder theory if the assumed concentration of electrons and their rate of scattering were chosen to fit the experiments. Only a few phenomena, such as the increase in electrical resistance with magnetic field, signaled the failure of the free-electron model and piqued the curiosity of the physicist.

Unsolved Problems

Intense activity in these highly specialized techniques has led not only to a remarkable advance in our knowledge of electron behavior in metals but also to a number of controversies such as generally arise in an active area of science. Greatly increased knowledge of the Fermi surface in metals, which is central to the whole problem of the properties of metals, has clarified our understanding of some aspects of metallic behavior but has also disrupted what we thought we understood about other aspects, just as Drude's free-electron model replaced one problem with another.

This step forward has spotlighted our ignorance of the effects of the interaction between individual electrons due to the electronic charge and the interaction due to the presence of the lattice. This latter interaction occurs as an electron moving through the crystal jostles the atoms and as they, in turn, jostle the other electrons. Such an interaction forms the basis for the theory of superconductivity, but also is manifested in metals which are not superconducting.

Whatever the problems that remain to be solved, this recent mastery of some of the intricacies of the motions of electrons in metals has provided an appealing and unusually graphic chapter in solid-state science.

Note added in proof: Various studies during the past few months have indicated that the true Fermi surface of copper is bulged out somewhat more than is shown in the direction of the square faces of the polyhedron.

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CURRENT PROBLEMS IN RESEARCH

Body Composition

The relative amounts of fat, tissue, and water vary with age, sex, exercise, and nutritional state.

Josef Brožek

The field of body composition is one of the focal points of contemporary human and animal biology. While the roots of one of the methods of investigation can be traced all the way back to Archimedes, and a baker's dozen of references date from the period 1920–1940, the overwhelming majority of the innovations in method are the contribution of the last two decades. This era was ushered in by A. R. Behnke's essay (*1*) in 1941. Many developments followed: mathematical body-composition models and calculational formulas (*2*–*5*); improvements in the hydrostatic technique (*6*) and measurements of body volume by helium dilution (*7*); intensive use of anthropometric methods (*8*) and the addition of roentgenographic methods (*9*); gasometric (*10*) and hydrometric approaches (*11*), and a multiplicity of means for measuring total and extracellular body water (*12*); electrolyte-determination methods, especially for potassium (*13*); methods for the simultaneous assessment of a large number of body compartments (*14*); and examination of the interrelations between the various approaches (*15*–*17*). With the passage of time, these methods were applied in an ever wider context of experimental, clinical, and field studies.

The fact that much of the literature on body composition is the fruit of the last two decades indicates that the field is in the stage of late adolescence rather than of full-blown maturity. A critical analysis of the current status of the

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methods confirms such an appraisal.

Cyclic fluctuations along the acceptance-rejection continuum are not unusual in the history of scientific methods. In the first, positive, creative stage the investigators, especially those who directly participate in the development of a new approach, are apt to be enthusiastic. They are impressed by how good the first approximations are. In the second, the critical, stage, the fact that these were only the first approximations is likely to be stressed. The complexities of methodology, glossed over at first, are likely to be found overwhelming. The quantitative assumptions are questioned, and the size of the standard errors rather than the typical values of the biological "constants" are stressed. It becomes clear, in time, that definitions must be sharpened, ambiguities of terminology reduced or eliminated, and quantitative assumptions replaced by factual data based on well-defined samples.

The greatest merit a theoretical model can claim is that of being stated in clear enough terms so that it can be replaced, in part or in toto, by a new set of quantitative relationships, established by further research. This was the point of view that guided Keys and me in making a systematic appraisal of body-composition methodology (*4*). Incorporated in this study were the new information on the density of human fat [obtained as petroleum ether extract (*18*)], on the density of the "reference man" (*19*), and on the mass ("obesity tissue") that is gained over a period of months by adult individuals as a result of positive caloric balance (*20*).

Ljunggren (*21*) supplemented the term *obesity tissue* with the concept of "nonobesity tissue," as a substitute for Behnke's "lean body mass." What the field needed, I feel, was not so much a new term as insistence that the existing terms be used clearly. The lack of distinction between *fat-free weight* and *lean body mass* is especially distressing. Ljunggren's "nonobesity tissue" is defined as body weight less obesity tissue, and thus it becomes close to, but not identical with, von Döbeln's (*22*) concept of lean body mass. The latter differs from Behnke's definition of the body compartment to which he gave the same name.

The first theoretical model of mammalian body composition, as visualized by Behnke and his productive "Navy school," was described in detail by Morales *et al.* (*2*). Recently Morales and Williams (*23*) again took up the problem, with emphasis on the relation between densitometric and hydrometric analysis of body composition and the logical independence of the two methods.

Clearly, there is a partial *operational* independence: in one case we measure body density (and extracellular water), in the other case we determine the total (and extracellular) body water. The bone of contention is the dependence or independence of the underlying models, specifying the compartments into which the body is partitioned, and of quantitative assumptions. Personally, I am more interested in the internal conceptual consistency of different systems of body-composition analysis and in their mutual "translatability" (*17*) than in their "independence." Thus, in principle, I look with favor on the work of Behnke and his colleagues (*15*), who replaced the previously accepted figure for the percentage of water in lean body mass (73.2 percent) by a new value (71.8 percent). In this way the estimation equation was adjusted so that the mean values for body fat as calculated from total body water (antipyrine dilution) and from specific gravity were identical (15.0 percent of body weight). Such adjustments in the biological "constants," if within the limits of empirically established fact, are not only permissible but desirable. At the same time such adjustments may be regarded as constituting a "contamination" of the two approaches and may be frowned upon by champions of independence of the densitometric and the hydrometric approaches.

The techniques for the estimation of water, fat, protein, and mineral were described and critically examined by Siri (*5*), who considered both the hydrometric and the densitometric approaches and combinations of the two. Anthropometry remained outside the scope of the presentation. Siri expressed the opinion that the anthropometric approach, including skin-fold measurements and somatotyping, can hardly be expected to give a precise quantitative picture of the gross composition of the human body, yet may yield highly useful indices where significant correlations can be demonstrated with physiological, nutritional, or clinical factors under study (*5*, p. 242).

By contrast, Tanner (*24*), in his survey of the methods of measuring body fat in man, emphasized the anthropometric procedures, including soft-tissue radiography. He pointed out that a specific contribution of the anthropometric methods is their characterization of the *distribution* of superficial body fat, whereas the physicochemical methods yield information about the total body fat.

The methods of measuring body composition, from the point of view of physical anthropology, are described briefly in the new edition of *An Introduction to Physical Anthropology* (*25*). The methodological problems were discussed in detail at a symposium on the techniques for the measurement of body composition (*26*).

A systematic, critical presentation of the results of the studies on body composition will require a similar monographic treatment and contributions from many individuals, since the range of topics is large and involves not only basic biomedical disciplines (anatomy, physical anthropology, physiology, biophysics, biochemistry) but also such diverse areas of application as internal medicine and surgery, physical education and the science of nutrition, gerontology, and actuarial science, which is concerned with somatic predictors of morbidity and mortality.

Applications

As an "interim report," this brief survey of selected areas of application may be useful. Most of the references cited deal with work published in the last 7 years. For previous work, see the review by Keys and me (*4*), with sections on the analysis of weight changes, metabolic rate, and standards of reference for such variables as cardiac output and for dosage of anesthetics. In this article, as in the earlier review, emphasis is placed on problems of human biology rather than on problems of medicine and surgery. In a measure I regret this, since I share the belief that the possibility of measuring, in pathological conditions, departures of body-composition parameters from the norm opens a new and significant avenue for quantitative evaluation of disease states (*27*). This, in turn, should provide a firmer basis for therapy.

Replacing the term *chemical anthropology* by *body composition* [to which it is closely related (see *28*)], we may take as our point of departure a recent statement by R. J. Williams (*29*, p. 267): "The importance of the analysis of body composition lies in the fact that it is capable of leading the way toward a better understanding of human differences." Basic advances in the analysis of human biological individuality have an inherent, theoretical merit. In addition, they should facilitate the elucidation of some practical problems of "fitness," as regards both performance capacity and health. In regard to the former criterion, considerations of space travel are stimulating analysis of the human body in terms of components that vary in their vibratory characteristics (*30*). This is a novel approach to body composition and brings into focus a totally new facet of relationships between physique and the ability to perform under conditions of stress.

Disease may be regarded, also, as the result of stress. With the conquest of many infectious diseases, the significance of the "degenerative" (noncongenital, noninfectious) diseases as a factor in mortality has increased dramatically. They clearly belong to the category referred to by Williams (*29*, p. 19), who noted that "among the diseases which strike mankind there are many which need to be attacked from the standpoint of their relationship to the individuals who contract them." In regard to individuality, man's physique —with body composition one of its basic facets—calls for special attention. Interindividual differences in body composition are large; they are the resultant of interaction between genetic, behavioral (physical-activity), and environmental (nutritional) determinants; and the available data, limited as they are, document the importance of differences in physique with regard to morbidity and mortality.

Substantial advances have been made in the last two decades in the application of the techniques for studying body composition in a variety of experimental, clinical, and epidemiological contexts. In this article I consider functional and pathological correlates of differences in body composition; growth, aging, and sex; physical activity; and nutrition, with special reference to intraindividual weight loss and weight gain and to interindividual differences in fatness. Brief reference is made, also, to results in animal research.

Body Composition in Animals

While we cannot expect much help from animal studies as regards validation of the specific quantitative parameters assumed in human body-composition models, such as the average mineral content of the body, various methodological problems can be elucidated on the basis of animal data. In the past, important concepts were defined and valuable data were gathered by individuals concerned with the growth and development of farm animals. Thus, Moulton (*31*) formulated the concept of "chemical maturity" and defined it as a state in which the composition of the fat-free mass approximates constancy. He also carried out early studies on changes in body composition during underfeeding (*32*).

I cannot attempt here to survey systematically the literature on animal body composition and must limit myself to two points.

1) Potential gains will result from a closer collaboration between students of human and of animal body composition. While research with the traditional laboratory animals, from mice to dogs, cannot be neglected, farm animals, especially the pig, are of special interest for the validation of indirect methods with direct criteria derived from anatomical and chemical analysis of carcasses.

2) I refer the reader of H. Pálsson's chapter on "Conformation and body composition" (*33*), published as a part of a comprehensive review of the significant "bulges" along the advancing front of animal husbandry (see *34*). Students of human physique and of growth will find other sections of Hammond's volume rewarding reading. I was struck by the discussion of the external similarities and the profound internal differences in the hump in animals of different species and even in different varieties of the same species. Wright (*35*) points out that in zebu cattle the hump over the thoracic vertebrae originated as a store of reserve fat, and that it still shows, as do the humps of camels, marked seasonal changes in size according to the abundance of the available food supply. By contrast, in the sanga cattle, widely distributed over the tropical areas of Africa, "the comparable development of a marked thickening in the cervico-thoracic region is of purely muscular origin and bears no relationship to fat storage" (*35*).

Even though much of the work on animal body composition has been done to improve "market quality," new data of fundamental importance to animal biology are being gathered through the application of indirect methods in animal research. Specifically, quantitative analyses of body composition in vivo revealed new facts about the differences between the breeds of a given animal species (*36*)—for example, that the "hot-blooded," lighter, and faster breeds of horses not only have a much greater volume of red cells (54.0 cm^3/kg) than the Percherons (37.8 cm^3/kg) but also have a higher water content (63.8 as against 55.2 percent) and a lower fat content (12.8 as against 24.5 percent).

Rearing animals on different "planes of nutrition" not only changes their body composition but importantly affects their longevity. Experiments carried on since 1917 on a variety of animal species indicate with surprising consistency that a high plane of nutrition during early life is not compatible with a long life span (*37*). Cows fed, respectively, 88, 100, and 115 percent of the Scandinavian standard allowances prior to the first calving and the normal (100 percent) allowance after the first calving had average life spans of 86.7, 80.1, and 67.2 months. Reid (*37*, p. 63) notes that a lower plane of nutrition and the resulting retardation of early growth (and changed body composition, at least in some species) is associated with a prolongation of the life span in protozoa, water and fruit flies, silkworms, rats, and mice as well as in cattle. In view of this overwhelming evidence, the pride of mothers, pediatricians, and baby-food manufacturers in babies' plumpness and rapid growth may be somewhat unfounded. In fact, there are few problems in human biology that call for the attention of research workers more urgently than does the relation between early growth rate and adult morbidity and longevity. Unfortunately, the problem cannot be recommended as a topic for Ph.D. theses; it is much too large for investigation by a single individual. The odds are in favor of the subjects' surviving the observer.

Funtional and Pathological Correlates

Body composition is a basic feature of the machinery of the body, and it is to be expected that the existing profound individual differences in body composition will have impact on a variety of biochemical processes and physiological functions (see *4*, p. 315).

Relative obesity, even when assessed as roughly as it is in the medico-actuarial investigations (*38*), has important implications for health and longevity. Among overweight individuals of both sexes mortality is higher than it is in individuals of standard weight, and it rises, in general, with degree of overweight. The increase is the result primarily of excessive death rates from the cardiovascular-renal diseases (diseases of the heart and circulatory system, vascular lesions of the central nervous system, and nephritis), diabetes, and diseases of the digestive system (*38*, p. 84).

It was pointed out by Tanner *et al.* (*39*) that more bodily measurements than those of height and weight must be made if maximally useful information regarding the physique-disease relationship is to be obtained. In their study, physique was characterized in terms of anthropometric measurements (including measurement of skin folds) and of derived body characteristics (surface area), somatotype ratings, and measures of bone, muscle, and fat obtained from roentgenograms (see *40*).

While in populations that are homogeneous with respect to racial origin, sex, age, and activity, the excess weight is a good indicator of fatness, for purposes of more precise analysis in heterogenous populations it is desirable to relate functional characteristics and pathology to more direct criteria of body composition, specifically to fat content.

Some aspects of body metabolism, such as oxygen consumption (for earlier references see *4*, p. 312) and amino acid catabolism, reflected in the formation and the urinary excretion of creatinine, were examined as bases for estimating "fat-free" weight and, by subtraction or from a direct prediction equation, body fat. Best, Kuhl, and Consolazio (*41*) demonstrated that healthy, lean individuals have higher creatinine coefficients (milligrams of creatinine excreted per 24 hours per kilogram of body weight) than obese individuals. The coefficient of correlation r, based on data obtained for 78 soldiers aged 18 to 37 years, between creatinine coefficient and percentage of body fat estimated on the basis of three skin-fold thicknesses was -0.64. At the same time, a simple index of fatness calculated as a ratio of height to abdominal girth showed a closer association ($r = 0.86$) with the percentage of body fat, and Best and his associates concluded that the creatinine coefficient, though a valid measure of obesity, is not as accurate as simpler anthropometric measures. Here the concern was with function as a potential indicator of structure, of body composition. We may take a look at the "function versus tissue masses relations" in reversed perspective.

The analysis of body composition into components of greater functional homogeneity provides more meaningful reference criteria than gross body weight or surface area (calculated from the weight and the height) for physiological functions, such as cardiac output (*42*), and metabolic processes, such as basal metabolism. It is well known that basal metabolic rate, expressed in reference to body surface ($\text{cal/m}^2\text{/hr}$), decreases in a fairly steady manner during maturity (ages 20 to 60), in men as well as in women. Shock (*43*) noted that there is no, or only a very small, decrement in basal metabolism when the oxygen uptake is related to total body water (O_2/lit.), which also diminishes with age and may be considered an index of the amount of "functioning protoplasm." Thus it appears that the metabolic rate of "cells" does not diminish substantially with age, at least not in the male. Earlier densitometric analyses of body composition (*19*, p. 790) indicated that age differences in basal oxygen consumption between normal younger and older men of the same body size was largest when the oxygen consumption per minute was related to gross body weight (age decrement of 15 percent), smaller when related to "fat-free" body weight (8 percent), and smallest (4 percent) when "active tissue mass" was used as a standard of reference.

Zak and Earle (*44*) concluded that "lean body mass" would be a better standard of reference for blood volume than body weight or surface area, particularly in obese subjects. No direct comparisons of the different standards of reference were actually made (see *45*).

Data on body composition have potential relevance for anesthesiology, especially in connection with anesthetics that may have affinity for a particular body component, such as fat. Thus, thiopental (Pentothal sodium) is highly soluble in fat, and it was believed that its anesthetic action is reduced and eventually terminated by its concentration in body fat rather than by metabolism of the drug. Price *et al.* (*46*) insist that the rate at which body fat concentrates thiopental is too slow to explain the rapidity with which the level in the central nervous system is decreased, and that, instead, the lean body tissues rapidly take up most of the anesthetic, which attains its peak concentration in the brain in less than 1 minute after intravenous injection. Thus it appears that fat plays a smaller role in limiting the duration of thiopental narcosis than has been formerly supposed. The problem calls for further investigation.

One function of the subcutaneous fat is that of an insulator. Among nude subjects, inactive during 2 hours of exposure to cold (59°F or 15°C), the core of the body is better protected in fat men. They maintain higher rectal temperatures than thin men. At the same time, their skin temperatures are lower (*47*).

Garn and Haskell (*48*) obtained statistically significant correlations between the thickness of subcutaneous fat, measured on radiographs of children taken at the lower-thoracic site, and several criteria of developmental status. Fat thickness was positively correlated with skeletal age in children 8.5 and 9.5, and 12.5 and 13.5, years of age. Children who were fatter at prepuberal age (8.5 and 9.5 years) completed the epiphyseal (tibial) union sooner, and the girls reached menarche earlier.

The fact that women do better under conditions of semistarvation is well known (*49*, p. 758). This is certain to be due to more than one factor, but body composition is likely to be involved, in view of the higher fat content of the female body. This interpretation is supported by experimental data of Baur and Filler (*50*). The survival of 8-week-old pigs deprived of calories, with water available, was longest in animals with the largest fat stores. When the animals were deprived of both calories and water, the higher water content was associated with longer survival. When the animals have access to food but are deprived of water, the time of survival is substantially reduced, and it appears to be unrelated to body composition.

In healthy young American men, serum cholesterol level is not significantly related to overweight or obesity, as determined from the radiographic measurements of the fat-plus-skin shadow at the level of the tenth rib on standard posteroanterior teleoroentgenograms (*51*). Similarly, absence of important correlation between fatness of the arm and serum cholesterol level (r, based on data for 88 subjects, was $+0.16$) was reported for adult Australian men by Whyte *et al.* (*52*), who cite the older literature.

Sex, Growth, and Aging

Profound changes take place, with time, not only in the total size (bulk) of the human organism but also in the absolute and relative contribution of individual organs and tissues. The literature on changes in body composition with age was summarized by Mickelsen (*53*). He points out the need for longitudinal studies on adults, especially on individuals over 60, and suggests, in view of the relative obesity (higher fat content) found to be associated with greater longevity, that the role in longevity of a moderate surfeit of fat be studied in older women.

To determine sex differences in body composition, studies must be made in individuals of comparable ages. This introduces, of necessity, consideration of age trends. Garn and Haskell (*54*) have shown that the increase in subcutaneous fat, measured at the lower thoracic site on serial chest plates, is small and roughly parallel in boys (from 3.0 millimeters at the age of 6.5 years to 4.5 millimeters at the age of 10.5 years) and in girls (from 4.0 to 5.5 millimeters at the same ages). Thereafter there is a sharp sex differentiation; in the boys the thickness is stabilized at about 4.5 millimeters between the 11th and the 17th year, while in the girls there is a sharp increase, the thickness reaching 8 to 9 millimeters by the 14th year.

This difference is brought out clearly also in Pařízková's (*55*) study of 380 boys aged 10 to 17 years and of 300 girls aged 10 to 16 years, on whom skin-fold measurements were made at ten sites and totaled. Anthropometric data were supplemented by body-density determinations in studies of growth and of physical activity (*56*) and of alimentation and weight reduction (*57*).

Friis-Hansen presented original data on changes with age in body-water components, against the background of the literature (*58*) and, in a brief form, in a collaborative work (*59*). In the human fetus the total body water, expressed as a percentage of body weight, decreases from 94 percent in the first to 82 percent in the eighth lunar month. The rapid decrease in water content continues through the first year of life, from about 78 percent in the newborn child to 60 percent in children in the age group ½ year to 2 years. The extracellular component, determined by the thiosulfate method, exhibits a gradual decrease, from around 42 percent at birth to 20 percent at puberty. The intracellular water, as a fraction of total body weight, is fairly constant during the first 2 years, or at least does not show the consistent decrements exhibited by the total and the extracellular components; there is some increase in subsequent years. A greater number of determinations is needed to differentiate accidental ups and downs from genuine, systematic changes. Furthermore, it would be desirable (but admittedly difficult in vivo) to relate the water components to the "fat-free" weight rather than to total body weight.

Friis-Hansen's data were supplemented (*60*) by information on body water in adults, with particular reference to sex differences. In ten "normal" males and ten females, aged 23 to 54 years, the total body water accounted for 54 and 49 percent, respectively, of the body weight. This statistically significant difference reflects a higher relative content of total body solids in the females, and, specifically, of fat. The percentages of extracellular water, measured as the radiobromide space, are much the same in both sexes (23 percent in males and females), while, again, there is a substantial sex difference with respect to intracellular water, levels being higher in men than in women (means of 31 and 26 percent, respectively). Determinations of the total exchangeable potassium, made independently of estimates of intracellular water, showed a similar pattern and indicate that a greater fraction of body weight is accounted for by muscle tissues in the male. The conclusion that in the males there are more tissues rich in intracellular and relatively poor in extracellular material is further supported by figures on intracellular and extracellular water, expressed as percentages of the total body water: 57 as against 53 percent (intracellular) and 43 as against 47 percent (extracellular) in males and females, respectively.

The interpretation of these differences as being due to muscular development is supported by the work of Suárez and Marquesán (*61*), who demonstrated a close correlation between intracellular water [measured as the difference between the total water (antipyrine space) and the extracellular water (thiocyanate space)] and the radiographically determined cross-sectional muscle area of the leg (see also *62*).

A large number of data on the average body composition of the "normal male" (*N*, 10; mean age, 36.8 yr; mean weight, 72.5 kg; relative weight, not specified) and "normal female" (*N*, 10; mean age, 33.7 yr; mean weight, 59.3 kg) were presented by McMurrey *et al.* (*63*). The information was obtained by means of radioactive tracer methods, as well as with nonradioactive solutes (Evans blue for the determination of plasma volume). The data are given for the total body [body weight; body fat (25.8 as against 33.6 percent of body weight in males and females, respectively); fat-free solids (19.9 as against 17.8 percent); and total body water (54.3 as against 48.6 percent)] and for the intravascular, the extracellular, and the intracellular phases.

Interesting sex differences were brought out in Pitts's studies on guinea pigs (*64*). It appears that female guinea pigs have a larger compartment for fat storage than males. There are also sex differences in the distribution of fat. The female guinea pigs store about 20 percent, and males only 12 percent, of their fat in the subcutaneous fat depots. Conversely, males store more fat in the internal depots than the females.

On the basis of data obtained in the Laboratory of Physiological Hygiene, University of Minnesota (*65*), and reanalyzed in the light of new information such as data on skin thickness and density of human fat, Škerlj (*66*) emphasized that inner fat increases more rapidly with age than outer (subcutaneous) fat, relative to the fat-free body mass. The values for inner fat were obtained as the difference between total body fat estimated densitometrically and subcutaneous fat estimated on the basis of skin-fold measurements.

Age changes in body composition during maturity are likely to be complex and nonlinear. In the age range from 20 to 60 years, density decreases both in men (from 1.072 to 1.041) and in women (from 1.040 to 1.016) (*25*). This decrease reflects largely a tendency toward the accumulation of body fat, external (subcutaneous) and internal. However, other factors, such as a decrease in bone mineralization, may affect body density and complicate estimation of total body fat. Thus, the values for fat, estimated densitometrically, must be regarded as only approximations.

Parker *et al.* (*60*) compared small groups ($N = 7$) of apparently normal males and females of average ages 75 and 68 years, respectively, with younger adults. The outstanding finding is, again, the decrease in intracellular water (from 30.9 to 25.4 percent in males, from 25.9 to 22.4 percent in females), which accounts for most of the decrease in the relative value for total body water. A study reported in 1956 by Olbrich and Woodford-Williams and cited by Parker *et al.* (*60*, p. 111) showed much the same general pattern of changes in body-water components with advanced age.

In the absence of other evidence (specifically, information on the measured amount of extracellular water and the inferred amount of intracellular water), it would be erroneous to interpret a decrease in the relative amount of total body water simply as an increase in fatness. In reality, the changes in body composition associated with aging involve the accumulation of certain body constituents (fat) and simultaneous decrement in other tissues (especially in musculature) and some demineralization of bones.

Physical Activity

Physical activity has a potentially profound influence on man's physique. It is of historical interest that Kohlrausch (*67*) in Germany became concerned with indirect methods for studying body composition in vivo in connection with studies on the effects of exercise in dogs. The high body density of overweight but lean professional football players was one of the important early findings reported by Behnke and his colleagues (*68*).

Pitts's (*64*) male guinea pigs, maintained on a severe exercise regimen from the time of weaning until they were 8 months old, differed in body composition, in the predictable direction, from the nonexercised adult series. They were slightly lighter (603 as against 708 g), the specific gravity of the eviscerated carcass was substantially higher (1.073 as against 1.057), and the total extractable fat, expressed as a percentage of "fat-free" body weight, was lower (11.7 as against 20.7 percent).

Body densities for the five athletes (chiefly weight lifters, and all under 30 years of age) studied by Behnke and Taylor (*27*) varied from 1.069 to 1.094 grams per cubic centimeter. The mean density for these five subjects is substantially higher than the mean for nonathletes of similar age. Determinations were made, also, of total body water, and of chloride and potassium spaces. The ratio of exchangeable potassium (an indicator of muscle mass) to exchangeable chloride (a measure of extracellular water) was higher in these men than in men of average physique. Another study along the same lines was reported, on the body composition, appraised densitometrically, of two groups of middle-aged men, matched in regard to height, who were characterized by long-standing differences in amount of habitual physical exercise (*69*). The principal finding was that the physically active men had a substantially larger "fat-free" weight.

Le Bideau (*70*) presented distributions of three skin folds, and of body density calculated from these skin folds, for 130 French students, 20 to 30 years of age, engaged in physical education and athletics. The values for body density were relatively high, ranging from 1.070 to 1.084 g/cm^3.

The changes in body composition in 12 soldiers as a result of 3 weeks of strenuous physical training were studied by Pascale *et al.* (*71*). There was a small average decrement in weight (−0.6 kg), there was no significant change in amount of extracellular fluid (as indicated by radiosulfate space), and there was an increase in total body water (deuterium oxide space, + 1.55 lit.). The mean increase in body density, as determined by underwater weighing, was small (+ 0.0026 g/cm^3) but statistically significant. The thickness of skin folds tended to decrease at all four sites; the decrement was largest at the abdomen. There was a small increase in basal oxygen consumption. These data are consistent with the results of the hydrometric analysis of body composition, which indicated statistically significant increases in the "cell mass," paralleled by a decrease in body fat.

Pařízková (*56*) found little difference in the average heights and weights of normally active girls and of gymnasts, aged 13 to 14 years. At the same time, the layer of subcutaneous fat was markedly thinner in the gymnasts (mean for ten sites, 9.0 mm) than in the control group (mean, about 12.3 mm). This finding illustrates the importance of body composition parameters other than height and weight.

Together with cross-sectional (group) comparisons, Pařízková carried out longitudinal studies on the effects of changes in mode of life. When the gymnasts had had 10 weeks of rest without gymnastic training, she found a weight gain and an increase in subcutaneous fat; after training had been resumed, there was no change in weight and there was a reduction in subcutaneous fat.

In the symposium on obesity (*72*), the relationship between obesity (excessive fat content of the body) and overweight (excess of gross body weight with respect to a weight standard) was examined (*73*). With reference to physical activity, comparisons were made, respectively, between Minnesota railroad clerks and switchmen, Swedish white-collar personnel and shipyard workers, Italian firemen and steel workers, and Japanese physicians and farmers and miners. When relative body weights were matched, the more active men tended to be leaner, while the more sedentary individuals were more often classified as fat, on the basis of skin-fold measurements. The results in this study brought out the need for differentiating more clearly between an excess or deficiency of gross body weight and individual differences in the amount of adipose tissue or muscularity, or both.

Lee (*74*) observed in 34 patients with chronic hemiplegia that skin-fold thickness was 22 to 45 percent greater on the diseased limbs than on the corresponding region of the normal limbs. She suggests that a unilateral increase in subcutaneous fat may reflect the decrease in activity of the diseased limb.

Physical activity is of interest to students of body composition as a factor influencing energy metabolism and placing mechanical stresses on bones and muscles (*75*) and thus affecting their growth. Here, also, we may have put the cart before the horse, and it would be well to examine the relation between human physique, including body composition, and performance (see *76*). Of special interest are quantitative data descriptive of man's structure that supplement data on gross body weight and body weight relative to skeletal size. Riendeau *et al.* (*77*) obtained significant negative correlations, ranging from −0.29 to −0.68, between the fat content of the body, estimated densitometrically, and results of seven athletic tests of motor fitness. The coefficients of correlation with body weight were also negative throughout, but they were low, and body weight did not significantly affect performance on any test except the 220-yard dash.

Appraisal of Nutriture

Body-composition analyses have an important, basic role in determining nutritional status, and nutritional research is a fruitful area of application of the "somatolytic" techniques. It is easy to see why studies in this field, typically extensive rather than intensive in character, rely heavily on the simpler anthropometric methods.

"Nutritional anthropometry" and the newer, more complex methods for describing body composition in terms of tissue masses were examined from the point of view of their significance for the science of nutrition, and their implications for physical anthropology, including the central problem of "body build" (physique), were considered (*78*). I approached the topic in a general way in an article that appeared in 1953 (*79*).

The problems were taken up in greater detail at the conference on the role of body measurements in the evaluation of human nutrition, held at Harvard University in 1955 under the sponsorship of the Committee on Nutritional Anthropometry, Food and Nutrition Board, National Research Council (*8*; see also *80*). Recommendations were made regarding the uses of nutritional anthropometry, and various aspects of the subject and closely related matters were discussed, in 11 papers. Problems of body composition were considered by Keys (*81*) at the Ames weight control colloquium.

It may be regarded as a sign of the methods' "coming of age" that we find chapters on body composition included in the best textbooks on nutrition (*82*). Keys (*83*) revised his section on undernutrition in Duncan's compendium of methods of diagnosis and treatment, in which body composition is specifically considered.

Loss and Gain of Body Weight

One of the fascinating but tricky problems of human and animal biology is that of composition of gains or losses in body weight resulting from alteration in food intake. While we must be cautious in applying animal data to man, especially as regards weight changes during adulthood, we have much to learn from studies on weight changes in animals.

Students of animal husbandry are interested in methods of analyzing body composition, especially in methods of determining water content and estimating body fat in vivo, as an indirect approach to the assessment of the energy value of rations in feeding experiments (*84*). In experiments on the "efficiency" of a diet, performed by the hundred, the weight gained by the animal is typically compared with the amount of food consumed. Animal experiments in which the original and the final body composition is examined (*85*) indicate that the assumption frequently made regarding the constant "composition" of the weight (that the mass gained consists of definite proportions of water, fat, protein, and salts) is not necessarily correct. The mass gained by rats force-fed the amount consumed by paired controls who had free access to food was almost identical, in terms of weight, with the mass gained by the controls but was somewhat lower in protein content, lower in water content, and markedly higher in fat content (23.6 as against 7.8 percent).

Of special interest is information on "fat-free" weight in pigs—a component regarded fairly generally as being of relatively constant composition. Clawson, Sheffy, and Reid (*86*) present data based on a study of 127 pigs which indicate that as the fat content of the whole empty body *increases* from 12 to 54 percent of the body weight, the water content of the fat-free portions *decreases* from 79.2 to 75.8 percent, while protein shows a slight *increase* (from 17.3 to 20.1 percent). Unfortunately it is not clear from the presentation whether the animals in the study were of similar age. One would surmise that this was the case, from the comment that "the distribution of the data for the 127 pigs studied was not adequate to study the influence of age."

Positive, though low and statistically nonsignificant, correlation ($r = 0.26$, $N = 15$ control animals) between the relative water content of fat-free carcass and the percentage of carcass fat in the ewe was reported by Kirton and Barton (*87*).

Important studies on the accumulation of body fat in the guinea pig were carried out by Pitts (*64*). Comment here is limited to the adult series. Accretion of fat is accomplished by means of two mechanisms—saturating existing adipose tissue and increasing the number or size of lipocytes. The fat content of the adipose tissue increases with increasing body fat. When the total body fat reaches about 25 percent of the live weight (less the weight of fur and gut content), the fat content of the adipose tissue reaches a saturation limit (75 to 80 percent of the wet weight). As this limit is approached, the weight of the cellular (fat-free) component of adipose tissue, as a percentage of the "fat-free" body weight, begins to increase markedly.

The data on weight gain resulting from the maintenance of positive caloric balance by adult men for a period of 6 months (*20*) were used in the development of the Minnesota system of densitometric analysis of body composition (*4*, especially p. 280). It was postulated that the tissue masses which account for interindividual differences in fatness are similar to, or identical with, the "obesity tissue." The mass gained from simple overeating contained not only fat but also "cellular tissues" and extracellular fluid. A more correct (higher) value for the density of the component labeled "cells" will alter (increase) the estimated value for fat in the weight gain. But other questions will remain: How about the extracellular component—is there a temporary increase in extracellular hydration or is such hydration present also under truly chronic conditions of obesity?

In experiments in which there was a large differential between daily caloric expenditure and food intake (about 2500 and 2000 calories, respectively) over relatively short periods (12 and 24 days), there were marked and progressive changes in the composition of the weight loss (*88*). A large part of the early weight loss was a loss in water, in spite of the fact that water was readily available to the subjects. It was estimated that the caloric equivalent of the weight loss increased from about 3000 to 8700 calories per kilogram. The estimates for the composition and the caloric equivalent of the weight were based on data for energy balance and nitrogen excretion.

In the same experiments, decrements in subcutaneous adipose tissue measured on soft-tissue teleoroentgenograms at six anatomical sites (*89*) were proportionate to the initial thicknesses. At different sites the rate of subcutaneous fat loss per kilogram of weight loss ranged from 0.1 to 0.7 millimeter.

In the department of physiology and medicine, University of Edinburgh, the problem of the composition of weight losses and weight gains was studied by Passmore and his colleagues (*90, 91*). In three habitually thin men the weight gained over a brief period (10 to 14 days) was accounted for by the deposition of fat and protein within the existing cells, with no evidence of any retention of water. Clearly, more information is needed on the nature of materials constituting weight gain under specified conditions (such as the over-all level of energy metabolism, as affected by the amount of physical work; initial nutriture; and degree and duration of excess calorie intake).

In the weight-reduction experiments reported by Passmore *et al.* (*91*), the over-all weight losses over a period of 40 to 45 days were fairly uniform with regard to the caloric value (7000 to 8000 cal/kg) of "obesity tissue" lost. Fat constituted 73 to 83 percent of the weight lost; protein, 4 to 7 percent; and water, 10 to 23 percent.

While additional data are needed, it is now well established that the composition of tissues lost (or gained) under various circumstances will vary. This has far-reaching consequences for the applicability of indirect methods of studying body composition, especially for densitometry, which is based on the concept of intraindividual changes (losses and gains) and interindividual differences accounted for by tissues of fixed chemical composition (and density). When such a constant composition cannot be postulated as even approximately correct, information on body density still may be useful, but it must be supplemented by data on body weight, protein and energy balances, and body water, from which the composition of the weight can be calculated. This is a feasible approach to the analysis of intraindividual changes in body weight. The relation of nitrogen retention to body composition was considered by Wallace (*92*).

Novotný and Pařízková (*57*) reported weight gains of high but uniform density (0.988 to 0.989 g/cm^3) in three asthenic patients. In eight obese patients there was appreciable varation in the density of the weight loss (the ratio of weight loss to volume loss). The two values at the lower range (0.888 and 0.899 g/cm^3), below or approaching the density of fat (see *18*), are probably the result of error of measurement. We know of no body tissues that could account for weight losses of such a density. The most likely source of error is the determination of residual air present in the lungs at the time of underwater weighing.

Entenman *et al.* (*93*) compared the composition of the tissue lost, as determined from volumetric and hydrometric data, with the composition of subcutaneous abdominal adipose tissue analyzed by chemical methods on biopsy samples taken before and after weight reduction. The density of the body as a whole increases, as does the density of the adipose tissue. In the biopsy samples of the adipose tissue the fat content decreased from 79.2 to 62.3 percent in a man who lost 14.9 kilograms of body weight, and from 85.7 to 78.9 percent in a second subject, who lost 8.4 kilograms. The water content and the relative residue content of the adipose tissue rose markedly. In regard to the composition of the total weight loss, Entenman and his associates conclude that "while adipose tissues probably contribute the greatest portion of the fat (and body weight) loss during weight reduction, other soft tissues also contribute significantly to the body weight decrease by losing non-fat components."

In prolonged undernutrition the relative increase in extracellular fluid masks the true extent of the loss of soft tissues (*49*, especially p. 278). In the presence of edema, manifest or latent (expansion of extracellular space without clinically recognizable edema), gross body weight is an unreliable indicator of the extent of the departure from the prestarvation weight level. Similarly, the results of analyses performed on muscle biopsy material obtained from children suffering from protein malnutrition indicate that body weight gives too low a measure of the degree of protein loss from the muscles (*94*). In children with kwashiorkor the water content of the body is high (about 75 percent), even after visible edema has disappeared (*95*). Standard, Wills, and Waterlow (*96*) explored two methods of assessing the progress of recovery (if not the initial extent of protein depletion): (i) measurement of creatinine output, and (ii) four body measurements (limb circumferences, skin-fold thickness) which yield an estimate of the "muscle bulk" and "fat bulk." In severely malnourished children the three characteristics—increase in creatinine output, and muscle bulk and fat bulk, as related to increase in body weight—yielded ratios larger than 1 (specifically, 1.29, 1.45, and 2.35)—that is, the gain was relatively more rapid than the gain in gross weight. This is accounted for by the continued loss of excess hydration while protein and fat are being gained.

So far we have considered intraindividual weight losses and weight gains, a subject of considerable interest to students of body composition. How about comparisons between different individuals, the task for which the indirect methods of studying body composition are typically used?

Keys and I have examined (*97*), in an exploratory fashion, the density and composition of tissues accounting for interindividual differences in total body density. The analysis involved data on young men matched for height and age but differing in fatness. The average differences in weight and volume for two groups consisting of 16 fat and 21 lean men, respectively, were 29.348 kilograms and 31.279 liters, values yielding a difference in density of 0.938 g/cm^3.

Seven percent of the difference in weight was accounted for by extracellular fluid; the remainder (the total difference less the difference attributable to extracellular fluid) was attributable to fat, "cells," and bone. Since the men were matched in height, and skeletal width was not considered in their selection, we may assume (in a provisional manner, at least) that the average bone mass in the two groups was the same. This leaves for consideration fat and "cells." Calculations based on the assumptions on which the breakdown of intraindividual weight gains (*20*) was based indicated that the gross difference in mass for the lean and the fat young men was attributable as follows: extracellular fluid, 7 percent; "cells," 22 percent; and fat, 71 percent. For comparison, we considered the total weight gain in middle-aged men from overeating for 6 months; this "obesity tissue," with a density of 0.948 g/cm^3, was made up of extracellular fluid, 14 percent; "cells," 24 percent; and fat, 62 percent. The results of the interindividual (group) comparison were so close to those obtained from the analysis of mean intraindividual weight gains in the fattening experiment that it was believed the differences could arise from errors of sampling and measurement. Alternatively, only trifling differences in bone mineral would yield a proportion of "cells" to fat which would be identical with that found in the fattening experiment. It was fully realized that this study hardly scratched the surface of a knotty problem. Nevertheless, it was felt that the outcome of the study strengthened the case for this type of indirect analysis of body composition.

Johnson and Bernstein (*98*) estimated the composition of "obesity tissue" on the basis of regression analysis of the relations of body fat, cell mass, and extracellular fluid to relative body weight of 17 healthy women, 21 to 59 years old. Their body weight ranged from 60 to 250 percent of the standard. The hypothetical tissue accounting for individual differences in fatness was assigned the following average composition: extracellular water, 6 percent (measured by inulin dilution); cell mass, 25 percent (calculated from intracellular water); and fat, 70 percent. These values were surprisingly similar to the results of densitometrical analysis reported by Keys and me (*97*). Johnson and Bernstein (*98*) measured total body water by antipyrine dilution and from it calculated the fat-free body mass. The value for fat was obtained by subtraction. The approach is an interesting one, but more definitive conclusions must be based on a larger sample, probably more homogeneous in age.

The composition of tissues accounting for the differences between groups of obese ($N = 17$) and normal ($N = 16$) females was examined by Ljunggren (*21*). Mean ages were 33 and 24 years. The average heights for the two groups were identical. The weight differential was very large (49.4 kg). Total body water accounted for 22 percent of the mass. The data on the extracellular water differed markedly, according to whether the space was measured by means of thiosulfate (result, 7 percent) or of radioactive bromide (result, 15 percent). The value for body solids (78 percent) was not broken down percentagewise, but data on intracellular water and the concentration of exchangeable sodium (15 milliequivalents per kilogram of water) were presented. Ljunggren regarded the figures as indicating that findings for the excess tissue in this study approximated those for "obesity tissue" in the study of middle-aged men (*20*). In view of the large uncertainty regarding the volume of intracellular water, stemming from the uncertainty (7 or 15 percent) in the value for the extracellular component, precise comparisons cannot be made.

The fundamental importance of such studies for appraising the validity of the densitometric analysis of body composition cannot be overemphasized.

Some Avenues of Advance

One common avenue of scientific advance is that of making increasingly precise measurements. In the field of body composition the acme of precision has not been reached, but efforts in this direction are not likely to be very rewarding. Certainly we would like to increase the reliability (repeatability) of some of the methods (especially the determinations of total body water) and the precision with which we can define and measure the extracellular water. But the principal avenue of advance involves the measurement of some additional parameters of body composition (such as the mineral content of the body) which show substantial interindividual differences and affect importantly the interpretation of the indirect criteria of body composition (such as body density).

Decreasing the uncertainty regarding the quantitative assumptions which underlie the estimation equations will be a significant contribution. In this regard, extension of the work on cadaver analysis is an especially urgent task. The anatomical and, more important, the chemical analysis of whole cadavers provides an undisputed basis for evaluating the indirect approaches, which are applicable to living man. Our information about some important facets of body composition, such as the ratio of bone mineral to the fat-free, bone-free fraction of the body is distressingly limited. As I have pointed out elsewhere (*99*), there is urgent need for additional data. Preferably, the chemical analysis should be combined with determinations of the density of the body and of its principal, anatomically and chemically separable parts. In the interest of adding to the fund of basic data for estimating the mineral content of the body and of muscle mass, selected body dimensions (circumferences, bone diameters) should be obtained as well.

Chemically, the human body is a complex system, and a great deal of time and effort can be devoted to analyzing it and its mineral and amino-acid composition. Analysis of individual organs represents, potentially, an almost endless task. To advance our knowledge of gross body composition we need to have a greater number of bodies analyzed, but the components that are of major concern are limited in number (total water, total fat, proteins, total minerals, and bone minerals). The relevant methods are well standardized. Emphasis should be placed on the clinical "normality" of bodies chosen for the analysis, and age as well as sex must be considered in the sampling process. Separation of the fat content of the nervous system from the total fat would be desirable, as the fat content of the nervous system appears to be relatively stable in the presence of large changes in the amount of depot fat.

The tendency to devote a great deal of effort to a small number of specimens is understandable, and the contributions of Mitchell *et al.* (*100*), Widdowson, McCance, and Spray (*101*), and Forbes *et al.* (*102*) have significantly enriched the meager treasury of indisputable facts about the composition of the human body. Nevertheless, there is room for more numerous but less detailed analyses, limited to determinations of water (by desiccation), fat (by ether extract), and ash. Successive analyses of the same human body by indirect and direct methods is still an unfilled desideratum.

Some ideas regarding methods occur again and again, at different times and in different places. In this category belong the attempts, repeated and uniformly disappointing when applied to living man, to determine body volume (a value needed in calculating body density) from changes in the air pressure of a chamber (see *49*, p. 183, for references going back to 1916). I know of at least four laboratories in this country in which substantial effort has been invested in this approach during the past 10 years. Yet, unfortunately, the "negative results" have not been reported, and thus each investigator is forced to start from scratch instead of being able to proceed from the point where his predecessors left off, or able at least to avoid the same blind alleys. As far as I am aware, only one abstract—and that a preliminary and too optimistic one—concerning a method for determining body volume of living man on the basis of air displacement has appeared in print (*103*).

Since a number of scientific disciplines interact in defining several of the parameters of body composition, a salutary influence is exerted by the efforts to develop a larger system, one in which the individual subsystems (such as the densitometric and hydrometric analysis of body composition) are considered in terms of their conceptual consistency and operationally defined "translatability." This matter has been considered in the past, but additional information on the interrelations between the body compartments defined and determined by different approaches is needed. This purpose is best served by the simultaneous application of the different methods on carefully defined samples of subjects.

Greater internal consistency of the body-composition models is desirable from a strictly theoretical standpoint. At the practical level, information is needed for "translating" the data obtained by manipulatively simpler techniques into the more complex and comprehensive systems, and for interpreting the physiological significance of the relationships between body components and functional (physiological), normal metabolic (see *104*), and pathological processes.

The practical needs are served by relating skin-fold thicknesses (*105*), or roentgenographic measurements of the skin plus the subcutaneous adipose layer (*106*), to body density. More important, however, is the potential gain to be derived from the rigorous comparison of approaches that involve the use of the same concepts (constructs) but arrive at them through different operational procedures.

Thus, from the practical as well as from the theoretical point of view, a simultaneous application, to a carefully defined sample or samples of individuals, of the major techniques for studying body composition may be regarded as the major avenue of advance in this field.

Science is an ongoing process. There are ideas and techniques (*107*) that open totally new vistas as regards the analysis of body composition, there are gaps to be filled, and there are syntheses to be attempted even if these are destined to be ultimately replaced by a more valid, more precise set of quantitative assumptions.

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Science and the News

The Space Administration: It Was Once Criticized for Slowness But Is Now Criticized for Speed

If the nation's space technology moves along with anything like the speed being shown by the National Aeronautics and Space Administration in its administrative decision-making, there may be ample justification to support the intrepid optimism of those who believe the U.S. will land men on the moon before the Soviets.

In a recent 30-day period, from 24 August to 23 September, NASA has selected Cape Canaveral for expansion into a site from which the U.S. will launch its manned space flights to the moon and beyond; picked a government-owned ordnance plant in New Orleans for the fabrication of launching vehicles; named Houston, Texas, as the location for a new $60-million space-flight command center for manned missions; hired new subleaders; and revamped its organizational structure.

Some measure of the rapidity with which NASA has been lining up its ducks for the moon shot is apparent in the fact that both NASA public information specialists and newsmen alike have been caught unawares by the sudden stacatto of "immediate releases" from NASA officialdom, each release spelling out a key and expensive decision for the future of the country's multibillion-dollar space effort. Information on NASA's reorganization, for example, was released on Saturday afternoon, pulling science reporters away from their day off—an unholy act in press agentry.

All this suggests that a new sense of urgency pervades the space agency. If there is a single factor reponsible for this sense of urgency it seems to be James E. Webb, NASA's administrator. Webb is a nonscientist and makes no pretense about the fact. But he is what President Kennedy wanted for the job—a man of keen political acumen, commendable experience in government and industry, and a man who understands policy-making and organization. Webb is also gaining a reputation as the Capital's most mellifluent speaker.

Webb has already appeared before one or another congressional committee more than 30 times, and just when he thought the debating and question-answering were behind him for a while, as he recently told a National Press Club luncheon, the Senate Aeronautical and Space Sciences Committee had scheduled a new set of hearings on NASA's program for 26 September.

Paradoxically, NASA, which has often been criticized for moving too slowly, is now being criticized for moving too fast. The Senate hearings, Webb said, were being held to re-explore the 10-year space effort asked for by President Kennedy because of a feeling in and out of Congress that the multibillion-dollar program had been accepted too quickly. (The hearings were postponed by the Senate Committee at the last minute because of scheduling difficulties.)

Certainly, the public debate that was anticipated following the President's challenge to the nation on 25 May that Americans should go to the moon never materialized. Similarly, congressional debate was limited to some expressions of skepticism, but little more, and the Administration got almost all of its $1,784,300,000 request. What debate there was came largely from some scientists who questioned whether the moon trip was necessary and asked whether the vast sums needed to finance a manned expedition to the moon might be better spent for a host of terrestrial challenges. But even these critics have become less critical of late.

Surprisingly, perhaps, the fact that President Kennedy's 10-year, $35-billion proposal has met with an eloquent silence and an eloquent acceptance is causing concern among many of the Administration's political observers. These observers know that this year's request for appropriations will be the smallest request for the next decade and that the requests for ever-increasing NASA funds will be decided on an annual basis. If the public or Congress waivers in its support of the effort, a set-back could prove disastrous.

If, for example, the thrill of U.S. space events or the pressure of Soviet successes wears thin, it might take a more mature public attitude to sustain the effort. It is for this reason that NASA must, concomitant with its rush to the launching pads, attempt to create better understanding of what it is trying to do, and why.

Space officials are not unaware of this potential dilemma. Webb, for example, always takes pains to underscore aspects of the 10-year space