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## The Influence of General Body Size on the Body Proportions in Man and Other Primates[1]

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The relation between general body size and the size of bodily parts began to be investigated about two centuries ago by ROBINSON[3] and by VON HALLER[4] who can be considered the discoverers of the laws of allometric growth. Soon it could be clearly demonstrated that, e.g., brain weight and the volume of the heart and of the eyes retain no constant relation to body size, but become proportionately smaller with increase in the general size of the animal, also in the small young these organs are relatively larger than in corresponding fully grown specimens. During the last 60 years, a great many papers have appeared dealing with allometric problems. HUXLEY[5], HAMMOND[6], LATIMER and AIKMAN[7], TEISSIER[8], and SCHULTZ[9] have studied some phases of this problem, while D'ARCY THOMPSON[10], HERSCH[11], ROBB[12], OSBORN[13], LUMER[14], GRAY[15], and others have dealt chiefly with its phylogenetic aspects. HALLER's allometric law, expressing the relative reduction of the parts in relation to increasing body size, has been tested for many structures, e.g. for the brain weight by CUVIER[16], SNELL[17], KEITH[18], DUBOIS[19], LAPICQUE[1], PEARL[2], OPPENHEIM[3], HRDLIČKA[4], WEBER[5], WEINERT[6], VON BONIN[7], GRIMM[8], CRILE and QUIRING[9], SCHULTZ[10], PORTMANN[11], COUNT[12], WIRZ[13], ANTHONY[14], GOOSEN[15], and MALTHANER[16]; for the eyeball and the orbit by WELCKER and BRANDT[17], LAPICQUE[18], KLATT and VORSTEHER[19], SCHULTZ[20], RENSCH[21], and MÖLLER[22]; for the endocrine glands by PADOUR[23]; and for the visceral organs, hair and feathers of different animals by RICHET[24], MANEA[25], PARROT[26], MAUREL[27], WELCKER and BRANDT[28], KESTNER and PLAUT[29], KLATT[30], DENZER[31] QUIRING[32], and RENSCH[33].

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In spite of so many investigations dealing with different aspects of allometry, the influence of general body size on the relative dimensions of the parts within homogenous groups or definite species deserves further study, particularly in man. Relevant observations were undertaken by PFITZNER[1], BERTILLON[2], HANSEN[3], MANOUVRIER[4], HARRIS[5], and BACH[6], but without very definite conclusions.

The writer has attempted to analyze the influence of body size on the size of a considerable number of different bodily dimensions in a very extensive series of human beings and in some other primates. This study, which promised to have a significant bearing on many anthropological problems, was undertaken at the suggestion and with the help of the writer's teacher, Prof. ADOLPH H. SCHULTZ, in the Anthropological Institute of the University of Zürich. In this greatly condensed English abstract of the work, published in detail (and in French) elsewhere[7], only the most essential facts, methods and results will be enumerated as follows: The entire analysis is based on measurements on a total of 68,040 adult individuals belonging to 63 human populations, roughly two thirds male and one third female, and measurements on a total of slightly over 400 monkeys and apes. This entire mass of data had been exclusively collected by others and for different purposes; a large part could be obtained from the literature and a smaller, unpublished part had very kindly been placed at the writer's disposal by a number of anthropologists. It seems certain, therefore, that all these individual measurements are free from any subconscious idea of allometry. Determined by the nature of the available data, this study deals chiefly with homogenous groups of adult man, while ontogenetic as well as phylogenetic questions could be investigated in only a preliminary way. The following measurements were selected for analysis: sitting height, trunk height, length of limbs and of all main limb segments, breadths of shoulders, hips and pelvis, total and upper face height, nose height, head length, and head breadth, or whenever given as such, mean head diameter. For a variety of good reasons, stature was considered as meaningless or as even misleading for the purposes of this study in which sitting height represents a far more suitable measure of body size. The absolute measurements of the bodily parts were all calculated by the writer from the original data in percentage of the trunk height.

Every population was scaled according to increasing sitting height. The indices of the segments $S$ have been calculated as $S \cdot 100/T$ ($T$ = trunk height). In order to distinguish any modification of the index, i.e. its increase or decrease from one extreme size-class of the population to the other extreme size-class, each population has been divided into 4 groups of an equal number of individuals, in such a manner that the first (I) of them contains the smallest sitting heights, the fourth one (IV) the largest. In each group and for every dimension referred to, the average index has been calculated. The indices compared furnish a quantitative expression of the modification of the segment under consideration throughout the population, in relation to its increasing general body size. The difference between the average indices I and IV shows in some few instances an increase or, more generally, a decrease of a few units. In order to compare various segments and their reciprocal modifications, this difference had to be put in relation to the absolute value of the corresponding index according to the following formula:

$$100 \frac{\dfrac{S_{\mathrm{I}} \cdot 100}{T_{\mathrm{I}}} - \dfrac{S_{\mathrm{IV}} \cdot 100}{T_{\mathrm{IV}}}}{\dfrac{S_{\mathrm{I}} \cdot 100}{T_{\mathrm{I}}}} = \frac{100\, T_{\mathrm{I}}}{S_{\mathrm{I}}} \left( \frac{S_{\mathrm{I}}}{T_{\mathrm{I}}} - \frac{S_{\mathrm{IV}}}{T_{\mathrm{IV}}} \right)$$

This expression, which was called "Growth reductional coefficient" or G.R.C., has been provided with a positive or negative sign, according to the increase or the decrease of the indices respectively.

A generally valid, negative or decreasing allometry has been clearly demonstrated in 42 human adult populations, and for 17 proportions. It was present in 94·88% of all the cases, and the G.R.C. averages −4·873. Increasing sitting height causes an evident decrease of the relative dimensions of many parts of the body. This reduction is most pronounced in head and face dimensions. Next come the lower and upper extremities with their parts: the distal segments (foot and hand) are in all cases more affected than the proximal (thigh and upperarm), and these are more affected than the intermediate ones (leg and forearm). These results confirm mathematically, and by new evidence, the old observation of the important role of the distal segment of the caudal extremity in increasing body size. The relative breadth of the pelvis is the least reduced dimension, although it, too, shows a marked reduction.

Evidence of a sexual difference in reference to this problem is not clearly present in human populations. In the Figure, the two lines for both sexes of the average G.R.C. are very near each other at most places. However, the size of some coefficients seems to indicate a sexual influence. The reduction of relative dimensions with increasing sitting height is less pronounced among women in several segments of the lower extremity, but

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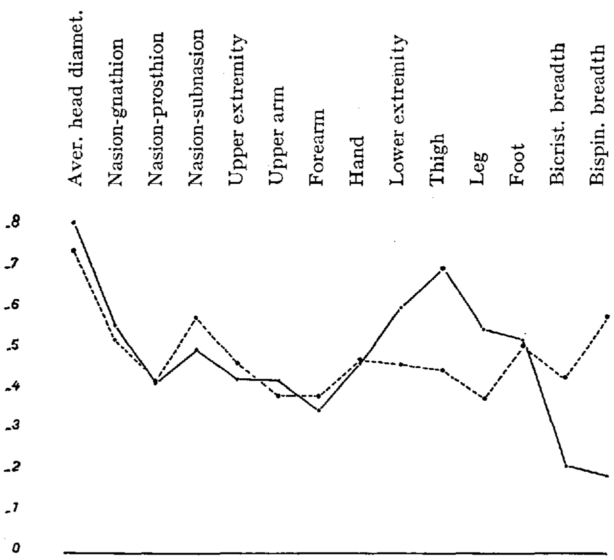
*Table I.*–Average Growth reductional coefficients in human adult populations with reference to sex and race

| Sex | Race | Total Upper extremity | Upper-arm length | Fore-arm length | Hand length | Total lower extremity | Thigh length | Leg length | Foot length | Bis-spinal breadth | Bi-cristal breadth | Average Head diam.[2] | Total Face height | Upper Face height | Nose height | Average G.R.C.[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ♂ | Whites . . . | – 6·85 | – 5·81 | – 5·29 | – 5·73 | – 4·30 | – 4·87 | – 5·45 | – 6·34 | – 6·79 | – 5·55 | – 8·01 | – 7·16 | – 5·85 | – 6·18 | – 6·06 (74) |
| ♂ | Negroids . . | – 3·31 | – 2·51 | – 3·10 | – 3·62 | – 3·62 | – 2·68 | – 1·90 | – 4·46 | – 3·77 | – 3·94 | – 7·43 | – 4·42 | – 3·60 | – 6·07 | – 4·09 (83) |
| ♂ | All populations[1] | – 4·64 | – 3·87 | – 3·83 | – 4·77 | – 4·63 | – 4·49 | – 3·82 | – 5·12 | – 5·84 | – 4·36 | – 7·42 | – 5·26 | – 4·21 | – 5·80 | – 4·86 (204) |
| ♀ | Whites . . . | – 5·04 | – 4·84 | – 5·49 | – 4·22 | – 3·27 | – 7·03 | – 5·78 | – 5·41 | – 4·97 | – 4·30 | – 7·55 | – 5·59 | – 5·51 | – 4·97 | – 5·43 (59) |
| ♀ | All populations[1] | – 4·31 | – 4·26 | – 3·51 | – 4·65 | – 6·05 | – 7·03 | – 5·78 | – 5·30 | – 1·93 | – 2·14 | – 8·08 | – 5·59 | – 4·13 | – 4·97 | – 4·88 (89) |

[1] Including other populations besides Whites and Negroids.
[2] (Length + Breadth)/2.
[3] In parenthesis, the number of calculated Growth reductional coefficients.

more so in diameters of the pelvis. It is a common place that a relatively wide pelvis and relatively short extremities are feminine secondary sexual characters[1]. The corresponding G.R.C.s seem to indicate that tall women show these sexual characteristics more clearly than do small women.




Average growth reductional coefficient (human ad. popul.)
.................. males ———— females

The average G.R.C.s are less marked in Negroes than in white races. The difference is quite evident for each studied segment and is usually larger than two units; its maximum is found in the leg, its minimum in the average head diameter and the nasal height. An increase of general body size determines again the negative allometry of body parts, but this influence is much less pronounced in Negroes than among Europeans. The Negro is macroscelic and the distal segment is mainly responsible for the elongation of the lower extremity. The Negro further has one of the shortest noses ever measured in anthropology. Both racial features are more clearly manifested in tall people, since the leg is relatively least and the nose relatively most reduced. Table I shows the average G.R.C. for both sexes and in the main racial groups.

[1] New evidence on this fact has been found in the present work, by comparing absolute dimensions among individuals of both sexes and of the same sitting height in a single population, thus eliminating the pseudo-sexual influence of general body size.

In infra-human primates, the same general allometric law has been tested and found to exist. Again increasing body size in a homogeneous adult population has a negative, i.e. decreasing influence on the relative dimensions of various parts. It can be demonstrated in about 98% of all cases. This reduction is more pronounced in the platyrrhine primates than in the catarrhines. Table II shows the average G.R.C. and compares them with the corresponding values in adult man. The gibbons have constantly greater, the chimpanzees smaller coefficients than man. A sexual difference, as far as our problem is concerned, is much more marked among monkeys and apes: the males show a much greater negative allometry than the females of the same group.

The connections between this negative allometry and age changes, hybridization and changes due to

*Table II.*–Average growth reductional coefficients in primates (adults of both sexes)

| Segment | Platyrrhinian | Gibbon | Man | Chimpanzee | Infra-human catarrh. |
|---|---|---|---|---|---|
| Total Upper extremity | | – 5·93 | – 4·55 | – 3·09 | – 4·55 |
| Upper arm length . . . | – 6·24 | – 6·12 | – 3·98 | | |
| Forearm length . . . . | – 5·98 | – 5·37 | – 3·74 | | |
| Hand length . . . . . | – 7·49 | – 6·34 | – 4·73 | – 4·50 | – 5·42 |
| Total lower extremity . | | – 5·51 | – 5·22 | – 2·40 | – 3·95 |
| Thigh length . . . . . | – 6·24 | – 6·00 | – 5·17 | | |
| Leg length . . . . . . | – 6·22 | – 5·16 | – 4·31 | | |
| Foot length. . . . . . | – 6·96 | – 6·36 | – 5·18 | – 3·75 | – 5·05 |
| Upper face height . . . | – 9·14 | | – 4·19 | | – 2·10 |
| Average segment . . . | – 6·89 | – 5·84 | – 4·56 | – 3·43 | – 4·21 |

migration have been studied for the dissertation in a preliminary way on a limited amount of data. In this abstract it can merely be mentioned that it was found that in most $F_1$-hybrid groups an increased sitting height was accompanied by reductions in the relative dimensions of the body parts investigated. The effects of migration, whenever consisting primarily in increased sitting heights, show clearly this law of negative allometry.

*Zusammenfassung*

Die vorliegende Arbeit befasst sich mit dem Einfluss der Sitzhöhe auf die relative Grösse der Kopfdurchmesser, der Gesichtshöhe, Nasenhöhe, Länge der Gliedmassen und deren Teile sowie der transversalen Durchmesser des Rumpfes. Sie stützt sich auf Masse, die an etwa 68000 Individuen (Menschen und Affen) gemessen wurden. Bei Zunahme der Sitzhöhe weisen die nach der Rumpfhöhe berechneten Indizes in 95-98% der Fälle eine progressive Abnahme auf. Zwischen beiden extremen Klassen der nach Sitzhöhe geordneten Bevölkerungen beträgt diese Abnahme ungefähr 5% des durchschnittlichen Indexes; sie wurde aber mehr im einzelnen, den verschiedenen Körperteilen und Primatenbevölkerungen nach sowie in Beziehung mit eventuellem Geschlechtseinfluss berechnet. Auch in den durch Alter, Verpflegungsverhältnisse, Wanderzüge und Kreuzung verursachten Änderungen der Sitzhöhe kommt die negative Allometrie zum Ausdruck.

# Brèves communications - Kurze Mitteilungen
# Brevi comunicazioni - Brief Reports

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## Mesure des âges géologiques par les halos pléochroïques

Nous avons étudié la possibilité de déterminer l'âge géologique des roches cristallines à partir des halos pléochroïques en combinant la photométrie des halos à la mesure de l'activité $\alpha$ des inclusions[1].

Nous croyons utile de publier ici quelques résultats préliminaires. Les détails expérimentaux et la bibliographie complète seront publiés ailleurs; citons cependant l'intéressant travail de HAYASE[2] sur le même sujet.

Les mesures ont été faites sur des lames minces classiques. Nous n'avons retenu que les halos dans la biotite formés par des inclusions de dimension supérieure à 50 $\mu$, de façon à être dans les conditions d'émission $\alpha$ en couche épaisse. L'activité $\alpha$ des inclusions a été mesurée par la technique des émulsions photographiques nucléaires (émulsion Ilford C2). L'absorption de la lumière par le halo a été mesurée sur la lame mince à l'aide d'un microphotomètre enregistreur. Nous avons éclairé la préparation par de la lumière blanche polarisée parallèlement à la direction d'absorption maximum de la biotite. La figure 1 représente un profil photométrique typique à travers un halo intense.

Pour exprimer l'intensité de coloration d'un halo, l'intégrale de la densité optique le long d'un profil[3], $D$, s'est avérée un paramètre intéressant. Elle est définie par:

$$D = -\int_0^r \log_{10} \frac{I_h}{\overline{I}_B}\, dx \quad \text{où}$$

$x$ = distance perpendiculaire au bord de l'inclusion;
$I_h$ = $I_h(x)$ = transmission en un point du halo;
$\overline{I}_B$ = transmission moyenne de la biotite non affectée par le halo;
$r$ = rayon d'action du halo (distance $x$ pour laquelle $I_h = \overline{I}_B$).

Soit $N_\alpha$ = l'activité spécifique mesurée de l'inclusion; elle est exprimée en nombre d'$\alpha$ émis par seconde et par cm$^2$ en couche épaisse.
$t$ = le temps pendant lequel la biotite a été soumise à l'action du rayonnement $\alpha$ de l'inclusion (âge);
$\alpha$ = l'irradiation totale ou nombre total d'$\alpha$ par cm$^2$ émis par l'inclusion pendant le temps $t$;
$\alpha$ = $N_\alpha t$ pour des roches dont l'âge est petit devant la période de l'U. Sinon, il faut tenir compte de la décroissance de l'activité.

On sait que $D = f(\alpha)$ présente une zone croissante linéaire, une zone saturée et une zone décroissante d'inversion[1].

Nous avons admis, pour les échantillons choisis, les 2 hypothèses suivantes:

[1] J. JOLY et E. RUTHERFORD, Phil. Mag. *25*, 644 (1913).
[2] I. HAYASE, Am. Miner., *39*, 761 (1954).
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