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EVOLUTIONARY RATE OF CRANIOMETRIC TRAITS IN HOMINIDAE

Abstract. — This paper contains a discussion on the evolutionary rate of 62 craniometric features in Hominidae. It is based on computation of average of absolute velocities and those of absolute accelerations with reference to individual traits time variations. In doing so the author adopted the division of the process of anthropogenesis into four evolutionary phases, i. e. *Pithecanthropus*, *Homo neanderthalensis*, *H. sapiens fossilis* and *H. sapiens recens*. Close investigation of the calculated data revealed velocities of specialized traits changes in the skull of Hominidae to increase with the lapse of time and to attain their maximum in the phase of *Homo sapiens fossilis* and that of *H. sapiens recens*.

INTRODUCTION

The author here attempts to determine the evolutionary rate of craniometric features in Hominidae. So far, this problem has not been investigated on the basis of actually existing material.

Two conflicting theories are advanced in contemporary anthropology. J. J. Roginskij (1951, 1955) is in favour of that claiming retardation in the evolutionary rate as regards specific features from *Homo sapiens* onwards. According to him, from the period of appearance of forms belonging to the species of *Homo sapiens*, i. e. since the upper palaeolithic period (First Interstadial Würm), the morphophysiological development of man seems to have been checked in contrast with the intensity of evolution believed to be associated with the earlier representatives of Hominidae. The process of stabilisation of the physical type of *Homo sapiens* is, according to Roginskij's theories, accompanied by the circumstance of man becoming independent of his natural environment, owing to his relatively high production level. This caused a slackening in the functions of biological factors of evolution, those of natural selection in particular.

Some Anglosaxon anthropologists are in favour of a different viewpoint. In their popular papers on the theory of anthropogenesis, L. H. Shapiro (1933) and W. Howells (1945) maintain that further evolution of the physical type of modern man was possible. With regard

to craniological features they suggest the hypothesis of progressive brachycephalization and reduction of the facial parts of the skull. In papers by F. Weidenreich (1948) and G. F. Debec (1948), brachycephalization of modern man is likewise considered an evolutionary process. In summing up his argumentation on the palaeoanthropology of the USSR, Debec suggests gracilization of the cranium as an evolutionary process which consists in shortening of the zygomatic diameter, weakening of the supraorbital region also increase of frontal angle and decrease of that of the nasal bone. Debec's conception is based on mean available material, ranging from the Neolithic to the Middle Ages, as recovered from the lower Wolga region, the middle Dniepr basin, and the Altai-Saians highlands. This material, however, does not seem of great significance in discussing evolutionary problems, inasmuch as account must be taken of the undeniable migration and infiltration of peoples within these areas. Nevertheless attention should be called that Debec supports his arguments by material of concrete facts.

In the present paper the author discusses the rate of evolutionary changes of craniometric features in Hominidae on the basis of the following fundamental assumptions:

1⁰ In the phylogenesis of Hominidae the evolutionary line of form groups occurs in the appropriate time sequence: I. *Pithecanthropus* (incl. *Sinanthropus* and *H. heidelbergensis*); II. *H. neanderthalensis*; III. *H. sapiens fossilis*; IV. *H. sapiens recens*. Groups of these forms constitute successive phases of the process of anthropogenesis.

2⁰ It is possible to render the meaning of terms of the anthropogenesis theory by terms of cinematics of the material point.

An exhaustive argumentation of the former of these two assumptions goes beyond the scope of the present paper. It would indeed require corroborating the time sequence of the above quoted forms of Hominidae and linking them, on their morphological criteria, into one evolutionary line, which does by no means confirm that all representatives of the geographic variations of these forms may be assembled in one single evolutionary line. It is, however, possible to present a brief justification of the above assumption by references to literature containing ample documentation on the subject. The time sequence is confirmed in papers by Roginskij (1951) and Wierciński (1956) on evidence of fossil material thus far recovered. They contain a discussion on all fossil finds regarded as supporting parallelistic conceptions in anthropogenesis. Thereupon it is shown that the test subjects held as proving the synchronous appearance of forms of *H. sapiens* up to the *Pithecanthropus* horizon or of the pre-Neanderthal, Steinheim type of man, are either wrongly dated

when, beyond doubt, taxonomically assignable to *H. sapiens*, or, when dated correctly, undoubtedly referable to *H. neanderthalensis*. This fossil material has been analysed by mathematical methods insuring unbiased taxonomical deduction. Thus far, therefore, adherents of parallelistic theories cannot claim one single palaeoanthropological find supporting their speculations.

Evidence for the linking up in one evolutionary line of the forms of *Pithecanthropus*, *H. neanderthalensis* and *H. sapiens* has been given by Hrdlička (1928/29), Weidenreich (1948), Washburne (1954), Jakimow (1951), Roginskij (1955) and Stęślicka-Mydlarska (1947; 1952). Unusually objective argumentation has been presented by Stęślicka-Mydlarska (1947), based on individual material by means of mathematical analysis of groups of specialized characters according to the differential method of J. Czekanowski. Recently, the results obtained by Stęślicka-Mydlarska have been confirmed in a paper published by Wanke (1956) who analyses the very same material by the relative points method. Thus from the viewpoint of both chronology as well as of morphology the assumption of successive phases in the process of anthropogenesis, beginning with *Pithecanthropus* and ending with *H. sapiens recens*, appears to be the most probable hypothesis.

The transferability of the terms of the theory of organic evolution with regard to evolutionary rate into the terms of cinematics is maintained in many palaeontological papers, to mention those published by Simpson (1949), Zeuner (1952), Schindewolf (1950), Stebbins (1949), Westoll (1949) as well as some others. Simpson (1949) has undertaken to put in order and to define the principal terminology of the theory of evolutionary rate. He has established the subdivision into the principal kinds of evolutionary rate, differentiating velocity of genetic changes, velocity of morphological changes and velocity of taxonomical changes. The methods of calculating velocities, as proposed by Simpson, are based upon calculation of the ratio of investigated quantitatively expressed changes to the time lapse or its correlatives.

In palaeontological literature, most papers analyse velocity of taxonomical changes, test subjects being easily accessible and but a very limited number of evolutionary theories under discussion. Considerably less numerous are papers concerned with the velocity of morphological changes, this being due to fragmentary fossil material, available for this purpose, and difficulty in establishing the most probable evolutionary series. Mention should be made here of a most noteworthy paper by Westoll (1949) on the evolutionary rate of the Dipnoi and that by Romer (1949), more generalized and based on the example of the evolution of Equidae.

Both papers are illustrated by graphs with Cartesian coordinates, showing time variations of individual features or groups of features.

The various types of evolutionary rate have been discussed in many palaeontological papers, with reference to such conceptions as absolute velocity, relative velocity and acceleration. Indeed, these conceptions express in a concise and unambiguous form the rate of evolutionary changes and make it possible to treat palaeontological data in a more precise and objective manner.

Thus there seem to be no reasonable causes not to apply the system of the fundamental principles of cinematics to the description of evolutionary rate of craniometric traits in Hominidae.

METHOD AND MATERIAL

The author here attempts to discuss the evolutionary rate of craniometric traits in Hominidae by the use of cinematic terminology. He makes use of the method proposed by Simpson (1949) for calculating the absolute velocities of individual morphological traits, counting units of time in terms of years. Craniometric traits were expressed in millimeters for chords and arcs, in degrees for angles and in index units for index features. For coordinates of movement points arithmetical means of values of individual features were used, based upon individual material appertaining to individual phases of anthropogenesis (*Pithecanthropus*, *H. neanderthalensis*, *H. sapiens fossilis*, *H. sapiens recens*) and averages of scale of the absolute time, in which scale these phases occurred. With regard to the average for angles XGI, BGI, LGI and the calotte height index only, have averages for *H. sapiens recens* been calculated from those presented by Steślicka-Mydlarska (1947) for Australians and Lapps, with intentional lowering of their values by means of the Australian series. The dating there was based on the chronology suggested by Zeuner (1946) for the Pleistocene. The *Pithecanthropus* phase was taken as origin of the coordinates system. The resulting data are shown in table 1.

Between phase I and II there appears a gap of time coinciding with the middle part of PIg₁, due to the fact that no finds are known referable to this period and that the majority of Neanderthal finds, from which averages were computed, belong to the period LIg₁ to LG₁.

The time increases (t_{ij}) for the several interphase periods of anthropogenesis are represented by differences between corresponding time coordinates, as shown in table 2.

In table 2 the author has introduced his symbolic marking for changes of interphase traits (s_{ij}), for time increases (t_{ij}), interphase velocities (v_{ij}) and accelerations (w_{ij}).

Table 1
Chronology of the four phases of anthropogenesis

Phases of anthropogenesis	Geologic phases	Time scale	Time points	Time coordinates
I. <i>Pithecanthropus</i>	EG ₁ — PIg ₁	590000 — 400000	$4.95 \cdot 10^5$	0
II. <i>Homo neanderthalensis</i>	PIg ₁ — LG ₁	250000 — 80000	$1.65 \cdot 10^5$	$3.30 \cdot 10^5$
III. <i>Homo sapiens fossilis</i>	LG ₁ — LG ₂	80000 — 0	$0.40 \cdot 10^5$	$4.55 \cdot 10^5$
IV. <i>Homo sapiens recens</i>	Holocene	0	0	$4.95 \cdot 10^5$

Table 2
Symbols used in cinematic terms

Interphases	t_{ij}	s_{ij}	v_{ij}	w_{ij}
Phase I - Phase II	$t_{12} = 3.30 \cdot 10^5$	s_{12}	v_{12}	
Phase II - Phase III	$t_{23} = 1.25 \cdot 10^5$	s_{23}	v_{23}	w_{23}
Phase III - Phase IV	$t_{34} = 0.40 \cdot 10^5$	s_{34}	v_{34}	w_{34}
Phase II - Phase IV	$t_{24} = 1.65 \cdot 10^5$	s_{24}	v_{24}	w_{24}

The interphase change of trait denotes the difference between the arithmetical means of this trait for given phases of anthropogenesis. The interphase velocities were computed as mean absolute velocities of motion according to the equation:

$$v_{ij} = \frac{s_{ij}}{t_{ij}}$$

The interphase mean absolute accelerations were computed by equation for the mean acceleration of motion:

$$w_{ij} = \frac{v_{ij} - v_{i-n, j-k}}{t_{ij}}$$

n and k being always positive natural numbers.

Furthermore, the author has computed the quotients of interphase velocities, in order to denote the frequency of velocity increase between the several interphases:

$$I_v = \frac{v_{ij}}{v_{i-n, j-k}}$$

Finally, the author has likewise prepared 5 charts of the time variation of traits, expressed in per cent of mean for *H. sapiens recens*. Material consisting of arithmetical means for each phase of anthropogenesis and of individual data, on which the author has computed

his own figures, were taken from papers by Weidenreich (1945), Stęślicka-Mydlarska (1947), Loth (1953) and Mollison (1915). The bulk, i. e. 56 means of various craniometric traits, are from Weidenreich's paper. Unfortunately Weidenreich presents means for *Sinanthropus*, *H. neanderthalensis* and *H. sapiens recens* only. The means for *H. soloensis* were not taken into account in the present paper, since Weidenreich did not mention the number of individuals on which his computation was based. For the above mentioned three phases of anthropogenesis only, were means obtained of face-brain index and of the percentage of the frontal lobes in the brain mass (Mollison, 1915, Loth, 1953). Average figures of five features have been calculated for all the four phases, based on individual material published by Loth (1953) and W. Stęślicka-Mydlarska (1947). They are angles XGI, BGI, LGI, calotte height index and the palato-cerebral index of Keith. For these features only have charts of motion been plotted (fig. 1-5).

Data on material and values of computed interphase velocities, interphase accelerations and velocity quotients are presented in tables 3 and 4.

The traits have been divided into groups, on the basis of the velocity values which they reveal and of the directions of time changes. No accelerations have been computed for traits of varying directions of time variance.

ANALYSIS OF RESULTS

On the basis of data listed in tables 3 and 4 the author has divided the investigated craniometric traits into two fundamental groups. As criterium for this division he has adopted the direction of time variance.

Group A comprises traits of varying directions of time variance. Of linear traits there belong to this group: maximum cranial length, maximum cranial breadth and its correlates. The following features were furthermore assigned to group A: cranial capacity in cc, arc *l-o*, breadth-length index, bregma I height index, inion height index and angle *n-ba-o*. It should be pointed out that seemingly the traits of group A contend against the thesis of the irreversibility of evolution. To wit, the majority of traits reveal positive increases in passing from phase I to phase II, but negative in passing from phase II to phase IV. However, it should not be forgotten that in Hominidae these traits are of secondary phylogenetic importance, since they do not belong to their principal direction of specialization. In the shaping of the skull this is revealed by its increased height, in the growing convexity of the frontal, parietal and occipital part, less distinct protrusion of the glabella and of the occipital region, and a reduction of splanchnocranium. Furthermore it should be noted

Table 3
Values of motion characteristics for group A features

Measurement	Subgroup	A ₁	A ₂	A ₃	S ₁₂	S ₂₁	P ₁₂	P ₂₁	V ₂₁ /V ₁₂
1. l projected to g—op	I	172.0	180.5	179.5	8.5	— 1.0	2.5758	0.6061	0.2353
2. i above n—o	I	47.0	35.5	36.8	—11.5	1.3	3.4848	0.7879	0.2261
3. n—o	II	145.3	148.0	135.0	2.7	— 1.3	0.8182	7.8788	9.6294
4. i projected to n—o	II	180.3	182.0	169.5	1.7	—12.5	0.5152	7.5758	14.7046
5. op projected to n—o	II	180.3	182.3	165.6	2.0	—16.7	0.6061	10.1212	16.6989
6. g—op	III	193.6	198.4	185.6	4.8	—12.8	1.4545	7.7576	5.3335
7. n—op	III	189.0	193.9	180.3	4.9	—13.6	1.4848	8.2424	5.5512
8. n—ba	III	105.5	111.0	102.7	5.5	— 8.3	1.6667	5.0303	3.0181
9. l projected to n—o	III	148.2	155.3	148.7	7.1	— 6.6	2.1515	4.0000	1.8592
10. „maximum“ breadth	III	141.0	147.9	133.6	8.9	—14.3	2.6970	8.6667	3.2136
11. cranial capacity cc.		1043	1400	1300	357	—100	108.1818	60.6061	0.5602
12. occipital arc n—o		114.0	116.6	114.0	2.6	— 2.6	0.7879	1.5758	2.000
13. n—b		109.8	108.8	112.1	—1.0	3.3	0.3030	2.0000	6.6007
14. n—ba—o		155.0	159.0	156.0	4.0	— 3.0	1.2121	1.8182	1.5000
15. I. length—breadth		72.2	73.3	72.8	1.1	— 0.5	0.3333	0.3030	0.9091
16. I. bregma height I		37.6	36.7	45.2	—0.9	8.5	0.2727	5.1515	18.8907
17. inion height		32.3	24.2	27.3	—8.1	3.1	2.4545	1.8788	0.7655

Legend for tables 3, 4 & 5:

A₁ — average of phase I

A₂ — " " " II

A₃ — " " " III

A₄ — " " " IV

$v_{ij} = p_{ij} \cdot 10^{-3}$ $w_{ij} = q_{ij} \cdot 10^{-10}$

Table 4
Values of motion characteristics for group B features

Measurement	Sub-group	A ₁	A ₂	A ₃	S ₁₂	S ₂₄	P ₁₂	P ₂₄	Q ₂₄	V ₂₁ /V ₁₂
18. bregma position projected to g-op	I	77.3	73.2	71.6	4.1	1.6	1.2424	0.9697	0.1653	0.7805
19. auricular above FH	I	98.4	111.5	113.5	13.1	2.0	3.9697	1.2121	1.6712	0.3053
20. l-o	II	84.0	89.3	92.8	5.3	3.5	1.6061	2.1212	0.3122	1.3207
21. b-l	II	96.2	110.3	116.5	14.1	6.2	1.7723	3.7576	1.2032	2.1202
22. o-op projected to FH	II	48.3	50.5	56.0	2.2	5.5	0.6667	3.3333	1.6162	4.9997
23. bregma/1/above g-op	II	72.9	73.5	82.7	0.6	9.2	0.1818	5.5758	3.2691	30.6700
24. lambda above n-o	II	82.3	88.8	94.6	6.5	5.8	1.9697	3.5152	0.9367	1.7846
25. bregma position projected to n-o	III	56.7	44.4	33.2	12.3	11.2	3.7273	6.7879	1.8548	1.8211
26. au-au	III	145.5	133.7	121.0	11.8	11.6	3.5758	7.0303	2.0936	1.9661
27. b.ba	III	115.0	125.0	134.0	10.0	9.0	3.0303	5.4545	1.4692	1.8000
28. bregma/2/above n-o	III	91.3	98.7	107.7	7.4	9.0	2.2424	5.4545	1.9467	2.4324
29. vertex above n-o	III	101.3	114.2	124.6	12.9	10.4	3.9091	6.3030	1.4509	1.6124
30. opisthocranium above n-o	III	47.0	54.8	67.0	7.8	12.2	2.3636	7.3939	3.0487	3.1282
31. calvarial above g-op		74.6	82.5	87.4	7.9	4.9	2.3939	2.9697	0.3490	1.2405
32. arc n-b		120.3	123.7	128.0	3.4	4.3	1.0303	2.6061	0.9550	2.5294
33. arc b-l		102.5	122.8	136.4	19.3	7.6	5.8485	4.6061	0.7530	0.7970
34. b-n ✕ n-op		44.3	48.0	50.8	3.7	2.8	1.1212	1.6970	0.3550	1.5136
35. g ✕ g-op		42.5	45.0	49.2	2.5	4.2	0.7576	2.5455	1.0836	3.3600
36. l-op ✕ op-g		62.7	67.0	75.9	4.3	8.9	1.3030	5.3939	2.4309	4.1396
37. l-op ✕ op-o		103.2	110.3	122.6	7.1	12.3	2.1515	7.4546	3.2140	3.4648
38. b-n ✕ n-o		58.0	66.3	72.6	8.3	6.3	2.5152	3.8182	0.7898	1.5181
39. l-o ✕ o-n		93.1	96.5	99.0	3.4	2.5	1.0303	1.5152	0.2939	1.4706
40. X-g ✕ g-i		52.5	64.0	90.0	11.5	26.0	3.4848	15.7576	7.4381	4.5218
41. b-g ✕ g-i		39.3	47.3	61.2	8.0	13.9	2.4242	8.4242	3.6264	3.4749
42. l-i ✕ i-g		63.0	67.5	96.7	4.5	29.2	1.3636	17.6970	9.8990	12.9781

Table 4 (continued)

Indices	Sub-group	A ₁	A ₂	A ₁	S ₁₂	S ₂₄	P ₁₂	P ₂₄	Q ₂₄	V ₂₄ /V ₁₂
43. calvarial height to g-op	I	38.5	40.9	47.5	2.4	6.6	0.7273	4.0000	1.9835	5.4998
44. l position above n-o	I	102.0	105.1	109.3	3.1	4.2	0.9394	2.5455	0.9733	2.7097
45. occipital length I	I	25.7	25.8	30.6	0.1	4.8	0.0303	2.9091	1.7447	96.0099
46. upper parietal breadth	I	64.2	66.4	81.2	2.2	14.8	0.6667	8.9697	5.0321	13.4539
47. frontal curvature	I	89.9	88.8	85.7	1.1	3.1	0.3333	1.8788	0.9367	5.6370
48. parietal curvature	I	94.1	93.2	89.4	0.9	3.8	0.2727	1.8788	0.9734	6.8896
49. occipital curvature	I	73.8	77.7	80.8	3.9	3.1	1.1818	1.8788	0.4224	1.5898
50. per cent of frontal lobes	I	33.0	35.5	43.0	2.5	7.5	0.7576	4.5455	2.2957	5.9999
51. length — total height	II	59.4	63.2	72.9	3.8	9.7	1.1515	5.8788	2.8650	5.1053
52. length — auricular height	II	50.9	56.7	61.7	5.8	5.0	1.7576	3.0303	0.7713	1.7241
53. breadth— height	II	75.6	85.2	100.6	9.6	15.4	2.9091	9.3333	3.8935	3.2083
54. breadth — auricular height	II	70.5	76.2	85.3	5.9	9.1	1.7879	5.5152	2.2590	3.0847
55. bregma height II	II	62.7	66.8	78.5	4.1	11.7	1.2424	7.0909	3.5439	5.7074
56. vertex height	II	69.4	77.7	91.0	8.3	13.3	2.5152	8.9606	3.3002	3.2047
57. lambda height	II	56.6	60.4	69.1	3.8	8.7	1.5152	5.2727	2.2773	3.4799
58. opisthocranion height	II	32.3	37.6	49.6	5.3	12.0	1.6061	7.2727	3.4343	4.5282
59. bregma position above n-o	II	38.9	29.8	24.2	9.1	5.6	2.7576	3.3939	0.3856	1.2307
60. palato-cerebral	III	30.0	40.0	57.5	10.0	17.5	3.0303	10.6061	4.5914	3.5000
61. calotte height	III	34.1	42.8	62.3	8.7	28.2	2.6364	17.0909	8.7603	6.4827
62. face-cerebral	III	72.0	54.0	42.0	18.0	12.0	5.4545	7.2727	1.1019	1.333

Legend:

see table 3.

that in palaeontology the so-called Dollo's law has been severely criticised by Romer (1949), who pointed out as an example the evolution of Equidae. Moreover, the number of traits in group A, as compared with the total of investigated traits, constitutes but 27.4 per cent. Neither should one ignore the important fact that in modern man cranial length and cranial breadth, with their correlates, show great variability, both racial and individual, and that they do not represent specific features.

When summarising the above discussion on traits of the A group it must be admitted that it does not question the claim for the occurrence of four evolutionary phases in the process of anthropogenesis. The linear traits of group A reveal average velocities between the phases *Pithecanthropus* and *H. neanderthalensis* (average $p = 1.6143$) three times slower as compared with velocities between *H. neanderthalensis* and *H. sapiens recens* (average $p = 5.6970$). These traits may be divided into 3 subgroups, according to the grouping of interphase velocities. Subgroup I comprises traits with v_{12} smaller than v_{24} (range $p_{12} : 2.5-3.5$; $p_{24} : 0.6-0.8$). To subgroup II should be allotted traits with small values v_{12} and values v_{24} , many times exceeding the value of v_{12} (range $p_{12} : 0.5-0.9$; $p_{24} : 7.5-10.2$). Subgroup III covers traits with average v_{12} with regard to larger v_{24} (range $p_{12} : 1.4-2.7$; $p_{24} : 4.0-8.7$). The remaining features, i. e. those of angle, arc, cubic capacity and index, had to be considered separately as not being homogenous in relation to linear features. Thus with regard to cranial capacity v_{24} appears almost 50 per cent less than v_{12} . The occipital arc is characterised by low values of both interphase velocities with greater v_{24} . The *n-ba-o* angle reveals v_{12} and v_{24} with low values and small differences. Much alike is the length-breadth index and inion-height index. Again on bregma I height index do we observe v_{24} many times larger than v_{12} .

Group B comprises the balance, i. e. 72.6 per cent of craniometrical traits. These traits reveal unidirectional time variation and are characterised by marked phylogenetic importance. They refer to height of skull, convexity of frontal, parietal and occipital regions, cranial base breadth, reduction of splanchnocranium and increase of mass of frontal lobes. In consideration of their unidirectional time variation, the accelerations have been computed within the interval between the phase of *H. neanderthalensis* and that of *H. sapiens recens*, as in group A the linear traits may be subdivided into 3 subgroups. Subgroup I comprises traits with values v_{24} smaller than v_{12} and with negative accelerations of w_{24} (range $p_{12} : 1.2-4.0$; $p_{24} : 0.9-1.3$; $q_{24} : 0.1-1.7$). To subgroup II should be allotted traits with v_{12} smaller than v_{24} (range $p_{12} : 0.1-2.0$; $p_{24} : 2.1-5.6$; $q_{24} : 0.3-3.3$). Subgroup III comprises traits characterized by high values of both v_{12} and v_{24} , with v_{24} larger than

v_{12} (range p_{12} : 2.2-4.0; p_{24} : 5.4-7.4; q_{24} : 1.4-3.1). Calvarial height shows a slight acceleration of v_{24} . In general terms the linear traits appear to have an average about twice higher for v_{24} than for v_{12} . Two arc traits belonging to group B reveal varying rates of velocity: arc *n-b* is characterized by a smaller v_{12} as compared to v_{24} at relatively low values of both velocities. Arc *b-l* reveals a negative acceleration at high values of v_{12} and v_{24} . The angle traits of group B are characterized by values v_{24} approximately four times higher than v_{12} and by very marked accelerations. As is well known, they comprise the convexity of the frontal, parietal and occipital regions. Particularly high velocities of v_{24} are revealed by angles XGI, BGI, LGI. The indices, numbering 20, are characterized by the average value of v_{24} being three and a half times as high (average $q_{12} = 1.6637$; $p_{24} = 5.9212$) as v_{12} . Three subgroups may be distinguished in the grouping of velocities. Subgroup I comprises the traits with minor values of v_{12} and somewhat higher values of v_{24} (range p_{12} : 0.03-1.2; p_{24} : 1.8-4.6; q_{24} : 0.4-5.1). With subgroup II are classed traits with medium values of v_{12} and high values of v_{24} (range p_{12} : 1.1-3.0; p_{24} : 3.0-9.4; q_{24} : 0.3-3.9). Subgroup III contains traits with high v_{12} and very high v_{24} (range p_{12} : 2.6-5.5; p_{24} : 7.2-17.1; q_{24} : 1.1-8.8). In summarising the above results of the investigation of traits of group B, i. e. traits of unidirectional time variation and of considerable phylogenetic importance, it should be stressed that they reveal distinct tendencies of increased velocities within the interphase of *H. neanderthalensis* and *H. sapiens recens*. The evolutionary rate of these features is varied, which fact made it possible to distinguish subgroups of features with different velocities of time changes.

Similar results were obtained not only for the three phases of anthropogenesis, but likewise when a fourth phase was added, namely that of *H. sapiens fossilis*. Unfortunately, due to lack of material, but 5 traits of definite phylogenetic importance were analysed, namely: angles XGI, BGI, LGI, calotte height index, and palato-cerebral index which characterises the process of face reduction with regard to neurocranium. The results of an analysis of all the four phases of the process of anthropogenesis are compiled in table 5 and 6 and in charts (fig. 1-5) showing time variations of traits.

The empirical curves do not fit by any mathematical function, because the number of points is too small. The author therefore merely joined the four points by straight lines. These charts reveal almost identical time variations, beginning with rather small velocities which, however, increase rapidly on reaching their maximum within the phase of *H. sapiens fossilis* and *H. sapiens recens*. Interphase accelerations reveal identical symptoms. Numerical data, agreeing with those in the charts,

are presented in table 6. All the above data confirm our results obtained for three phases only of anthropogenesis, but they likewise corroborate the assumption of interconnection between the four assumed phases of

Table 5
Values of motion characteristics for the 4 phases of anthropogenesis

Measurement	A ₁	A ₂	A ₃	A ₄	S ₁₂	S ₂₃	S ₃₄
40. X—g—i	52.5	64.0	78.6	90.0	11.5	14.6	11.4
41. b—g—i	39.3	47.3	54.4	61.2	8.0	7.1	6.8
42. l—i—g	63.0	67.5	78.0	96.7	4.5	10.5	18.7
60. palato-cerebral	30.0	40.0	50.0	57.5	10.0	10.0	7.5
61. calotte height	34.1	42.8	52.0	62.3	8.7	9.2	10.3

	P ₁₂	P ₂₃	P ₃₄	Q ₂₃	Q ₃₄	V ₂₃ /V ₁₂	V ₃₄ /V ₂₃
40.	3.4848	11.6800	28.5000	6.5562	42.0500	3.3517	2.4401
41.	2.4242	5.6800	17.0000	2.6046	28.3000	2.3430	2.9929
42.	1.3636	8.4000	46.7500	5.6291	95.8750	6.1602	5.5655
60.	3.0303	8.0000	18.7500	3.9758	26.8750	2.6400	2.3438
61.	2.6364	7.3600	25.7500	3.8589	45.9750	2.7917	3.4987

Table 6
Graphs fig. 1—5 coordinates

X	O	3.30·10 ⁵	4.55·10 ⁵	4.95·10 ⁵
Y ₁₀	○	30.67	69.60	100.00
Y ₄₁	○	36.53	68.95	100.00
Y ₁₂	○	13.35	44.51	100.00
Y ₆₁	○	30.85	63.47	100.00
Y ₆₀	○	36.36	72.73	100.00

anthropogenesis, in view of the unidirectional variation of investigated specific features, even when account is taken of the continuous increase of velocities and accelerations. It seems beyond doubt that *H. sapiens fossilis* is the starting form for *H. sapiens recens*. The above results contradict parallelistic conceptions and also conceptions which claim a retarded degree of evolution beginning with *H. sapiens fossilis*. Modern

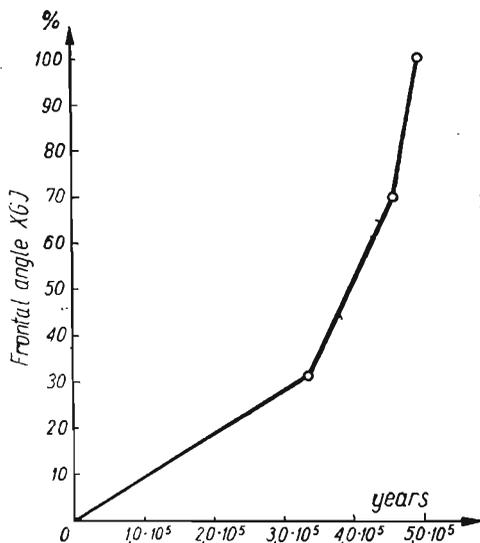


Fig. 1. Motion of frontal angle XGI.

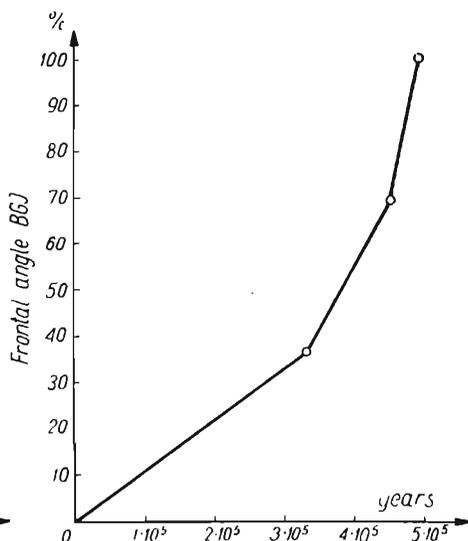


Fig. 2. Motion of frontal angle BGI.

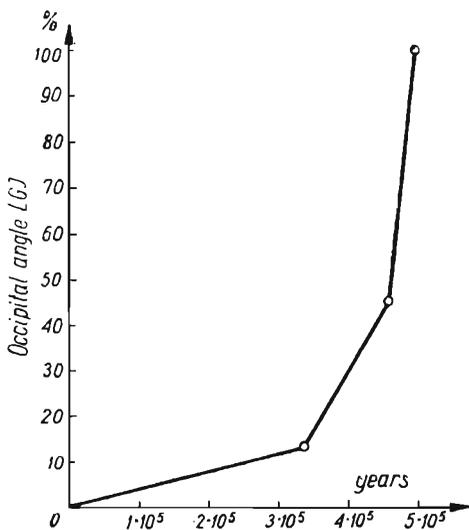


Fig. 3. Motion of occipital angle LGI.

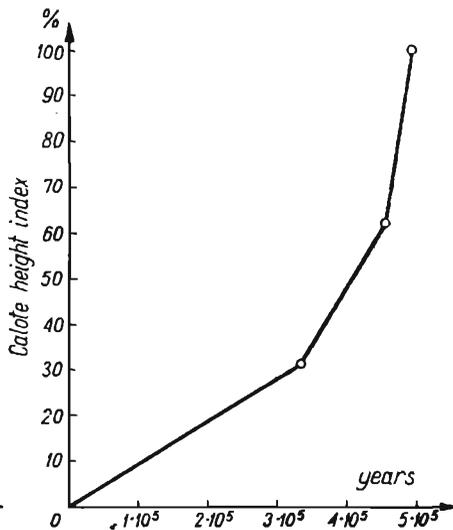


Fig. 4. Motion of calotte height index.

Graphs (fig. 1-5) show time variations of the specialized traits in the skull of Hominidae, accepting the lapse of a year as the time-unit. The variability of any one feature is expressed in its percent divergence from the mean of that feature in the *Pithecanthropus* phase. For the *Homo sapiens recens* phase the divergence of the mean has been accepted as being 100 per cent.

man passes through his intensive phase of evolution tending to rapidly increasing convexity of forehead (which is in agreement with data given by Debec, 1948) and of the parietal and occipital regions, to an upward growth of the skull and a reduction of the face part. These data, however, must be confirmed on further evidence supplied by investigation of additional features, whereby a reasonably precise determination of averages should be reached both for *H. sapiens fossilis* and *H. sapiens recens*. These results may also be somewhat modified, in line with the accumulation of new fossil findings. However, there is no reason to believe that any such changes should affect the very essence of results obtained in this paper, i. e. the acceleration of the tempo of evolution

within the most recent phase of anthropogenesis. A verification of the above results is necessary, based upon material from populations relatively isolated from migratory changes, and dating from neolithic to present times. Towards establishing the causes of acceleration of the rate of evolution in *H. sapiens* it may prove highly useful to investigate the rate of specialized traits within the phases of ontogenesis and the effect of the process of urbanization upon changes in the physical type of man.

GENERAL CONCLUSIONS

Summarising the results obtained in this paper the following conclusions are in order:

1^o On the basis of a study of average absolute velocities and average absolute accelerations in 62 craniometric traits of Hominidae, the conception proves most plausible of the existence in anthropogenesis of four phases, i. e. 1) *Pithecanthropus*, 2) *Homo neanderthalensis*, 3) *H. sapiens fossilis*, 4) *H. sapiens recens*. The high degree of probability is here based upon the unidirectional time variation of fundamental specialized traits in the development of the skull. These traits are: total

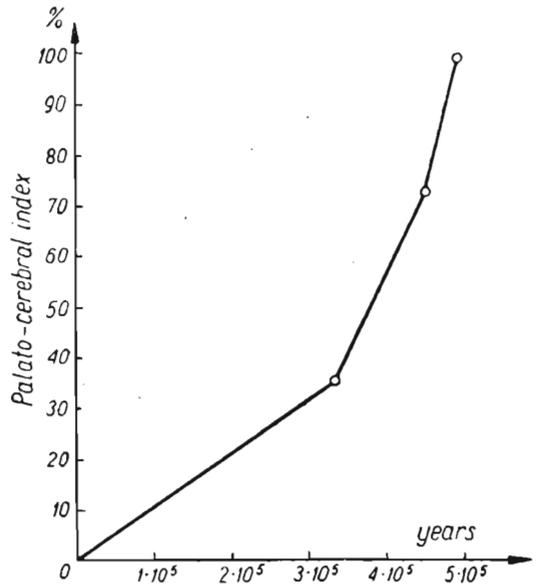


Fig. 5. Motion of palato-cerebral index.

cranial height, calotte height, width of cranial base, convexity of frontal, parietal and occipital regions, increased mass of frontal lobes and reduction of the splanchnocranium.

2^o The rate of evolution in Hominidae is not uniform in different craniometric traits. It is most intensive in specialized features.

3^o The average rate of evolution in the initial phases of anthropogenesis is slow, reaching its maximum acceleration in the phases of *H. sapiens fossilis* and *H. sapiens recens*.

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ANDRZEJ WIERCINSKI

TEMPO EWOLUCYJNE CECH KRANIOMETRYCZNYCH U HOMINIDAE

Streszczenie

W niniejszej pracy dokonano analizy tempa ewolucyjnego 62 cech kraniometrycznych u Hominidae, zakładając występowanie w procesie antropogenezy czterech kolejnych faz ewolucyjnych (*Pithecanthropus*, *Homo neanderthalensis*, *H. sapiens fossilis*, *H. sapiens recens*) oraz możliwości opisu w języku kinematyki punktu materialnego tempa przemian ewolucyjnych. Zostały więc obliczone średnie prędkości bezwzględne i średnie przyśpieszenia bezwzględne, przyjmując jako odpowiednik pojęcia przyrostu różnice między odpowiednią parą średnich arytmetycznych badanej cechy, obliczone dla danych faz antropogenezy. Datowanie bezwzględne 4 faz antropogenezy ustalono na podstawie chronologii plejstocenu, podanej przez Zeunera (1946).

W wyniku dokonanych obliczeń i wykresów ruchu okazało się, że badane cechy można podzielić na 2 zespoły. Do zespołu A weszły cechy o nikłym znaczeniu filcgenetycznym (długość i szerokość czaszki wraz ze swymi korelatami), charakteryzujące się różnokierunkową zmiennością w czasie. Do zespołu B weszła większość cech, wykazujących zmienność jednokierunkową w czasie i duże znaczenie specjalizacyjne. Są to cechy wyrażające stopień wysklepienia czaszki Hominidae w okolicy czołowej, ciemieniowej i potylicznej, wzrost wysokości czaszki i redukcję części twarzowej. Na podstawie uzyskanych przez autora danych dla wszystkich 4 faz antropogenezy, niestety tylko 5 cech z zespołu B o zasadniczym znaczeniu specjalizacyjnym można było przedstawić w formie wykresów ruchu (fig. 1-5), przyjmując za początek układu współrzędnych dane dla fazy *Pithecanthropus*, a dane dla *Homo sapiens recens* — za 100%. Zarówno obliczenia, jak i sporządzone wykresy uzasadniają tezę o narastaniu tempa ewolucyjnego przemian w czaszce Hominidae. Najwyższą wartość osiąga owe tempo na ostatnim odcinku antropogenezy, mianowicie między fazami *H. sapiens fossilis* i *H. sapiens recens*. Jednokierunkowa zmienność w czasie cech specjalizacyjnych stanowi dodatkowy argument na korzyść tezy

o występowaniu 4 faz antropogenezy. Wykonane obliczenia wartości prędkości i przyspieszeń wskazują także na fakt niejednakowego tempa ewolucyjnego różnych cech kraniometrycznych Hominidae.

OBJASNIENIA DO ILUSTRACJI

Wykresy (fig. 1-5) przedstawiają zmienność cech specjalizacyjnych czaszki Hominidae w czasie. Jako jednostkę czasu przyjęto 1 rok. Zmienność danej cechy została wyrażona w ‰ odchyłeń od średniej tej cechy w fazie *Pithecanthropus*, przy czym odchylenie średniej dla fazy *Homo sapiens recens* przyjęto za 100‰.

Fig. 1 (p. 252)

Ruch kąta czołowego XGI.

Fig. 2 (p. 252)

Ruch kąta czołowego BGI.

Fig. 3 (p. 252)

Ruch kąta potylicznego LGI.

Fig. 4 (p. 252)

Ruch wskaźnika wysokości kaloty.

Fig. 5 (p. 253)

Ruch wskaźnika podniebienno-mózgowego.

АНДРЖЕИ ВЕРЦИНСКИ

ЭВОЛЮЦИОННЫЙ ТЕМП КРАНИОМЕТРИЧЕСКИХ ПРИЗНАКОВ
У HOMINIDAE

Резюме

В настоящей работе анализируются: эволюционный темп 62 краниометрических признаков Hominidae, принимая, что в ходе антропогенеза выступают 4 последовательные эволюционные стадии (*Pithecanthropus*, *Homo neanderthalensis*, *H. sapiens fossilis*, *H. sapiens recens*), а также возможность выразить на языке кинематики материальной точки явление темпа эволюционных изменений. И так произведен расчет средних абсолютных скоростей и средних абсолютных ускорений, принимая в качестве понятия, отвечающего понятию прироста — разность между каждыми соответствующими парами арифметических средних исследуемого признака, вычисленных для данных стадий антропогенеза. Абсолютное установление 4 стадий антропогенеза совершено, основываясь на хронологии плейстоцена, данной Цейнером (F. E. Zeuner, 1946).

В результате вычислений и графиков движения оказалось, что исследуемые черты можно разбить на 2 комплекса. К комплексу А относятся черты, имеющие

минимальное филогенетическое значение (длина и ширина черепа в совокупности с их коррелятами), характеризующиеся изменчивостью во времени в различных направлениях. К комплексу В отнесено большинство признаков, проявляющих изменчивость в одном определенном направлении и большое значение в специализации. Это признаки выражающие степень сводчатости черепа *Hominidae* в лобной, теменной и затылочной областях, увеличение высоты черепа и редукцию лицевой части. На основании полученных автором данных для всех 4 стадий антропогенезиса, только 5 черт комплекса В, имеющих основное специализационное значение, можно было изобразить в виде графиков развития (фиг. 1—5 в английском тексте), принимая в качестве начала координат данные для стадии *Pithecanthropus*, а данные для *Homo sapiens recens* — за 100%. Как расчеты, так и вычерченные графики обосновывают тезис о возрастании темпа эволюционных изменений в черепе *Hominidae*. Этот темп достигает наибольшей величины в последнем до сего времени отрезке антропогенезиса, а именно в промежутке между стадией *H. sapiens fossilis* и *H. sapiens recens*. Развивающаяся во времени в одном и том же направлении изменчивость признаков специализации является еще одним доказательством в пользу тезиса о проявлении 4 стадий антропогенезиса. Произведенный расчет величины скорости и ускорения равным образом указывает на факт неодинакового эволюционного темпа различных краниометрических черт *Hominidae*.
