CHANGES IN PHYSIOCHEMICAL PROCESSES WITH AGE*

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Chemical and hematological tests of human blood reflecting anabolic, catabolic, immunological and regulatory mechanisms were carried out on 501 nonvegetarian adult males residing in Calcutta. The mean values fell within the normal range for North American and West European populations for amylase activity, acid phosphatase, alkaline phosphatase, calcium, total cholesterol, free cholesterol, creatinine, glucose, nonprotein nitrogen, serum *p*H, total protein, urea, uric acid, erythrocytes, leukocytes, neutrophils, lymphocytes, hemoglobin, oral temperature, pulse, systolic and diastolic pressure. They fell outside the normal range for chlorides, cholesterol ester, eosinophils and sedimentation rate. Increased values with advancing age were observed for cholesterol (total, free and ester), creatinine, glucose, nonprotein nitrogen, urea, neutrophils, sedimentation rate, systolic and diastolic pressure. The opposite trend occurred for alkaline phosphatase, total protein, eosinophils and oral temperature. Multiple regression equations permitting computation of the expected values of the chemical and hematological tests for any individual, given his age, height and weight, are presented. Mean values for each five-year age group are reported for all chemical and hematological tests, and bivariate frequency distributions are shown for age in relation to glucose, to sedimentation rate and to diastolic pressure.

INTRODUCTION

An individual can be regarded as a point in a three-dimensional space having as its dimensions age, height and weight. The point moves, as the individual grows from birth to maturity, along all three dimensions, increasing in age, height and weight. After reaching maturity, the point continues to move along the age dimension, and may also move along the weight dimension. This three-dimensional space can be conceived of as a physiological life space, and the position of the individual in that space is indicated by his age, height and weight. As a dimension, age denotes the length of time that an individual has lived; it also connotes qualitative changes, which are particularly marked during the period from birth to maturity. Height, as a dimension, is a measure of skeletal size, while weight is a composite value contributed to by

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muscle, skeleton, fat, water and other constituents of the body. Physiochemical processes are the chemical processes which take place as part of the normal functioning of the body and organs (Dorland 1954). As the point representing an individual moves through the space, these physiochemical processes undergo changes, which may be referred to as micro-level changes in the physiological life space. Also associated with the physiological life space are psychological, sociological and economic variables; changes in these variables which occur as an individual moves through the physiological life space may be referred to as macro-level changes. The purpose of the present study is to consider micro-level changes in physiochemical processes which occur with changes in age, height and weight after maturity has been reached. The approach is cross-sectional, that is selected physiochemical processes have been studied in a number of individuals varying in age, height and weight.

The status and nature of changes in physiochemical processes with age have been considered in terms of various blood constituents. For the present research, the following blood constituents were measured: amylase activity, calcium, chlorides, cholesterol (total, free and ester), creatinine, glucose, non-protein nitrogen, phosphatase (acid and alkaline), protein (total), serum *p*H, urea, uric acid, erythrocytes, leukocytes, neutrophils, lymphocytes, eosinophils, hemoglobin and sedimentation rate. These blood constituents have been examined in a series of researches by this laboratory over the past decade (Das 1959, 1960, 1961, 1964; Das and Bhattacharya 1961*a*, *b*; Das and Mukherjee 1963).

Methods

Subjects for this study were 501 male residents of West Bengal, engaged in office work, nonvegetarians whose main source of carbohydrate was rice. They were selected by drawing random samples, within age groups, of the employees of the Indian Statistical Institute, Calcutta.

The following routine was adopted for collecting the experimental data. Subjects came to the laboratory in the morning in a fasting condition (no meal since the previous evening). Upon arrival, the subjects sat quietly for 20 minutes, after which pulse, blood pressure and oral temperature measurements were made. The circulatory variables were measured first on the right arm and second on the left arm. Age, customary diet and other identification information were recorded. Height was measured with an anthropometer (G.P.M., Switzerland) and weight was measured on a Salter Scale (Grosvenor, England) which had been standardized. Venous blood was then removed for the chemical and hematological tests; it was always removed between 9.30 a.m. and 10.30 a.m. and immediately processed for the different estimations. This procedure had been adopted in previous studies (Das 1959, 1960, 1961, 1964).

The chemical and hematological tests are listed as variables in column (2) of Table I. The laboratory method, material analysed (blood or serum) and unit of measurement for each variable are specified in columns (3) and (4). The references for the laboratory methods are as follows: King and Wooten (1956) for variables 4, 5, 7, 12, 13, 14 and 15; Hawk *et al.* (1954) for variables 6, 10 and 18; Gradwohl (1956) for variables 8 and 9; Tárnoky (1958) for variable 11; Varley (1962) for variable 17; Hepler (1955) for variables 16, 19 to 25; and the American Heart Association (1951) for variables 28 to 31.

The techniques of correlation and multiple regression analysis have been used along with central tendency measures and bivariate frequency distributions to statistically analyse the data (Walker and Lev 1953). Correlation coefficients, expressing the relationship between two variables, X and Y, as a pure number ranging in value from $-1{\cdot}0$ through 0 to $+1{\cdot}0$, were computed using the formula

$$\rho = \frac{N\Sigma XY-(\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2-(\Sigma X)^2][N\Sigma Y^2-(\Sigma Y^2)]}}.$$

A positive sign preceding the coefficient indicates that Y increases as X increases, whereas a negative sign indicates that Y decreases as X increases. Asterisks are used to denote coefficients which differ significantly from zero, i.e. exhibit a nonchance relationship between X and Y. For each variable measured, its mean and standard deviation are reported in Table I along with the coefficients of correlation with age, height and weight. Tables II, III, IV and V give the means of all age groups on each variable. Bivariate percentage frequency distributions have been obtained by converting entries in two-way frequency tables to percentages of the 501 cases examined. Tables VI, VII and VIII present these distributions for glucose, sedimentation rate and diastolic pressure in relation to age. Multiple regression analysis has been utilized to examine the regression of each blood constituent on age, height and weight simultaneously. Columns (3), (4) and (5) of Table IX give the standard partial regression coefficients computed by the Fisher modification of the Doolittle Method. These coefficients are pure numbers, unaffected by the scale of measurement, and can be compared with each other. Their significance was tested by t tests. Columns (6) through (8) give the multiple regression equation of the general form

$$Y' = A+b_{y1\cdot 23}X_1+b_{y2\cdot 13}X_2+b_{y3\cdot 12}X_3,$$

where Y' is the value of the variable as estimated by weighted values of X_1 (age), X_2 (height) and X_3 (weight). Column (6) gives the constant A and columns (7), (8) and (9) give the partial regression coefficients $b_{y1\cdot 23}$, $b_{y2\cdot 13}$ and $b_{y3\cdot 12}$ which differentially weight the values of X_1, X_2 and X_3. Given an individual's measurements on X_1, X_2 and X_3, it is possible to compute Y' if the partial regression coefficients are known. The multiple correlation

TABLE I

Laboratory methods with observed means, standard deviations, and correlation with age, height and weight

Variable		Method and material analysed	Unit of measurement	Mean	Standard deviation	Correlation		
Sl. No.	Name					Age	Height	Weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Age		year	36·99	11·89	–	0·2227*	0·3373*
2	Height	anthropometer	cm	162·13	6·97	0·2227*	–	0·4891*
3	Weight	standardized scale	kg	55·30	10·85	0·3373*	0·4891*	–
4	Amylase activity	Somogyi, serum	units/100 ml	94·73	32·12	−0·0315	−0·0949†	−0·0525
5	Calcium	Modified EDTA, serum	mg/100 ml	8·56	1·11	0·0673	0·0727	0·1212*
6	Chlorides	Whitehorn, blood	mg/100 ml	520·18	30·18	0·0441	0·0568	−0·0038
7	Total cholesterol	Zak, serum	mg/100 ml	162·12	43·21	0·3420*	0·2234*	0·4694*
8	Free cholesterol	Zak, serum	mg/100 ml	63·27	16·93	0·3447*	0·2297*	0·4747*
9	Cholesterol ester	Zak, serum	mg/100 ml	98·80	26·52	0·3370*	0·2175*	0·4612*
10	Creatinine	Folin and Wu, blood	mg/100 ml	0·99	0·18	0·1211*	0·1014†	0·1238*
11	Glucose	Asatoor and King, blood	mg/100 ml	66·01	23·13	0·2545*	0·0767	0·2706*
12	Nonprotein nitrogen	King, blood	mg/100 ml	36·24	6·37	0·1361*	0·0888†	0·1798*
13	Acid phosphatase	King and Armstrong, serum	KA units/100 ml	2·84	2·07	−0·0236	−0·0919†	−0·0411
14	Alkaline phosphatase	King and Armstrong, serum	KA units/100 ml	9·18	5·34	−0·1972*	−0·1485*	−0·2000*
15	Total protein	micro-Kjeldahl, serum	g/100 ml	7·18	0·77	−0·0923†	0·0660	0·0587
16	Serum *p*H	*p*H meter, serum	*p*H	7·29	0·35	0·0139	0·0121	0·0223
17	Urea	Urease Nesslerization, blood	mg/100 ml	18·67	4·83	0·1854*	0·0988†	0·1835*
18	Uric acid	Brown, blood	mg/100 ml	2·21	1·20	0·0422	0·0297	0·1567*
19	Erythrocytes	erythrocyte count, blood	million/c mm	4·32	0·25	0·0156	0·1489*	0·3719*
20	Leukocytes	leukocyte count, blood	number/c mm	6832·57	1002·48	−0·0113	−0·0052	−0·0227

* $P < 0{\cdot}01$; † $P < 0{\cdot}05$.

TABLE I—(*concluded*)

Variable		Method and material analysed	Unit of measurement	Mean	Standard deviation	Correlation		
Sl. No.	Name					Age	Height	Weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
21	Neutrophils	differential count, blood	percentage	59·52	7·24	0·1193*	0·0508	0·1515*
22	Lymphocytes	differential count, blood	percentage	32·43	5·40	0·0345	−0·0062	−0·0364
23	Eosinophils	differential count, blood	percentage	6·33	6·73	−0·1588*	−0·0555	−0·1507*
24	Hemoglobin	Sahli-Hellige, blood	g/100 ml	13·59	0·89	0·0238	0·1157*	0·3238*
25	Sedimentation rate	Wintrobe and Landsberg, blood	mm/hour	13·33	13·36	0·2272*	0·0083	−0·0297
26	Pulse (right)	standard procedure	pulsations/min	71·33	8·25	−0·0067	−0·0698	−0·0459
27	Pulse (left)	standard procedure	pulsations/min	71·23	8·28	−0·0152	−0·0748	−0·0473
28	Systolic pressure (right)	auscultatory	mm Hg	114·80	14·95	0·4143*	0·1441*	0·3835*
29	Diastolic pressure (right)	auscultatory (5th phase)	mm Hg	69·43	9·65	0·3239*	0·0929†	0·2876*
30	Systolic pressure (left)	auscultatory	mm Hg	114·44	15·08	0·4111*	0·1274*	0·3761*
31	Diastolic pressure (left)	auscultatory (5th phase)	mm Hg	69·81	9·95	0·3493*	0·0975†	0·3056*
32	Oral temperature	standard procedure	degrees Fahrenheit	98·58	0·70	−0·1240*	−0·1041†	0·0520

* $P < 0{\cdot}01$; † $P < 0{\cdot}05$.

TABLE II

Mean values of height, weight and blood chemistry variables according to age group and their correlations with age

Age (years)	N	Height (cm)	Weight (kg)	Amylase activity (units/100 ml)	Calcium (mg/100 ml)	Chloride (mg/100 ml)	Cholesterol		
							Total (mg/100 ml)	Free (mg/100 ml)	Ester (mg/100 ml)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
10–14	5	152·00	37·00	92·00	8·20	522·00	102·00	40·50	60·50
15–19	16	160·75	47·00	99·50	8·26	516·69	118·25	46·38	73·25
20–24	50	161·60	50·40	98·50	8·43	528·50	139·50	53·50	84·50
25–29	70	161·79	53·14	96·29	8·50	523·43	148·79	58·21	91·07
30–34	92	161·51	54·12	96·78	8·50	523·14	158·20	61·78	96·89
35–39	72	163·39	56·10	99·85	8·92	528·32	168·25	65·75	102·56
40–44	67	162·82	60·28	97·45	8·61	528·04	188·49	74·50	114·35
45–49	53	161·91	57·09	97·38	8·78	528·04	173·79	67·14	105·07
50–54	34	165·97	63·03	105·38	8·79	522·29	178·18	69·50	106·85
55–59	15	164·67	59·33	93·67	9·30	525·33	172·00	68·50	104·50
60–64	16	165·44	59·81	93·25	8·58	538·56	176·06	69·50	107·00
65–69	6	164·50	59·50	82·83	8·37	541·17	170·33	67·83	109·50
70–74	3	165·33	52·00	78·67	7·87	512·00	212·00	81·17	127·83
75–79	2	169·50	57·00	74·50	7·20	537·00	199·50	79·50	124·50
All	501	162·46	55·58	97·66	8·62	526·14	163·20	63·76	99·34
Correlation with age		0·2227*	0·3373*	—0·0315	0·0673	0·0441	0·3420*	0·3447*	0·3370*

* $P < 0{\cdot}01$.

TABLE III

Mean values of blood chemistry variables according to age group and their correlations with age

Age (years)	N	Creatinine (mg/100 ml)	Glucose (mg/100 ml)	Nonprotein nitrogen (mg/100 ml)	Phosphatase (KA units/100 ml)		Total protein (mg/100 ml)	Serum pH (pH)	Urea (mg/100 ml)	Uric acid (mg/100 ml)
					acid	alkaline				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
10–14	5	1·03	56·95	35·45	4·95	20·35	6·05	7·24	16·45	1·45
15–19	16	0·94	58·07	35·26	2·82	15·20	7·45	7·34	18·08	1·76
20–24	50	0·99	60·15	34·25	3·11	10·27	7·41	7·26	18·35	2·43
25–29	70	0·94	60·52	36·24	2·78	8·58	7·41	7·30	17·95	2·02
30–34	92	0·99	60·60	36·53	2·82	9·04	7·30	7·30	17·94	2·28
35–39	72	1·00	64·26	35·37	3·64	9·06	7·31	7·32	18·08	2·53
40–44	67	0·98	70·17	36·48	2·65	9·11	7·18	7·28	19·09	2·35
45–49	53	0·99	81·36	37·36	2·46	9·35	7·09	7·34	19·43	2·45
50–54	34	1·03	77·60	39·36	3·01	8·07	7·07	7·31	20·69	2·22
55–59	15	1·04	74·28	37·12	4·02	8·88	7·38	7·28	18·78	2·52
60–64	16	1·11	80·58	36·51	2·08	8·45	7·26	7·31	21·51	1·95
65–69	6	0·95	63·28	37·45	2·95	6·62	7·28	7·38	20·78	1·95
70–74	3	0·95	58·28	34·12	2·95	5·95	7·45	7·37	19·12	1·45
75–79	2	0·85	54·95	42·45	2·95	5·95	7·45	7·30	24·95	1·95
All	501	0·99	66·64	36·33	2·95	9·34	7·27	7·30	18·69	2·28
Correlation with age		0·1211*	0·2545*	0·1361*	−0·0236	−0·1972*	−0·0923†	0·0139	0·1854*	0·0422

* $P < 0{\cdot}01$; † $P < 0{\cdot}05$.

TABLE IV

Mean values of haematological variables according to age group and their correlations with age

Age (years)	N	Erythrocytes (M/c mm)	Leucocytes (N/c mm)	Neutrophils (%)	Lymphocytes (%)	Eosinophils (%)	Haemoglobin (g/100 ml)	Sedimentation rate (mm/hour)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10–14	5	3·82	6949·50	60·50	31·00	8·50	12·20	22·95
15–19	16	4·24	6812·00	56·37	32·94	9·62	13·42	8·70
20–24	50	4·28	6839·50	60·30	31·30	6·58	13·62	11·75
25–29	70	4·38	6756·64	58·36	32·43	7·19	13·87	9·24
30–34	92	4·36	7042·98	58·74	33·14	6·57	13·84	11·47
35–39	72	4·34	6846·72	60·47	32·69	5·50	13·73	13·14
40–44	67	4·37	7033·08	61·66	31·48	5·55	13·80	14·80
45–49	53	4·25	6853·27	61·67	32·28	4·61	13·48	21·37
50–54	34	4·33	6867·15	60·38	33·18	5·38	13·88	15·24
55–59	15	4·25	6782·83	59·17	35·00	3·97	13·67	16·28
60–64	16	4·28	6812·00	62·00	33·25	4·50	13·58	25·58
65–69	6	4·29	6666·17	61·17	31·17	5·17	13·28	26·62
70–74	3	4·37	7416·17	61·17	27·00	9·83	13·70	21·62
75–79	2	4·24	5749·50	59·50	34·50	2·50	13·70	9·95
All	501	4·32	6889·94	60·00	32·48	6·04	13·71	14·05
Correlation with age		0·0156	−0·0113	0·1193*	0·0345	−0·1588*	0·0238	0·2272*

* $P < 0{\cdot}01$.

TABLE V

Mean values of circulatory variables and oral temperature and their correlations with age

Age (years)	N	Pulse Right (N/min)	Pulse Left (N/min)	Systolic pressure right (mm Hg)	Diastolic pressure right (mm Hg)	Systolic pressure left (mm Hg)	Diastolic pressure left (mm Hg)	Oral temperature (°F)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10–14	5	69·00	70·00	100·50	60·00	100·50	60·00	99·50
15–19	16	70·12	70·12	111·37	64·81	111·38	64·50	98·88
20–24	50	72·10	71·80	111·10	67·80	110·10	67·10	98·70
25–29	70	70·79	70·86	110·07	66·79	110·36	67·14	98·53
30–34	92	73·96	73·58	114·07	69·77	112·98	70·21	98·66
35–39	72	70·82	70·33	115·61	72·49	115·47	72·62	98·56
40–44	67	72·15	72·52	117·49	71·78	117·48	72·75	98·66
45–49	53	71·15	70·87	119·97	73·51	119·78	73·41	98·37
50–54	34	71·85	70·97	121·56	74·06	120·68	75·97	98·69
55–59	15	69·33	69·67	123·17	73·00	124·50	74·00	98·33
60–64	16	75·44	74·81	141·37	76·69	140·75	77·62	98·70
65–69	6	74·50	75·33	129·50	78·67	131·17	78·67	98·53
70–74	3	65·33	63·67	121·17	75·33	117·83	75·33	98·20
75–79	2	67·00	67·00	144·50	74·50	154·50	79·50	97·95
All	501	71·88	71·68	116·27	70·70	115·97	71·10	98·60
Correlation with age		−0·0067	−0·0152	0·4143*	0·3239*	0·4111*	0·3493*	−0·1240*

* $P < 0{\cdot}01$.

coefficients reported in column (10) of Table IX represent, for each variable, the relationship between the observed values of Y and the values of Y' computed by the multiple regression equation. A multiple correlation coefficient ranges in value from zero to unity and is always positive; unity indicates a perfect correspondence between Y and Y'.

Discussion

The first question to be considered deals with physiochemical processes as shown by measurements of the blood. Are the measurements on a population of India similar to or different from those for populations more completely studied, e.g. of North America and Western Europe? To answer this question, the values reported in columns (5) and (6) of Table I may be compared with those regarded as normal for North America and Western Europe (Altman *et al.* 1959; Goodale 1955; Gradwohl 1956; Hawk *et al.* 1954; Hepler 1955; Tárnoky 1958; Varley 1962). In the discussion which follows, the mean from Table I and the normal range for Western Europe and North America are given in parentheses after each variable. The Indian values fall within the normal range for the following variables: amylase activity (95, 80–150), acid phosphatase (3, 1–5), alkaline phosphatase (9, 3–13), total protein (7, 6–8), leukocytes (6800, 5000–10000), neutrophils (60, 50–70) and lymphocytes (32, 20–40). The Indian values are slightly above or below the upper limit of the normal range for free cholesterol (63, 45–61), nonprotein nitrogen (36, 25–35) and pulse (71, 47–75). Conversely, the Indian values are slightly above or below the lower limit for calcium (9, 9–11), total cholesterol (162, 150–250), creatinine (1, 1-2), glucose (66, 65–95), serum *p*H (7·29, 7·35–7·45), urea (19, 15–40), uric acid (2·2, 2·2–3·5), erythrocytes (4·3, 4·5–6·0), haemoglobin (14, 14–18), systolic (115, 96–155) and diastolic (70, 57–101) pressure. In comparison with American and European populations, eosinophils (6, 1–3) and sedimentation rate (13, 0–9) are high and above the normal range of values, while chlorides (520, 570–620) and cholesterol ester (99, 105–189) are low and below the normal range of values. For male residents of urban and semi-urban West Bengal, India, these results suggest a tendency towards anaemia; presence of chronic infections; loss of chlorides due to perspiration; a relatively low sugar, fat and protein dietary intake; rapid pulse and low blood pressure.

The second question to be considered asks about age-related changes in physiochemical processes. Do these processes, as indicated by measurements on the blood, show significant changes with age? The coefficients of correlation presented in column (7) of Table I show that the following variables increase significantly as age increases: cholesterol (total, free and ester), creatinine, glucose, nonprotein nitrogen, urea, neutrophils, sedimentation rate, systolic and diastolic pressure. The coefficients also show that the following

TABLE VI

Bivariate percentage frequency distribution for glucose and age

Age (years)	Glucose (mg/100 ml) 50·0–59·9	60·0–69·9	70·0–79·9	80·0–89·9	90·0–99·9	100·0–109·9	110·0–119·9	120·0–129·9	130·0–139·9	140·0–149·9	150·0–159·9	160·0–169·9	170·0–179·9	180·0–189·9	190·0 +	Row total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
5–9	0	0	0·19	0	0	0	0	0	0	0	0	0	0	0	0	0·19
10–14	0·79	0·19	0	0	0	0	0	0	0	0	0	0	0	0	0	0·99
15–19	2·19	0·99	0	0	0	0	0	0	0	0	0	0	0	0	0	3·18
20–24	6·17	3·18	0·19	0	0·39	0	0	0	0	0	0	0	0	0	0	9·96
25–29	8·96	3·18	1·59	0	0	0	0	0·19	0	0	0	0	0	0	0	13·94
30–34	9·36	7·76	0·99	0·19	0	0	0	0	0	0	0	0	0	0	0	18·32
35–39	5·17	6·37	1·99	0·19	0·59	0	0	0	0	0	0	0	0	0	0	14·34
40–44	3·78	5·77	1·99	0·99	0	0·19	0	0	0·19	0	0	0·19	0	0	0·19	13·34
45–49	2·58	3·98	1·39	0·19	0·39	0	0·59	0·19	0	0	0·39	0·39	0	0	0·39	10·55
50–54	1·59	1·99	1·39	0·59	0·19	0·39	0·19	0	0	0	0·19	0	0	0	0·19	6·77
55–59	0·39	1·39	0·79	0·19	0	0	0	0	0	0	0	0·19	0	0	0	2·98
60–64	0·79	0·79	0·79	0·19	0	0·19	0	0·19	0	0	0	0	0	0	0·19	3·18
65–69	0·39	0·59	0·19	0	0	0	0	0	0	0	0	0	0	0	0	1·19
70–74	0·39	0·19	0	0	0	0	0	0	0	0	0	0	0	0	0	0·59
75–79	0·39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0·39
Column total	43·02	36·45	11·55	2·58	1·59	0·79	0·79	0·59	0·19	0	0·59	0·79	0	0	0·99	100·00

TABLE VII

Bivariate percentage frequency distribution for sedimentation rate and age

Age (years)	Sedimentation rate (mm/hour)										Row total
	0–9·9	10·0–19·9	20·0–29·9	30·0–39·9	40·0–49·9	50·0–59·9	60·0–69·9	70·0–79·9	80·0–89·9	90·0–99·9	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
5–9	0	0	0·19	0	0	0	0	0	0	0	0·19
10–14	0·39	0·39	0	0	0	0	0	0·19	0	0	0·99
15–19	2·19	0·79	0·19	0	0	0	0	0	0	0	3·18
20–24	6·17	2·39	0·39	0·39	0·59	0	0	0	0	0	9·96
25–29	9·16	3·98	0·39	0·39	0	0	0	0	0	0	13·94
30–34	9·96	6·37	1·59	0·19	0	0	0	0	0	0·19	18·32
35–39	7·17	4·58	1·59	0·19	0·59	0·19	0	0	0	0	14·34
40–44	5·57	5·17	1·79	0·19	0·19	0	0	0·19	0·19	0	13·34
45–49	2·98	2·98	2·58	0·99	0·39	0·19	0	0	0	0·39	10·55
50–54	2·58	2·78	0·39	0·79	0	0·19	0	0	0	0	6·77
55–59	0·99	0·99	0·59	0·39	0	0	0	0	0	0	2·98
60–64	1·19	0·19	1·19	0	0·19	0	0	0·19	0	0·19	3·18
65–69	0	0·39	0·39	0·19	0·19	0	0	0	0	0	1·19
70–74	0·19	0·19	0	0	0·19	0	0	0	0	0	0·59
75–79	0·19	0·19	0	0	0	0	0	0	0	0	0·39
Column total	48·80	31·47	11·35	3·78	2·39	0·59	0	0·59	0·19	0·79	100·00

TABLE VIII

Bivariate percentage frequency distribution for diastolic pressure (right side, fifth phase) and age

Age (years)	Diastolic pressure (mm Hg) 35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–99	100–109	105–109	Row total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
5–9	0	0	0	0	0·19	0	0	0	0	0	0	0	0	0	0	0·19
10–14	0·19	0	0	0	0	0·39	0·19	0·19	0	0	0	0	0	0	0	0·99
15–19	0	0	0	0·39	0·39	0·99	0·19	0·99	0	0·19	0	0	0	0	0	3·18
20–24	0	0	0	0·19	0·99	3·18	0·19	4·38	0·19	0·59	0·19	0	0	0	0	9·96
25–29	0	0·19	0	0·39	0·79	5·17	1·19	4·78	0·59	0·79	0	0	0	0	0	13·94
30–34	0	0	0	0	0·59	5·97	0·39	8·36	0·99	1·39	0·19	0·39	0	0	0	18·32
35–39	0	0	0	0·19	0·19	1·99	0·99	7·76	0·39	1·79	0·59	0·19	0	0·19	0	14·34
40–44	0	0·19	0·19	0	0·19	2·58	1·19	5·17	1·19	1·79	0·19	0·19	0	0·39	0	13·34
45–49	0	0	0	0	0·19	2·19	0·59	3·98	0·59	1·99	0·19	0·59	0	0·19	0	10·55
50–54	0	0	0	0·39	0	0·99	0·59	1·79	0·79	1·39	0·19	0·39	0	0·19	0	6·77
55–59	0	0	0	0·39	0	0·19	0·79	0·79	0·19	0·19	0	0	0	0	0·39	2·98
60–64	0	0	0	0·19	0	0·39	0	0·79	0·39	0·59	0·39	0·19	0·19	0	0	3·18
65–69	0	0	0	0	0	0·19	0	0	0·39	0·39	0	0·19	0	0	0	1·19
70–74	0	0	0	0	0	0	0	0·39	0	0·19	0	0	0	0	0	0·59
75–79	0	0	0	0	0	0·19	0	0	0	0	0·19	0	0	0	0	0·39
Column total	0·19	0·39	0·19	2·19	3·58	24·50	6·37	39·44	5·77	11·35	2·19	2·19	0·19	0·99	0·39	100·00

variables decrease in value as age increases: alkaline phosphatase, total protein, eosinophils and oral temperature. No significant change with age was noted for amylase activity, calcium, chlorides, acid phosphatase, serum *p*H, uric acid, erythrocytes, leukocytes, lymphocytes, haemoglobin and pulse. Thus it may be said that in comparison with a younger person, an older person tends to have higher cholesterol, creatinine, glucose, nonprotein nitrogen, urea, sedimentation rate, systolic and diastolic blood pressure, and to have lower alkaline phosphatase, total protein, erythrocytes, eosinophils, haemoglobin and oral temperature. The nature of the changes with age is exhibited in Tables II to V. In these tables, mean values for each age group are reported. These age group means are the expected values at the various points along the age dimension of the physiological life space. The coefficients of correlation with age are also presented. The data underlying significant correlations with age are illustrated for a chemical, a haematological and a circulatory variable in Tables VI to VIII. In these tables, the underlying data are presented as bivariate percentage frequency distributions. Using these percentages, expected frequencies for any sample can be computed. The row totals give the age group percentage frequency distribution, and the column totals give the percentage frequency distribution for the variable being studied. The quantitative change in any variable due to age can be determined from the multiple regression analysis. The coefficients of the multiple regression equations, in columns (7) to (9) of Table IX, indicate the degree of change in the variable per unit change in age, height or weight. Thus, for example, an increase of +0·76 mg per 100 ml total cholesterol is expected for each year of age. The yearly change in any determination of the blood is indicated by its regression coefficient in column (7) of Table IX.

A third question can also be asked: what is the expected value of a variable for any individual? To answer this question, all three dimensions of the physiological life space need to be considered, for the prediction of the variable will be more accurate if its regression on age, height and weight are simultaneously considered (Walker and Lev 1953). By means of the multiple regression equations in Table IX, it is possible to predict the expected value for any individual, given his age, height and weight. This expected value may be interpreted as his individual norm or standard.

Having demonstrated that significant age-related changes in blood determinations take place, the underlying physiochemical processes remain to be considered. Four physiochemical processes investigated in the present study apparently change with age. One physiochemical process which is affected is anabolism, the constructive phase of metabolism. Cholesterol, glucose, alkaline phosphatase and total protein all reflect anabolic activities. Another physiochemical process which changes with age is catabolism, the destructive or oxidative phase of metabolism. Nonprotein nitrogen, creatinine and urea

TABLE IX

Multiple regression analysis of age, height and weight as predictors of blood chemistry, blood morphology and circulatory variables

Variable		Standard partial regression coefficients			Regression equation				Multiple correlation coefficient
						Regression coefficients			
Number	Name	Age	Height	Weight	Constant	Age	Height	Weight	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
4	Amylase activity	−0·0096	−0·0902	−0·0051	163·9251	−0·0260	−0·4157	−0·0152	0·0956
5	Calcium	0·0288	0·0155	0·1039†	7·4681	0·0027	0·0025	0·0106	0·1252†
6	Chlorides	0·0464	0·0736	−0·0555	472·6790	0·1177	0·3188	−0·1544	0·0802
7	Total cholesterol	0·2088*	−0·0239	0·4107*	67·6357	0·7588	−0·1484	1·6360	0·5088*
8	Free cholesterol	0·2095*	−0·0191	0·4134*	24·0847	0·2984	−0·0465	0·6452	0·5139*
9	Cholesterol ester	0·2064*	−0·0263	0·4044*	43·3423	0·4605	−0·1002	0·9887	0·5004*
10	Creatinine	0·0865	0·0472	0·0715	0·6721	0·0013	0·0012	0·0012	0·1553*
11	Glucose	0·1899*	−0·0876	0·2494*	70·0397	0·3694	−0·2905	0·5317	0·3303*
12	Nonprotein nitrogen	0·0855	−0·0054	0·1536*	30·3584	0·0458	−0·0049	0·0901	0·1969*
13	Acid phosphatase	−0·0049	−0·0940	0·0065	7·3243	−0·0008	−0·0279	0·0012	0·0921
14	Alkaline phosphatase	−0·1428*	−0·0558	−0·1246†	21·8793	−0·0642	−0·0427	−0·0614	0·2477*
15	Total protein	−0·1303*	0·0589	0·0738	6·1463	−0·0084	0·0065	0·0052	0·1423†
16	Serum *p*H	0·0071	0·0010	0·0194	7·2409	0·0002	0·0001	0·0006	0·0233
17	Urea	0·1393*	0·0013	0·1359*	13·0809	0·0566	0·0009	0·0605	0·2256*
18	Uric acid	0·0080	−0·0611	0·1893*	2·7878	−0·0008	−0·0105	0·0210	0·1658*

TABLE IX—(*concluded*)

Variable		Standard partial regression coefficients			Regression equation				Multiple correlation coefficient
						Regression coefficients			
Number	Name	Age	Height	Weight	Constant	Age	Height	Weight	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
19	Erythrocytes	−0·1217*	−0·0341	0·4296*	4·0606	−0·0026	−0·0012	0·0101	0·3909*
20	Leukocytes	−0·0046	0·0081	−0·0251	6786·2741	−0·3913	1·1661	−2·3196	0·0241
21	Neutrophils	0·0793	−0·0366	0·1427*	58·6400	0·0483	−0·0380	0·0952	0·1709*
22	Lymphocytes	0·0520	0·0113	−0·0595	31·7722	0·0236	0·0087	−0·0295	0·0624
23	Eosinophils	−0·1240*	0·0333	−0·1252†	7·9995	−0·0702	0·0322	−0·0777	0·1916†
24	Haemoglobin	−0·0932†	−0·0490	0·3792*	13·1413	−0·0069	−0·0062	0·0310	0·3390*
25	Sedimentation rate ..	0·2670*	0·0097	−0·1245†	7·6936	0·3001	0·0186	−0·1534	0·2538*
26	Pulse (right)	0·0140	−0·0633	−0·0197	83·9450	0·0097	−0·0749	−0·0150	0·0723
27	Pulse (left)	0·0053	−0·0683	−0·0157	84·8972	0·0037	−0·0811	−0·0120	0·0759
28	Systolic pressure (right) ..	0·3269*	−0·0820	0·3133*	104·2094	0·4109	−0·1757	0·4318	0·4938*
29	Diastolic pressure (right) ..	0·2614*	−0·0826	0·2398*	68·3250	0·2121	−0·1143	0·2133	0·3821*
30	Systolic pressure (left) ..	0·3272*	−0·0992†	0·3143*	109·7122	0·4151	−0·2146	0·4369	0·4900*
31	Diastolic pressure (left) ..	0·2837*	−0·0899	0·2539*	68·9432	0·2373	−0·1282	0·2327	0·4098*
32	Oral temperature	−0·1493*	−0·1589*	0·1801	100·8470	−0·0088	−0·0159	0·0116	0·2108*

* $P < 0{\cdot}01$; † $P < 0{\cdot}05$.

are breakdown products of protein digestion and tissue metabolism. A third physiochemical process which changes with age is the body's defence mechanism against sources of external infection. Sedimentation rate reflects this process. The fourth physiochemical process concerns the regulating mechanisms themselves. Eosinophil level, systolic and diastolic pressure and oral temperature are examples of steady states which are apparently disturbed with advancing age. Further study of these physiochemical processes may elucidate the changes which occur as an individual progresses through the physiological life space.

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