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# Variability of Human Body Heat Conductivity in Population I. Methodological and Theoretical Approaches

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**KEYWORDS** Constitutive Heterochromatin. Chromosomal Q-Heterochromatin. Cell Thermoregulation. Body Heat Conductivity. Human Adaptation

**ABSTRACT** An attempt has been made to estimate human body heat conductivity (BHC) in population. Calorimetric method of measuring heat conductivity in solids known in thermo physics has been modified for this purpose. Results obtained show that individuals in population substantially differ from each other in BHC. It is assumed that cell thermoregulation which is determined by density of peripheral layer of condensed chromatin (CC) around cell nucleus underlie various human BHC. The density of peripheral layer of CC depends on amount of chromosomal Q-heterochromatin regions (Q-HRs) in human genome. Since the amount of chromosomal Q-HRs in human population genome is usually determined by climatic and geographical conditions of permanent residence and not their ethnic and racial peculiarities, a hypothesis that human BHC is possibly connected with its adaptability to different environmental thermal conditions has been put forward. The question of place and possible role of human BHC in norm and pathology is also being discussed.

## INTRODUCTION

Human uniqueness in addition to all his known characteristics is that he is the only who managed to populate the whole Earth surface including such extreme areas as Far North and high altitudes remaining single tropic biological species. Moreover, all this took place in a short period of time (around 30,000 - 50,000 years), an unprecedented fact in life evolution (Stringer 1996).

There is bulk of literature dedicated to various aspects of human adaptation including biological ones. Numerous International Projects and Programs aimed at studying different aspects of human adaptation to different climatic and geographical conditions using methods of modern medicine and biology were carried out. Three specific biomes - high altitude, tropical and circumpolar - received special study in these Projects. In spite of considerable success in ascertainment of various aspects of human adaptation to different environmental conditions, there are still a lot of questions to solve (reviewed in: Collins 1999; Little and Garruto 2000; Beall 2007).

It is known that of all physical environmental factors able to influence life, temperature is the most substantial. Role of temperature in biological life is obvious. As, in fact, life known to science is possible at positive temperature. And its highest form, mammals are able to maintain relatively permanent body temperature keeping high level of metabolism.

It is generally considered that the human is well adapted to hot climate. Probably this is connected with the fact that the human is a biological species developed in tropical climate of East Africa. Nevertheless he managed to populate cold Earth areas as well including circumpolar zone of Northern Hemisphere, as well as high altitudes. Some morphophysiological adaptive characteristics of organisms of North and high altitude aborigines are clarified. But the finest biological, including genetic mechanisms of human adaptation are still unknown. At present, the search of genetic basis of human adaptation to extreme environmental conditions is mainly conducted in high altitude populations. But perennial studies for hypothetical structural genes facilitating human adaptation to hypoxia in genome of high altitudes population did not bring any positive results. Anyway, researches in this direction are still being carried out in all mountain provinces, from the Tibet to the Andes (Little and Garruto 2000; Beall 2007).

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Our own experience in search for genetic basis of human adaptation to Northern Siberia, as well as the Pamir and the Tien Shan high altitudes show that the human could adapt just to the cold, but he can only acclimatize to high altitude hypobaric hypoxia. It is seen through the fact that permanent settlements in the mountains of the Pamir and the Tien Shan, as in other high altitude provinces, can be found only on the lower levels of the highlands (about 4,200 meters above see level). At the same time we have obtained some data showing that the human, at the process of genetic adaptation to the cold probably used non-genic part of his genome (Ibraimov 1993, 2003, 2007 b, 2010 a; Ibraimov and Mirrakhimov 1982 a, b, c, d, 1985; Ibraimov et al. 1982, 1986, 1990, 1991, 1997).

It is found that non-genic part of human genome makes about 98% of cell nucleus DNA. Approximately 15-20% of this non-coding part of human DNA is constitutive heterochromatin (John 1988). Human chromosomes possess two types of constitutive heterochromatin: C- and Q-heterochromatin (Caspersson et al. 1970; Arrighi and Hsu 1971; Paris Conference 1971, Suppl. 1975). Chromosomal C-heterochromatin regions (C-HRs) are found in the genome of all higher eukaryotes, and Q-heterochromatin regions (Q-HRs) are only in the genome of three higher primates (*Homo sapiens*, *Pan troglodytes* and *Gorilla gorilla*) (Pearson 1973, 1977; Verma 1988). However, there is a fundamental difference between them: quantitative variability of chromosomal Q-HRs in the genome exists only in human populations (ISCN 1978). Moreover, chromosomal Q-HRs are distributed in human genome not accidentally. Specifically:

a) The amount of chromosomal Q-HRs in human population genome depends on climate and geographical conditions of permanent residence and not their ethnic and racial peculiarities. The largest amount of chromosomal Q-HRs is found in the genome of populations living in low altitude subequatorial Africa and India, and the least - in Northern Siberia aborigines, as well as indigenous people of Tien Shan and Pamir high altitudes and Ethiopian upland (Ibraimov and Mirrakhimov 1982 b, c, d; Ibraimov et al. 1982, 1986, 1997; Kalz et al. 2005);

b) Individuals capable of successfully adapting themselves to the extreme high-altitude climate (e.g. mountaineers) and newcomers of the Far North (e.g. oil industry workers of the Jamal peninsula of polar Eastern Siberia) are characterized by extremely low amounts of Q-HRs in their genome (Ibraimov et al. 1990, 1991).

c) The amount of Q-HRs per individual in a population is greatest in newborns than in older age groups (Buckton et al. 1976; Ibraimov and Karagulova 2006 a) despite the fact that the number, location and size of Q-HRs do not change in ontogenesis.

d) The amount of chromosomal Q-HRs appeared to be the highest in infants died at first weeks, months or years of their lives (Ibraimov and Karagulova 2006 b).

These data show that there is some connection between the amount of Q-heterochromatin in human genome and his adaptability to some physical environmental conditions. Since human chromosomal Q-HRs have no structural genes, the traditional "genotype g phenotype" approach is unacceptable in this case. However, it turned out impossible (reviewed in: Grewal and Jia 2007) to explain the connection of existing conceptions on possible biological role of chromosomal HRs (Ibraimov 1993, 2003, 2007a, b; Ibraimov and Tabaldiev 2007).

To search a way out of the situation, we came back to the hypothesis of cell thermoregulation (CT) (Ibraimov 2003). CT is the process of equalization of temperature difference between cytoplasm and nucleus and finally inside of the whole cell. Structural basis of CT is peripheral layer of condensed chromatin (CC) which is chromosomal Q-HRs. We assume that thermal energy transfer between the cytoplasm and the nucleus is carried out through this dense layer of peripheral CC, located inside of the nuclear envelope.

Certainly, CT hypothesis should be checked on the cell level. But we have not had the opportunity till present. Nevertheless, we have checked this hypothesis on the level of human organism assuming that CT is the basis for heat conductivity of whole cell part of body (Ibraimov and Tabaldiev 2007). This research showed that in fact there are differences in the BHC between individuals in population.

But some biological questions still remain unsolved including methodical ones in studying the human BHC variability. This work presents new data on human BHC variability in population obtained using, as we assumed, more advanced methods for human BHC estimation.

## MATERIALS AND METHODS

Objects of the given study were groups of individuals from different sex, age and ethnic and racial groups.

The first group (n = 100) consisted of soldiers from the Kyrgyz Republic National Guard. Age of the guardsmen varies from 18 to 22. All examined individuals were males of Kyrgyz nationality who are over 170 cm tall. All servicemen resided on the territory of a military unit in the barracks.

The second group (n = 68) consisted of schoolchildren from gymnasium located in the same area where the above mentioned military unit is stationed. The Kyrgyz children coming from all regions of Kyrgyzstan go to this school and live in one hostel. Age of the schoolchildren varied from 12 to 16. All examined individuals had the same day regimen, living conditions and food.

Kyrgyz individuals undertaking the health resort treatment on the base of the Research Center for Balneology and Rehabilitation located at the same area as two preceding were additionally examined to study sex and age influence on human BHC variability in population.

Possibility of race and ethnic origin influence on the level of BHC was investigated studying the groups of Kyrgyz (n = 30 ♂) and Indian (n = 30♂, Uttar Pradesh State, India) students from Kyrgyz State Medical Academy, as well as Chinese (n = 30 ♂; n = 14 ♂, Guangdong province, China) from Kyrgyz Pedagogical University in the city of Bishkek.

Their weight, height, body constitution (normosthenic, asthenic and hypersthenic), blood pressure and pulse rate were measured in addition to passport records. The researches were being carried out not earlier than in two hours after having a meal.

BHC estimation of individuals was conducted indoors at a temperature of ~20ºC. At first the temperature of individual's left palm and armpit was measured using a mercury thermometer. Thermometer readings were rounded off for convenience of analysis of numerical results to obtain an integral number. Measuring the palm temperature was necessary for preparation of 'hot' and 'cold' water to determine heat conductivity of hand by calorimetric method. 'Hot' and 'cold' water were prepared in three variants. In the first variant, number nine was added to the thermometer reading to prepare 'hot' water for a particular individual depending on palm temperature, and number nine was subtracted from the thermometer reading to prepare 'cold' water (substantiation of number nine is given in 'Discussion'). For instance, if an individual's palm temperature was 31.0ºC, then 'hot' and 'cold' water temperature for his hand should be 40ºC and 22ºC, respectively. In the second variant both 'hot' and 'cold' water temperatures were constant (40ºC and 15ºC, respectively) for all surveyed individuals. In the third variant of the experiment only 'hot' water temperature was changed depending on the individual's palm temperature.

Then the surveyed individuals' "hand volume" (HV), as we conventionally call it, was measured. For this purpose, left hand up to the wrist was plunged slowly in a vessel filled with water to the brim. Under the first one there was another empty vessel where the displaced by the examinee's hand water, which was measured in milliliters, was pouring out. Then this number was multiplied by four so that the obtained volume of water could let the hand being loose in the liquid not touch the vessel walls to measure heat conductivity. Such calculation is made to decrease HV influence on estimation accuracy of the heat conductivity of this part of a body.

The examinee sits down on a chair with his body upright, head is raised, hands hang down naturally on both sides of his body and muscles are relaxed. Then the examinee plunges slowly his left hand up to the wrist (as the HV was measured) in everyday food vacuum flask placed against shin and filled with 'hot' or 'cold' water. During the heat conductivity measuring which takes 20 minutes, the individual under test should not divert his attention away, keep the hand in water and not press it against the flask walls. At the end of experiment, the changes of water temperature in the vacuum flask were measured by a laboratory mercury thermometer to one tenth of a degree of Celsius (tºC). For convenience of analysis of numerical results while measuring when the mercury level coincided with an odd point of the thermometer, its value was decreased by one-tenth of a degree to have an even number. For instance, if the thermometer showed 1.5ºC, it was recorded as 1.4ºC. Soon after a hand plunge into the flask up to the wrist the water, surface was covered with tea spoonful of refined vegetable oil to decrease evaporation. Any other additional measures of protection from the air temperature of the room where the experiment was taking place

were not taken. All the measuring was performed by skilled medical personnel.

The mean numbers of change of the water temperature were compared using the Student t-test.

## RESULTS

Since both water temperature decrease and increase show heat conducting ability of human hand tissue (Ibraimov and Tabaldiev 2007), it was decided to focus on their sum (↑+↓) as the indicator indirectly showing body heat conductivity (BHC) of a particular individual.

The possible influence of 'hand volume', weight, height and other human morphophysiological characteristics on BHC of his hand was tested on the servicemen, as the more physically and ethnically homogeneous group of individuals.

As shown in the Tables 1, 2, 3, 'hand volume', weight and height do not effect on the variability of BHC in population. Such morphophysiological traits of the individuals, as types of body constitution (normosthenic, asthenic and hypersthenic), pulse rate and level of arterial pressure also did not render statistically significant influence on distribution of BHC among military men. The same results have given all other groups studied by us, irrespective of their sex, age and racial-ethnic origin (data not shown).

**Table 1: Distribution of body heat conductivity (BHC) depending on 'hand volume'.**

| *BHC (in ºC)* | *250-299 ml (n = 29)* (↑+↓) | *300-349 ml (n = 44)* (↑+↓) | *350 ml and more (n = 27)* (↑+↓) |
|---|---|---|---|
| | *I* | *II* | *III* |
| 4.4 | | 1 | |
| 4.6 | | | |
| 4.8 | | 1 | |
| 5.0 | 1 | 2 | |
| 5.2 | | 2 | 1 |
| 5.4 | 2 | 5 | 2 |
| 5.6 | 3 | 3 | 5 |
| 5.8 | 2 | 3 | 2 |
| 6.0 | 3 | 1 | 1 |
| 6.2 | 1 | 1 | 3 |
| 6.4 | 1 | 4 | 2 |
| 6.6 | 2 | 3 | 2 |
| 6.8 | 2 | | 1 |
| 7.0 | 1 | 1 | 1 |
| 7.2 | 2 | 1 | |
| 7.4 | 1 | 1 | |
| 7.6 | 2 | 3 | 1 |
| 7.8 | | | 2 |
| 8.0 | | 2 | |
| 8.2 | 1 | 2 | 1 |
| 8.4 | 1 | 1 | |
| 8.6 | | 1 | |
| 8.8 | 2 | 1 | 1 |
| 9.0 | 1 | 1 | |
| 9.2 | | 1 | 1 |
| 9.4 | | 1 | 1 |
| 9.6 | | | |
| 9.8 | 1 | 1 | |
| 10.0 | | | |
| 11.0 | | 1 | |
| Total | 198.6 | 299.2 | 178.7 |
| Mean number | 6.85 ± 0.23[1] | 6.80 ± 0.23 | 6.62 ± 0.23 |
| Statistics | $t_{I,II}$ = 0.127; df = 71; P = 0.899; | $t_{I,III}$ = 0.684; df = 54; P = 0.497; | $t_{II,III}$ = 0.521; df = 69; P = 0.604; |

[1] ± here and elsewhere standard error of the mean.

**Table 2: Distribution of body heat conductivity (BHC) depending on weight.**

| *BHC (in ºC)* | *61-65 kg (n = 48)* (↑+↓) | *66-70 kg (n = 39)* (↑+↓) | *71 kg and above (n = 13)* (↑+↓) |
|---|---|---|---|
| | *I* | *II* | *III* |
| 4.4 | | 1 | |
| 4.6 | 1 | | |
| 4.8 | 1 | | |
| 5.0 | 3 | | |
| 5.2 | 2 | 1 | |
| 5.4 | 6 | 3 | |
| 5.6 | 4 | 6 | 1 |
| 5.8 | 3 | 3 | 1 |
| 6.0 | 3 | | 2 |
| 6.2 | 1 | 2 | 2 |
| 6.4 | 4 | 2 | 1 |
| 6.6 | 3 | 2 | 2 |
| 6.8 | 1 | 1 | 1 |
| 7.0 | 2 | 1 | |
| 7.2 | 1 | 2 | |
| 7.4 | 1 | 1 | |
| 7.6 | 3 | 2 | 1 |
| 7.8 | 1 | 1 | |
| 8.0 | 1 | 1 | |
| 8.2 | 2 | 1 | 1 |
| 8.4 | 1 | 1 | |
| 8.6 | 1 | | |
| 8.8 | 1 | 2 | 1 |
| 9.0 | 1 | | |
| 9.2 | 2 | | |
| 9.4 | 2 | | |
| 9.6 | | | |
| 9.8 | 1 | 1 | |
| 10.0 | | | |
| 11.0 | | 1 | |
| Total | 316.8 | 268.7 | 86.8 |
| Mean number | 6.60 ± 0.19 | 6.89 ± 0.24 | 6.68 ± 0.27 |
| Statistics | $t_{I,II}$ = 0.920; df = 85; P = 0.360; | $t_{II,III}$ = 0.464; df = 50; P = 0.645; | $t_{I,III}$ = 0.183; df = 59; P = 0.855; |

**Table 3: Distribution of body heat conductivity (BHC) depending on height.**

| *BHC (in ºC)* | *170-174 cm (n = 14)* (↑+↓) | *175-179 cm (n = 67)* (↑+↓) | *180 cm and above (n = 19)* (↑+↓) |
|---|---|---|---|
| | *I* | *II* | *III* |
| 4.4 | 1 | | |
| 4.6 | | | |
| 4.8 | 1 | | |
| 5.0 | | 3 | |
| 5.2 | | 3 | |
| 5.4 | | 7 | 2 |
| 5.6 | 2 | 7 | 2 |
| 5.8 | 1 | 6 | |
| 6.0 | 3 | 1 | 1 |
| 6.2 | | 4 | 1 |
| 6.4 | 1 | 3 | 3 |
| 6.6 | 2 | 3 | 2 |
| 6.8 | | 1 | 2 |
| 7.0 | 1 | 2 | |
| 7.2 | | 3 | |
| 7.4 | | 2 | |
| 7.6 | | 5 | 1 |
| 7.8 | | 1 | 1 |
| 8.0 | | 2 | |
| 8.2 | 1 | 3 | |
| 8.4 | | 1 | 1 |
| 8.6 | 1 | | |
| 8.8 | 1 | 3 | |
| 9.0 | | 2 | |
| 9.2 | | 2 | |
| 9.4 | | 1 | 1 |
| 9.6 | | | |
| 9.8 | | 1 | 1 |
| 10.0 | | | |
| 11.0 | | 1 | |
| Total | 91.6 | 451.0 | 123.2 |
| Mean number | 6.54 ± 0.33 | 6.73 ± 0.16 | 6.48 ± 0.36 |
| Statistics | $t_{I, II} = 0.483$; df = 79; P = 0.631; | $t_{II, III} = 0.914$; df = 84; P = 0.363; | $t_{I, III} = 1.022$; df = 31; P = 0.315; |

Influence of a sex and age on human BHC is studied on ethnic Kyrgyz: schoolboys from a gymnasium, military men and individuals in the age of 40-54 years who take the rehabilitation therapy on the basis of Research Center for Balneology and Rehabilitation (Tables 4 and 5).

Table 4 shows that the used method of estimation of BHC has not revealed differences in sex on the population level. However, the individuals representing different age groups in population significantly differ in heat conductivity of their bodies; its level steadily changed decreasing with age (Table 5).

Data presented in the Table 6 testify the influence of the racial-ethnic factor on BHC obtained on the sample of students from India, China and Kyrgyzstan.

As follows from the statistical analysis of the given table, this method of BHC estimation has not revealed possible influence of the racial-ethnic factor on this physical characteristic of a human body.

## DISCUSSION

### Substantiation of the Chosen Approach of an Estimation of Heat Conductivity of a Human Body

From the point of view of physicists, heat conductivity (HC) is a transfer of energy from more heated sites of a body to less heated ones as a result of thermal movement and interaction of micro particles. HC leads to equalization of body temperature. As is known, the heat conductivity caused by transfer of energy is one of the three phenomena of transfer existing in the Nature. All substances possess with HC: gases, liquids and solid bodies. The convection is impossible in solid bodies unlike gases and liquids, therefore transfer of heat is carried out only by heat conductivity.

Virtually, there is nothing new in the idea that the body of the human should possess some heat conductivity. Nevertheless, it (heat conductivity) has not drawn the attention of nor physicists, neither physiologists for the present as the important physical characteristic of a human body. Apparently, it is connected with known physical heterogeneity (in sense, density) of a human body. Besides, direct heat transfer (conduction) has rather small value at redistribution of heat in an organism since the majority of tissues badly conduct heat. Probably that's why, we did not manage to find in the literature not only a special method, but even any attempt to estimate body heat conductivity (BHC) of alive organisms in vivo (Ibraimov and Tabaldiev 2007). On the other hand, basic elements of organ-based physiological thermoregulation are well-known and now scientists' efforts are directed for research of their complex interactions on cellular and molecular levels (reviewed in: Romanovsky 2007).

In thermo physics, measurement of heat conductivity of solid bodies (f.e. metal) is carried out by definition of heat conductivity coefficient by a calorimetric method. Transfer of heat occurs through a metal rod, the ends of which are placed in a calorimeter with the water taken at temperatures $T_1$ and $T_2$ ($T_1 > T_2$). It is necessary

**Table 4: Distribution of body heat conductivity (BHC) depending on sex.**

| *BHC (in °C)* | *Boys (n = 38) (↓+↑)m* | *Girls (n = 30) (↓+↑)* | *Men (n = 28) (↓+↑)* | *Women (n = 30) (↓+↑)* |
|---|---|---|---|---|
| | *I* | *II* | *III* | *IV* |
| 5.0 | | | 2 | |
| 5.2 | | | | |
| 5.4 | | | | |
| 5.6 | | | 5 | 2 |
| 5.8 | | | 7 | 5 |
| 6.0 | | | 8 | 8 |
| 6.2 | | | 7 | 6 |
| 6.4 | | 2 | | 7 |
| 6.6 | | | | |
| 6.8 | | | | |
| 7.0 | | | | |
| 7.2 | | | 1 | |
| 7.4 | | | | |
| 7.6 | 1 | 4 | | |
| 7.8 | 3 | 6 | | |
| 8.0 | 22 | 6 | | |
| 8.2 | 11 | 5 | | |
| 8.4 | | 2 | | |
| 8.6 | 1 | 1 | | |
| 8.8 | 1 | | | |
| 9.0 | 1 | | | |
| 9.4 | 1 | | | |
| 10.0 | | | | |
| 11.0 | 1 | | | |
| Total | 305.8 | 242.6 | 167.2 | 180.2 |
| Mean number | 8.05 ±0.03 | 8.09 ± 0.15 | 5.97 ± 0.06 | 6.00 ± 0.07 |
| Statistics | $t_{I,II}$ = 0.290; df = 66; P = 0.772 | | $t_{III,IV}$ = 0.436; df = 56; P = 0.664 | |

estimation of human BHC, where decrease (↓) to define quantity of heat and time transferred through experiment to measure the heat-conductivity coefficient of the given metal rod. It is obvious that direct transfer of a method of measurement of the heat conductivity, applied in thermo physics is unacceptable to a human body both for technical and ethical reasons. However we have tried to approximate to the decision of this problem indirectly, by an estimation of part of a human body. For this purpose, we had to modify the standard technique of physicists so that it was acceptable to the human.

Why we have chosen such approach? As is known inorganic and organic bodies have different mechanisms of equalization of temperature (*T*): in the first case it is carried out through HC, in the second, besides HC, liquids circulating on all body (blood, a lymph, saps) participate. It is obvious that wide variability of BHC, found out by us, in a population cannot be connected with *T* of blood, because its *T* is under the strict control of the central (hypothalamus) organ based system of physiological thermoregulation. Therefore, in our opinion it was highly probable that the possible reason of differences of individuals in heat conductivity of their bodies in a population could be any other physical factor. Under the latter (the physical factor), we meant human body heat conductivity (Ibraimov and Tabaldiev 2007). However the problem lies in an objective estimation of human body heat conductivity. As the direct transfer of the method generally accepted in thermo physics turned out unacceptable, we had to adapt it for human body, maintaining its main principle (a temperature gradient).

Earlier we used 'hot' and 'cold' water with constant temperature (40ºC and 15ºC, respectively) for the estimation of quantity of transferred thermal energy from human body to another body and vice versa. Results of the first researches have shown that individuals in population essentially differ from each other in

how their hands cool and heat 'hot' and 'cold' water (Ibraimov and Tabaldiev 2007).

However, we had to change T of 'cold' water with the lapse of time. The matter is that some individuals complained about unpleasant sensations when *T* of "cold" water was 15ºC. Besides, the temperature modes of 'cold' and 'hot' water chosen by us earlier (15ºC and 40ºC, respectively) created different physical conditions (temperature drop) for transfer of thermal energy between two bodies.

As is known, people differ from each other in temperature of a palm. In the Tables 10 - 12, data are presented on distribution of temperature (in ºC) of the left palm of hand of the groups surveyed by us. So, at *T* of palms on the average ~31ºC, in case of "cold" water the difference of *T* between two bodies made ~16ºC, and in case of 'hot' water only ~9ºC. But the problem consists in how many degrees is it possible to increase or decrease *T* of 'hot' and 'cold' water, maintaining as much as possible great difference in *T* between a hand and water?

Searching the way out we decided to carry out a special study on the guardsmen as homogeneous group in physical, sexual, age and ethnic relations. Our empirical experience has shown that acceptable value is ~9ºC allowable for raising the *T* of 'hot' water relative to the *T* of palms. Certainly, no fundamental physical

**Table 5: Distribution of body heat conductivity (BHC) depending on age.**

| *BHC (in ºC)* | *School children (n = 68)* (↓+↑) | *Guardsmen (n = 100)* (↓+↑) | *40-54 years (n = 58)* (↓+↑) |
|---|---|---|---|
| | *I* | *II* | *III* |
| 4.4 | | 1 | |
| 4.6 | | | |
| 4.8 | | 1 | |
| 5.0 | | 3 | 2 |
| 5.2 | | 3 | |
| 5.4 | | 9 | |
| 5.6 | | 11 | 7 |
| 5.8 | | 7 | 12 |
| 6.0 | | 5 | 16 |
| 6.2 | | 5 | 13 |
| 6.4 | 2 | 7 | 7 |
| 6.6 | | 7 | |
| 6.8 | | 3 | |
| 7.0 | | 3 | |
| 7.2 | | 3 | 1 |
| 7.4 | | 2 | |
| 7.6 | | 5 | 6 |
| 7.8 | 9 | 2 | |
| 8.0 | 28 | 2 | |
| 8.2 | 16 | 4 | |
| 8.4 | 2 | 2 | |
| 8.6 | 2 | 1 | |
| 8.8 | 1 | 4 | |
| 9.0 | 1 | 2 | |
| 9.2 | 2 | | |
| 9.4 | 1 | 2 | |
| 9.6 | | | |
| 9.8 | | 2 | |
| 11.0 | 1 | 1 | |
| Total | 584.4 | 676.8 | 347.4 |
| Mean number | 8.06 ± 0.07 | 6.77 ± 0.14 | 5.99 ± 0.04 |
| Statistics | $t_{I, II}$ = 7.391; | df = 166; | P = <0.001; |
| | $t_{II, III}$ = 24.903; | df = 124; | P = <0.001; |
| | $t_{I, III}$ = 4.237; | df = 156; | P = <0.001; |

**Table 6: Distribution of body heat conductivity (BHC) depending on their racial-ethnic origin.**

| *BHC (in ºC)* | *Indians (n = 30)* (↓+↑) | *Chinese (n = 37)* (↓+↑) | *Kyrgyz (n = 30)* (↓+↑) |
|---|---|---|---|
| | *I* | *II* | *III* |
| 2.6 | 1 | 1 | 1 |
| 2.8 | | | 1 |
| 3.0 | 2 | 1 | |
| 3.2 | 1 | | |
| 3.4 | 1 | | |
| 3.6 | 1 | 1 | |
| 3.8 | 1 | 1 | |
| 4.0 | 1 | 1 | 1 |
| 4.2 | 3 | | |
| 4.4 | 2 | 1 | |
| 4.6 | 1 | 4 | 1 |
| 4.8 | 1 | 1 | 3 |
| 5.0 | 2 | 5 | 1 |
| 5.2 | | 2 | 4 |
| 5.4 | 1 | 1 | |
| 5.6 | | 3 | 2 |
| 5.8 | | | 2 |
| 6.0 | 2 | | |
| 6.2 | 3 | 2 | |
| 6.4 | 3 | 1 | 1 |
| 6.6 | | 2 | 1 |
| 6.8 | 1 | 3 | 2 |
| 7.0 | | 2 | 3 |
| 7.2 | | 2 | |
| 7.4 | | 1 | 1 |
| 7.6 | | 1 | 1 |
| 7.8 | 1 | | |
| 8.0 | 2 | 2 | 2 |
| 8.2 | 1 | | |
| 8.4 | | | |
| 8.6 | | 1 | |
| 8.8 | | | |
| 9.0 | | | |
| 9.2 | | | |
| 9.4 | | | |
| 9.6 | | 1 | |
| 9.8 | | | |
| 10.0 | 1 | | |
| Total | 166.4 | 219.0 | 168.6 |
| Mean number | 5.56 ± 0.34 | 5.92 ± 0.23 | 5.62 ± 0.25 |
| Statistics | $t_{I, II}$ = 0.937; | df = 65; | P = 0.352; |
| | $t_{II, III}$ = 0.871; | df = 65; | P = 0.387; |
| | $t_{I, III}$ = 0.173; | df = 58; | P = 0.863; |

constant of a human body is at the back of this number. But, it is also undesirable to increase the *T* of 'hot' water more than 9ºC. In that case, we could face with denaturation of proteins in cells of individuals whose *T* of palms are close to that of armpit. As regards the *T* of 'cold' water, we could not find the optimal mode (see below).

So, the data presented in the Table 7 show the importance of considering the role of *T* of a palm at the preparation of 'hot' and 'cold' water at the and increase (↑) of water temperature as well as their sums (↑+↓) are shown at the repeated research of the same military men from the National Guards.

As the table shows, when the *T* of 'hot' and 'cold' water remained permanent (40ºC and 15ºC, respectively) for all individuals, the scope of variability of BHC distribution has appeared considerably narrow. When the *T* of 'hot' and 'cold' water was corrected (±9ºC) depending on the *T* of palms, the same individuals have shown wider scope of variability.

However, there is significant difference in mean number of BHC depending on that, the *T* of what water - 'hot' or 'cold' - were corrected. In the first case, temperature of water was poorly cooled on the average (3.05 ± 0.04) when it was not corrected depending on the *T* of palms. However, when the *T* of 'hot' water was corrected depending on the *T* of palm of the surveyed individuals the average value of BHC had raised (3.41± 0.10, differences are statistically significant). The change of *T* of 'cold' water shows the contrary. When the *T* of 'cold' water made 15ºC for all surveyed individuals the mean number of BHC appeared significantly higher, than at its permanent correction of the *T* (3.89 ± 0.06 and 3.32 ± 0.11, respectively).

As it was found out, this circumstance has great importance at comparative estimations of BHC of individuals at the population level. So, for example, it has been shown above that there have been no significant differences (see Table 7) in the comparison of three ethnic groups when the *T* of 'cold' and 'hot' water were constantly corrected and their values were summarized. However, when the same individuals were analyzed depending on how they decreased and increased the *T* of water it has appeared that they significantly differ in their abilities to decrease the *T* only of 'hot' (Table 8), but not 'cold' water (Table 9).

What conclusion can be made on the basis of these observations? It seems that necessity in constant correction of *T* of water depending on *T* palm is proved only for "hot" water since at that the maximum allowable level of temperature drop for human body is developed. As regards the *T* of "cold" water the question of its constant correction of *T* of a palm still remains undetermined. The fact of the matter is even the lowest *T* for "cold" water was not lower than T of room (19ºC at *T* of palm 27ºC) where BHC was estimated under our experimental conditions. Probably for this reason the "cold" water was heated poorly when its *T* was corrected depending on size of *T* of a palm (see Table 8), as in this situation the transfer of thermal energy between hand and "cold" water is complicated due to low level of temperature drop. Thus, we came to the conclusion that it is possible to be limited by measuring decrease of *T* only for "hot" water to estimate BHC by the above mentioned method (see Table 8 and 9).

However, it turned out that the *T* of a palm can take quite informative effect on BHC itself and in particular when it is considered in the close connection with *T* of armpit, even without measuring the changes of T of "hot" and "cold" water. Below is presented data on distribution of *T* of a palm in the groups from different sex-age and racial-ethnic groups (Table 9 - 12).

As the Table 10 shows, the average *T* of human palm decreases significantly with age on the population level. However, Table 11 shows rather discrepant results concerning the differences between two sexes. The data presented in Table 12 testify the possibility of influence of racial-ethnic factor on this indication. Thus, the average of Kyrgyz's *T* of a palm turned out significantly lower than Chinese's and Indian's one. At that the two last groups did not differ from each other despite the fact that they present different racial-ethnic groups (see below).

Comparisons of the same groups regarding the *T* differences between palm and armpit have provided very important data that promote the understanding of the nature of widen variability of BHC in the human population (Table 13 - 15).

Actually, such method of comparison shows existence of statistically significant differences between various sex-age and racial-ethnic groups. Unfortunately, there were no females among the Indian students surveyed by us.

The data gave us the ground to suppose that probably the individuals with great difference

**Table 7: The change of temperature (in ºC) of 'hot' and 'cold' water without taking into account and in view of temperature of palm.**

| *Change of temperature of water (in* ºC) | *40°C (n = 100) (↓)* | *15°C (n = 100) (↑)* | *40º 15ºC (n = 100) (↓+↑)* | *+9ºC (n = 100) (↓)* | *–9°C (n = 100) (↑)* | *(±9°C) (n = 100) (↓+↑)* |
|---|---|---|---|---|---|---|
| | *I* | *II* | *III* | *IV* | *V* | *VI* |
| 1.2 | | | | | 2 | 1 |
| 1.4 | | | | 1 | 1 | |
| 1.6 | | | | 1 | | |
| 1.8 | | | | 2 | | |
| 2.0 | | | | 4 | 6 | |
| 2.2 | 10 | | | 3 | 14 | |
| 2.4 | 6 | | | 5 | 10 | |
| 2.6 | 5 | 1 | | 5 | 6 | |
| 2.8 | 12 | 2 | | 8 | 4 | |
| 3.0 | 14 | 4 | | 8 | 6 | |
| 3.2 | 22 | 8 | | 8 | 10 | |
| 3.4 | 15 | 7 | | 5 | 4 | |
| 3.6 | 12 | 16 | | 7 | 6 | |
| 3.8 | 3 | 18 | | 8 | 1 | |
| 4.0 | 1 | 10 | | 9 | 3 | |
| 4.2 | | 15 | | 9 | 6 | |
| 4.4 | 6 | 5 | | 3 | 1 | |
| 4.6 | | 3 | | 2 | 2 | |
| 4.8 | | 4 | | | 3 | 1 |
| 5.0 | | 3 | | 2 | 6 | 3 |
| 5.2 | | 1 | | 3 | 6 | 3 |
| 5.4 | | 2 | | | | 9 |
| 5.6 | | | | | 2 | 11 |
| 5.8 | | 5 | | 3 | | 7 |
| 6.0 | | 5 | | | | 5 |
| 6.2 | | 5 | | | | 5 |
| 6.4 | | 5 | | | | 7 |
| 6.6 | | 14 | | | | 7 |
| 6.8 | | 16 | | | | 3 |
| 7.0 | | 13 | | | | 3 |
| 7.2 | | 14 | | | | 3 |
| 7.4 | | 8 | | | | 2 |
| 7.6 | | 8 | | | | 6 |
| 7.8 | | 3 | | | | 2 |
| 8.0 | | | | | | 2 |
| 8.2 | | 1 | | | | 4 |
| 8.4 | | 1 | | | | 2 |
| 8.6 | | 2 | | | | 1 |
| 8.8 | | | | | | 4 |
| 9.0 | | | | | | 2 |
| 9.2 | | | | | | 2 |
| 9.4 | | | | | | 2 |
| 9.6 | | | | | | |
| 9.8 | | | | | | 2 |
| 10.0 | | | | | | |
| 11.0 | | | | | | 1 |
| Total | 305.0 | 389.0 | 692.2 | 341.2 | 331.6 | 676.8 |
| Mean number | 3.05±0.04; | 3.89±0.06; | 6.92±0.06 | 3.41±0.10; | 3.32±0.11; | 6.77±0.14; |
| Statistics | $t_{I, II}$ = 11.566; df = 198; P = <0.001; | | $t_{IV, V}$ = 0.650; df = 198; P = 0.516; | | $t_{III, VI}$ = 1.043; df = 198; P = 0.298; | |
| | | $t_{I, IV}$ = 2.250; df = 198; P = 0.026; | | $t_{II, V}$ = 4.658; df = 198; P = <0.001; | | |

**Table 8: Distribution of body heat conductivity (BHC) of individuals from different racial groups at decreasing the temperature (in ºC) of 'hot' water.**

| *BHC (in ºC)* | *Indians (n = 30) (↓)* | *Chinese (n = 30) (↓)* | *Kyrgyz (n = 30) (↓)* |
|---|---|---|---|
| | *I* | *II* | *III* |
| 1.2 | | | 2 |
| 1.4 | | | |
| 1.6 | 2 | | |
| 1.8 | 1 | | |
| 2.0 | 1 | | 3 |
| 2.2 | 1 | | |
| 2.4 | 1 | 1 | 1 |
| 2.6 | 1 | | 1 |
| 2.8 | 1 | 1 | 2 |
| 3.0 | 4 | 1 | 6 |
| 3.2 | 3 | 5 | 3 |
| 3.4 | 1 | 2 | 1 |
| 3.6 | 2 | 2 | 1 |
| 3.8 | 3 | 3 | 3 |
| 4.0 | 2 | 5 | 3 |
| 4.2 | 4 | 4 | |
| 4.4 | 1 | 2 | 1 |
| 4.6 | | 2 | |
| 4.8 | | | 3 |
| 5.0 | 2 | 1 | |
| 5.2 | | 1 | |
| Total | 99.8 | 114.6 | 95.8 |
| Mean number | 3.32 ± 0.17 | 3.82 ± 0.12 | 3.19 ± 0.17 |
| Statistics | $t_{I, II}$ = 2.391; df = 58; P = 0.020; | $t_{II, III}$ = 2.990; df = 58; P = 0.004; | $t_{I, III}$ = 0.550; df =58; P = 0.585; |

**Table 9: Distribution of body heat conductivity (BHC) of individuals from different racial-ethnic group at increasing the temperature (in ºC) of 'cold' water.**

| *BHC (in ºC)* | *Indians (n = 30) (↑)* | *Chinese (n = 30) (↑)* | *Kyrgyz (n = 30) (↑)* |
|---|---|---|---|
| | *I* | *II* | *III* |
| 0.8 | 1 | | |
| 1.0 | 5 | 2 | |
| 1.2 | 2 | 4 | |
| 1.4 | 3 | | |
| 1.6 | 1 | 1 | |
| 1.8 | 2 | | |
| 2.0 | 4 | 3 | |
| 2.2 | 5 | 2 | 5 |
| 2.4 | 1 | 4 | 3 |
| 2.6 | 1 | 4 | 2 |
| 2.8 | 1 | 3 | 3 |
| 3.0 | 2 | 5 | |
| 3.2 | 3 | 1 | |
| 3.4 | 1 | 1 | 1 |
| 3.6 | 1 | 1 | 1 |
| 3.8 | 2 | 2 | |
| 4.0 | 1 | 4 | |
| 4.2 | 1 | | |
| Total | 63.0 | 79.4 | 75.2 |
| Mean number | 2.10 ± 0.20 | 2.65 ± 0.12 | 2.51 ± 0.18 |
| Statistics | $t_{I, II}$ = 1.651; df = 58; P = 0.104; | $t_{II, III}$ = 0.140; df = 58; P = 0.510; | $t_{I, III}$ = 0.901; df =58; P = 0.371; |

of T between palm and armpit cool worse "hot" water but heat better "cold" water and vice versa.

In order to check the assumption, we surveyed the group of military servants once again. For this purpose, the guardsmen were divided into three groups for convenience: 1st group was composed of soldiers with *T* of a palm less than 29ºC as the group presumably with low BHC; 2nd group was composed of individuals with *T* of a palm from 30 - 32ºC as the group with average BHC and 3rd group was composed of guardsmen with T of a palm higher than 33ºC as the group of individuals with high BHC. If our suggestion is true, then the 1st group of individuals is to cool worse "hot" water but to heat better "cold" water and 3rd group, on the contrary, is to cool better "hot" water but to heat worse "cold" water (Table 16).

Indeed, as the table shows, the individuals with low temperature of palm cool worse "hot" water and heat better "cold" one and vice versa. Though it should have been the contrary; the cooler is body the better it cools hot water and vice versa. The fact can be explained reasonably by only recognizing the close connection of *T* difference between two parts of body and human BHC. In other words, a hand of individuals with *T* of a palm less than 29ºC having initially low heat conductivity of cells better maintains the heat in a tissue and gets cold slower under the effect of "cold" water and vice versa that fully meets the factual data (Table 16).

Finally, the data presented in the Table 17 testify the possibility of existence of connection between T difference between two parts of body and human BHC. Distributions of individual's BHC were compared here depending on difference of *T* between palm and armpit (there were divided into four groups with interval in 3ºC for the convenience of analysis of numerical data).

As the table shows, the less is *T* difference between palm and armpit the higher is human BHC and vice versa. Here is given the estimations of individuals' BHC depending on their ability to decrease *T* only for "hot" water taking into account the experiment presented in the Table 16.

Thus, our experiment has shown that it should

**Table 10: Distribution of temperature (in ºC) of palms depending on age (Kyrgyz males).**

| *Temperature of palms (in ºC)* | *School children (12-16 лет) (n = 38)* | *Guardsmen (18-22 года) (n = 100)* | *40 - 54 years (n = 30)* |
|---|---|---|---|
| | *I* | *II* | *III* |
| 27 | 1 | 3 | 8 |
| 28 | | 2 | 9 |
| 29 | 2 | 7 | 8 |
| 30 | 8 | 25 | 4 |
| 31 | 7 | 9 | 1 |
| 32 | 7 | 25 | |
| 33 | 9 | 20 | |
| 34 | 5 | 8 | |
| 35 | | 1 | |
| Total | 1206 | 3136 | 851 |
| Mean number | 31.74±0.24; | 31.36±0.17 | 28.37±0.21 |
| Statistics | $t_{I, II}$ = 1.179; | df = 136; | P = 0.240; |
| | $t_{I, III}$ = 10.219; | df = 66; | P = <0.001; |
| | $t_{□□, □□□}$ = 8.875; | df = 128; | P = <0.001; |

be measured *T* of human palm and "hand volume" for preparation of "hot" water with required *T* and required quantity in order to estimate the human BHC. It is necessary to measure decrease of *T* of "hot" water in ºC for preparation of some quantitative estimation and awareness of *T* difference between palm and armpit for qualitative evaluation of BHC of this individual. As regards "cold" water, the issue has remained undetermined due to the complexity of its *T* correction.

Thereby, as a whole our results show that on the population level: a) on the average BHC of males is higher than that of females; b) individuals differ in BHC from different age groups, on the average human BHC level is steadily changed decreasing with age; c) natives of low altitude regions of southern latitude differ on the average by higher BHC than population of high mountains and northern latitude.

It is interesting that these results meet the data obtained during investigation of quantitative variability of chromosomal Q-HRs in human population, namely: a) as a rule, amount of chromosomal Q-HRs in male karyotype is higher than in female one on the population level (Paris Conference 1971; Suppl. 1975); b) amount of chromosomal Q-HRs is practically equal in the genome of Indian and Chinese population but reliably more than Kyrgyz's one (Ibraimov and Mirrakhimov 1982a), and c) amount of chromosomal Q-HRs in various age groups is different, the largest amount of Q-heterochromatic material is in the genome of newborns, and the less quantity is in the genome of old men (Buckton et al. 1976; Ibraimov and Karagulova 2006a).

Generally speaking, we wish to state that: a) the less is *T* difference between palm and armpit, the higher is BHC of the individual and vice versa (r = -0.883); b) individuals equalize better and faster the *T* difference between different

**Table 11: Distribution of temperature (in ºC) of palms depending on sex.**

| *Temperature of palms (in ºC)* | *Kyrgyz* | | *Indians* | | *Chinese* | |
|---|---|---|---|---|---|---|
| | ♂ *(n =38)* | ♀ *(n = 30)* | ♂ *(n = 30)* | ♀ *(n = 30)* | ♂ *(n = 30)* | ♀ *(n = 14)* |
| | *I* | *II* | *III* | *IV* | *V* | *VI* |
| 26 | | | 1 | | | 1 |
| 27 | | | 6 | 4 | | |
| 28 | | | 10 | 5 | | 1 |
| 29 | 2 | | 9 | 8 | | |
| 30 | 8 | 8 | 3 | 5 | | |
| 31 | 7 | 2 | 1 | 3 | | 3 |
| 32 | 7 | 10 | | 5 | 1 | 1 |
| 33 | 9 | 3 | | 7 | 5 | |
| 34 | 5 | 7 | | | 17 | 3 |
| 35 | | | | | 5 | |
| Total | 1206 | 959 | 850 | 883 | 1016 | 446 |
| Mean number | 31.74±0.24; | 31.97±0.27; | 28.33±0.20; | 29.43±0.30; | 33.9±0.13; | 31.85±0.63 |
| Statistics | $t_{I, II}$ = 0.628; df = 66; p = 0.532; | | $t_{III, IV}$ = 3.038; df = 58; P = 0.004; | | $t_{V, VI}$ = 4.309; df = 42; P = <0.001; | |

**Table 12: Distribution of temperature (in ºC) of palms depending on their racial-ethnic origin (male students from China, India and Kyrgyzstan).**

| *Temperature of palms (in ºC)* | *Chinese (n = 30)* | *Indians (n = 30)* | *Kyrgyz (n = 30)* |
|---|---|---|---|
| | *I* | *II* | *III* |
| 22 | | | 1 |
| 23 | | | |
| 24 | | | |
| 25 | | | 3 |
| 26 | | | |
| 27 | | | 1 |
| 28 | | | 1 |
| 29 | | | |
| 30 | | 1 | 7 |
| 31 | | 2 | |
| 32 | 1 | 3 | 1 |
| 33 | 7 | 3 | 6 |
| 34 | 17 | 12 | 7 |
| 35 | 5 | 8 | 3 |
| 36 | | 1 | |
| Total | 1016 | 1011 | 935 |
| Mean number | 33.9 ± 0.130; | 33.7 ± 0.25; | 31.2 ± 0.63; |
| Statistics | $t_{I, II}$ = 0.116; | df = 58; | P = 0.908; |
| | $t_{I, III}$ = 3.908; | df = 58; | P = <0.001; |
| | $t_{II, III}$ = 3.670; | df = 58; | P = <0.001; |

**Table 13: Distribution of temperature defference (in ºC) between palms and armpit depending on their racial-ethnic origin (male students from China, India and Kyrgyzstan).**

| *Difference of temperature (in ºC)* | *Chinese (n = 30)* | *Indians (n = 30)* | *Kyrgyz (n = 30)* |
|---|---|---|---|
| | *I* | *II* | *III* |
| 0 | | | 1 |
| 1 | 4 | 12 | 4 |
| 2 | 17 | 8 | 5 |
| 3 | 8 | 5 | 5 |
| 4 | 1 | 2 | 1 |
| 5 | | 2 | 1 |
| 6 | | 1 | 7 |
| 7 | | | |
| 8 | | | 1 |
| 9 | | | |
| 10 | | | 1 |
| 11 | | | 2 |
| 12 | | | 1 |
| 13 | | | 1 |
| Total | 66 | 67 | 145 |
| Mean number | 2.20 ± 0.130 | 2.23 ± 0.26 | 4.83 ± 0.66 |
| Statistics | $t_{I, II}$ = 0.116; | df = 58; | P = 0.908; |
| | $t_{I, III}$ = 3.908; | df = 58; | P = <0.001; |
| | $t_{II, III}$ = 3.666; | df = 58; | P = <0.001; |

parts of body with high BHC and vice versa. If this is true then it would have found a simple explanation, for example, for the known resistance of South natives to high temperature of environment. Namely, they effectively equalize *T* difference in different parts of bodies and faster take out surplus heat in the environment due to high HC of their bodies. At that rate, aboriginals of the Far North or high altitudes could better and longer maintain the metabolic heat in the body due to low HC of their bodies with all ensuing consequences. The same way it might have been explained why do males endure better the heat load than females and the latter are more stable to cold than males.

**Table 14: Distribution of temperature difference (in ºC) between palms and armpit depending on age.**

| *Difference of temperature (in ºC)* | *Kyrgyz* | | |
|---|---|---|---|
| | *School children (n = 68)0* | *Guardsmen (n = 100)* | *40-54 years (n = 58)* |
| | *I* | *II* | *III* |
| 1 | | 1 | |
| 2 | 11 | 9 | |
| 3 | 13 | 20 | |
| 4 | 17 | 24 | 5 |
| 5 | 10 | 9 | 4 |
| 6 | 15 | 25 | 8 |
| 7 | 2 | 7 | 17 |
| 8 | 2 | 13 | |
| 9 | 10 | | |
| 10 | 2 | 1 | |
| 11 | | 1 | |
| Total | 283 | 466 | 411 |
| Mean number | 4.16±0.19 | 4.66±0.19 | 7.09±0.20 |
| Statistics | tI,II=2.021; df=161; P=0.045; | tII,III=8.406; df=156; P=<0.001; | tI,III=10.912; df=119; P=<0.001; |

## Cell Thermoregulation and Condensed Chromatin

Based on our original investigations of chromosomal heterochromatin region variability in human populations, as well as on the analysis of existing literary data on the condensed chromatin (CC), structure of interphase nucleus and redundant DNA in the genome of higher eukaryotes, an attempt is made to justify the view of possible participation of CC in cell thermoregulation (Ibraimov 2003). CC, being the densest domains in a cell, apparently conductsheat between the cytoplasm and nucleus when there is a difference in temperature between them. The assumed heat conductivity effect of CC is stipulated by its principal features: a condensed state during the interphase,

association with the lamina and the inner nuclear membrane, replication at the end of the S period of a cell cycle, formation of the chromocenter, genetic inertness, and wide variability in the quantitative contents both within and between species (Ibraimov 2003, 2004).

Chromosomal HRs is localized in the interphase nucleus along the periphery of nucleus and is in close association with nucleus membrane (Fig. 1). The fact that CC strands are fastened to the nuclear membrane in the interphase has been shown both on the sections and preparations of spread interphase nuclei using the electronic microscopy (DuPraw 1965; Comings and Okada 1970; Lampert 1971). The layer is often so dense that it can itself form the quite rigid structure able to maintain spatial organization of nucleus (Comings and Okada 1970). Chromosomal HRs is a basis of periphery layer of CC chromatin in cells (Lampert 1971; Bostock and Sumner 1978; Prokofyeva-Belgovskaya 1986).

It has been determined that sometimes individuals in population differ from each other in amount of C-HRs in autosomes 1, 9 and 16 as well as in Y chromosome. However, differences have not been discovered regarding content of chromosomal C-HRs in genome under comparison of different human populations (Erdtmann 1982; Ibraimov and Mirrakhimov 1982 a). In contrast to C-HRs, human chromosomal Q-HRs shows the great quantitative interindividual and interpopulation variability (Gereadts and Pearson 1974; Müller et al. 1975; McKenzie and Lubs 1975; Buckton et al. 1976; Lubs et al. 1977; Yamada and Hasegawa 1978; Al-Nassar et al. 1981; Ibraimov and Mirrakhomov 1982 b,c,d; 1985; Ibraimov et al. 1982, 1986, 1990, 1991, 1997; Stanyon et al. 1988; Kalz et al. 2005; Dècsey et al. 2006; Bhasin 2007).

We suppose that amount of chromosomal Q-HRs in genome can influence on the density of compactization peripheral layer of CC by the following reasons: a) these specific chromosomal segments consist of short, highly repetitive DNA sequences containing mainly A-T pairs; b) the notable feature of DNA, which mainly consists of short DNA sequences, is that they promote a dense compactization of CC (Bostock and Sumner 1978; Lima-de-Faria 1983; Prokofyeva-Belgovskaya 1986).

Certainly, the dense layer of peripheral CC cannot participate directly in metabolic heat production. This is not allowed by its molecular nature composed from highly repetitive DNA sequences which are not able to code

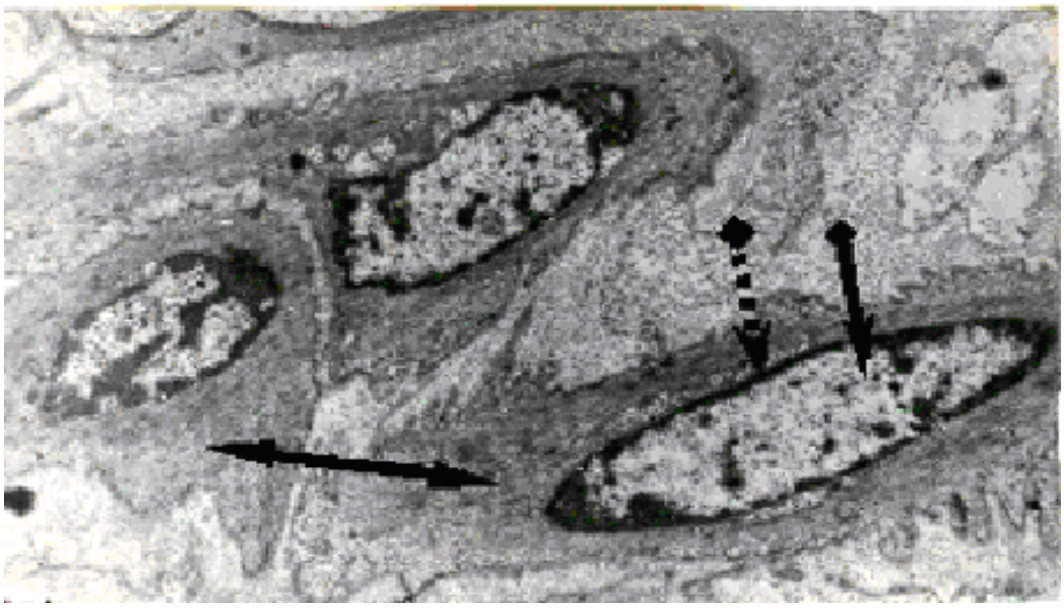

**Fig. 1. Electron micrograph of smooth muscle cells of a bull (x 8 000). In nuclei can be seen condensed (heterochromatin) and decondensed chromatin (euchromatin). ◆– – –→ peripheric layer of condensed chromatin; ⊖⟶ euchromatin; ⟷ cytoplasm**

**Table 15: Distribution of temperature difference (in ºC) between palms and armpit depending on sex.**

| *Difference of temperature (in ºC)* | *Chinese* | | *Kyrgyz* | |
|---|---|---|---|---|
| | ♂ *(n = 30)* | ♀ *(n =14)* | ♂ *(n = 30 )* | ♀ *(n = 30 )* |
| | *I* | *II* | *III* | *IV* |
| 1 | 4 | 1 | 4 | 1 |
| 2 | 17 | 1 | 1 | |
| 3 | 8 | 6 | 14 | 6 |
| 4 | 1 | 1 | 5 | 8 |
| 5 | | 4 | 3 | 8 |
| 6 | | | 2 | 4 |
| 7 | | | 1 | 2 |
| 8 | | 1 | | 2 |
| 9 | | | | |
| 10 | | 1 | | |
| Total | 66 | 62 | 102 | 144 |
| Mean number | 2.20 ± 0.130 | 4.42 ± 0.59 | 3.40 ± 0.27; | 4.80 ± 0.26 |
| Statistic | $t_{I, II}$ = 5.045; | df = 42; P = <0.001; | $t_{III, IV}$ = 3.708; | df = 58; P = <0.001; |

**Table 16: The change of temperature (in ºC) of 'hot' and 'cold' water depending on palm's temperature.[1]**

| *Change of temperature of water (in ºC)* | *Temperature of palm (in ºC)* | | | | | |
|---|---|---|---|---|---|---|
| | *to 29°C (n = 13)* | | *30°C - 32°C (n = 57)* | | *33°C and above (n = 30)* | |
| | *(↓)* | *(↑)* | *(↓)* | *(↑)* | *(↓)* | *(↑)* |
| | *I* | *II* | *III* | *IV* | *V* | *VI* |
| 1.2 | 2 | | | | | |
| 1.4 | | 1 | | | | 1 |
| 1.6 | 1 | | | | | |
| 1.8 | | 2 | | | 1 | |
| 2.0 | 4 | | | 2 | | 5 |
| 2.2 | 1 | 1 | 2 | 9 | | 5 |
| 2.4 | 1 | | 4 | 6 | | 3 |
| 2.6 | | | 5 | 5 | | 3 |
| 2.8 | | | 8 | 3 | | 3 |
| 3.0 | 1 | | 7 | 3 | | 2 |
| 3.2 | | 1 | 2 | 6 | 3 | |
| 3.4 | | | 1 | 1 | 3 | 1 |
| 3.6 | 1 | 2 | 4 | 3 | | |
| 3.8 | 1 | | 6 | 1 | 1 | |
| 4.0 | | 2 | 5 | 1 | 5 | |
| 4.2 | | 1 | 6 | 2 | 4 | |
| 4.4 | 1 | 1 | 1 | 1 | 3 | 2 |
| 4.6 | | 1 | | 3 | 2 | |
| 4.8 | | 1 | | 3 | 2 | |
| 5.0 | | 1 | 2 | 4 | 2 | 1 |
| 5.2 | 1 | 1 | 3 | 2 | 3 | |
| 5.4 | | | | | | |
| 5.6 | | 1 | | 1 | | |
| 5.8 | | | | | 3 | |
| Total | 31.4 | 54.2 | 187.2 | 192.0 | 130.2 | 86.4 |
| Mean number | 2.41±0.28 | 4.18±0.25 | 3.28±0.11 | 3.37±0.14 | 4.34±0.14 | 2.88±0.20 |
| Statistics | t I, II = 4.720; df = 24; P = <0.001; | t III, IV = 0.466; df = 112; P = 0.642; | | t V, VI = 5.923; df = 58; P = <0.001; | | |

1 *T* of 'hot' and 'cold' water are corrected in accordance to *T* of palm.

the known in science proteins and enzymes. However, it can influence the speed of heat transfer between nucleus and cytoplasm being the densest structure in the interphase cells and thereby can participate in maintaining the inner cellular thermoregulation (Ibraimov 2003). At that the speed of temperature difference equalization is to depend on the density of CC peripheral layer that is determined by quantitative and qualitative composition of chromosomal HRs in genome of this individual (Ibraimov 2004). We mean this circumstance as cell heat conductivity and in the final analysis as heat conductivity of whole cellular part of human body (Ibraimov and Tabaldiev 2007).

**Why is the Nucleus More Vulnerable to Intracellular Temperature Increase?**

It is known that heat induces a significant increase in proteins bound to the nuclear matrix. Aberrant protein binding to this structure has the potential to disrupt a large number of nucleus functions. Transcription and RNA processing, as well as DNA replication are known to be inhibited by heat shock (Sadis et al. 1998; Wong et al. 1989; Sakkers et al. 1999). Heat shock induces a disruption of the timing and coordination of DNA replication as cells progressed through S. Lepock and Warters (2004) have shown that using differential scanning calorimetry on isolated nuclei and isolated matrix preparations that the nuclear matrix is among the more heat sensitive organelles showing significant endothermic changes as low as 40 ºC.

Hyperthermia effects on proteins include unfolding and exposing hydrophobic groups, and aggregation of unfolded proteins due to the interactions of the exposed hydrophobic groups. Protein aggregation and unfolding will have effects throughout the cell but should have significant impact within the nucleus because of the large number of proteins and the large amount of DNA packed within in. For example, over 2 m of DNA ($5 \times 10^9$ base pairs) and a nucleus (Berezney and Coffey 1974; Pienta et al. 1991; Berezney et al. 1995; Nickerson et al. 1995; Jackson and Cook 1995; Agutter 1995).

The following theoretical considerations to the above mentioned experimental data can be added. If for any reason the temperature in the nucleus begins to exceed that in cytoplasm, there is a need for dissipation of surplus heat outside the nucleus. To do this, the nucleus has two options: increasing its volume or increasing the heat conductivity of the nuclear membrane. The first option is limited for obvious reasons. The second option is the more promising one should the heat conductivity of the nuclear membrane be increased somehow. Since the nuclear envelope consists of double-membrane extension of the rough endoplasmic reticulum, the nuclear membrane cannot essentially change its structure. But it is necessary to remove the surplus heat from the nucleus somehow. Since the proposed idea is based on cell phenomena, from the authors' point of view, nature 'found' a very simple and effective solution: it increased its heat conductivity through compression of the internal layer of the nuclear membrane by CC (Ibraimov 2003, 2004).

**Why Hands?**

Certainly, hand tissues are not that part of the organism which makes it possible to judge unambiguously about the heat conductivity of the whole cell part of a human body. But if CT is really the basis of BHC, then the hand heat conductivity could have served as a certain guideline in this issue. It could be so because amount of chromosomal HRs remains constant in any human body cell irrespective of their degree of differentiation and specialization in the organism. (Prokofyeva-Belgovskaya 1986).

Some physiological data testify the favor of our choice of the part of a body (hand). Aschoff (1958) has recognized that the distal parts of the body may be more important heat loss effectors of the shell. The palmer sides of the hands, plantar sides of the feet, ears, lips, cheeks and nose tip contain artriovenous anastomoses (reviewed in: Van Someren et al. 2002). These shunts between the arteries and the venous plexus are regulated through sympathetic innervation and little responsive to changes in local skin temperature. If opened, they strongly increase the local skin blood flow, and thus ultimately heat transfer from the core to the environment. In human and animal studies, the skin areas where they are present have been recognized as specialized heat exchanging areas, also because these areas have a high surface-to-volume ratio, an absence of fur and a dense network of blood vessels

**Table 17: Distribution of body heat conductivity (BHC) depending on the difference of temperature (in ºC) between palm and armpit.[1]**

| *BHC (in ºC)* | *Distribution of temperature difference (in ºC) between palm and armpit* | | | |
|---|---|---|---|---|
| | *to 2ºC (n = 49)* | *3 - 5ºC (n = 52)* | *6 - 8ºC (n = 49)* | *9ºC and above (n = 30)* |
| | *I* | *II* | *III* | *IV* |
| 1.2 | | | | 3 |
| 1.4 | | | 1 | 2 |
| 1.6 | | 1 | | 2 |
| 1.8 | | 1 | 2 | 1 |
| 2.0 | | | 2 | 7 |
| 2.2 | | 1 | 1 | 5 |
| 2.4 | 2 | 1 | 4 | 3 |
| 2.6 | | 1 | 5 | 2 |
| 2.8 | 2 | 1 | 9 | |
| 3.0 | 5 | 3 | 6 | |
| 3.2 | 4 | 6 | 1 | 1 |
| 3.4 | 1 | 2 | 2 | |
| 3.6 | 2 | 13 | 8 | 2 |
| 3.8 | 10 | 9 | 5 | 2 |
| 4.0 | 6 | 5 | 3 | |
| 4.2 | 7 | 5 | | |
| 4.4 | | 1 | | |
| 4.6 | 4 | | | |
| 4.8 | 1 | | | |
| 5.0 | | 2 | | |
| 5.2 | 4 | | | |
| 5.8 | 1 | | | |
| Total | 190.0 | 184.8 | 146.8 | 66.8 |
| Mean number | 3.88 ± 0.11 | 3.55 ± 0.90 | 2.99 ± 0.09 | 2.23 ± 0.13 |
| Statistics | | $t_{I, II}$ = 2.309; df = 99; P = 0.023; | $t_{II, III}$ = 4.306; df = 99; P = <0.001; | $t_{III, IV}$ = 4.852; df = 77; P = <0.001; |

1 Estimation of BHC produced only on lowering of temperature of 'hot' water.

(Romanovsky et al. 2002). Examples of such heat exchangers other than the human hands and feet are the rabbit ear and the rat tail.

Besides, under our experimental conditions only temperature of a palm of hand has shown wide variability in population among available for measure of heat conducting parts of human body (see Tables 10 - 12). We see this fact as the most important one, as it is known that nuclear, rectal or armpit temperature is the same for all physically healthy people at rest and at room temperature.

## Are there any Analogues of Physical Thermoregulation in Inanimate Systems?

In this regard, the endothermal organisms (EO) and modern cars, equipped with forced cooling system are the most well-known and simple analogues. Indeed, they have much in common (Table 18). Within the problem discussed it is important to note that both structures are able to function under constantly varying temperature conditions of environment.

Thus, parameters of most elements of both EO and cars in physical thermoregulation systems are originally predetermined by evolution and designers, respectively. These parameters cannot be changed without detriment to the normal work of whole system. Nevertheless, at least one element remains in each thermoregulation system enabling to adapt to changes of environmental temperature. These are the cooling system of a car and amount of chromosomal heterochromatin of EO in genome, forming peripheral layer of CC in metabolically active cells, the density of which depends the quantity and qualitative composition of constitutive heterochromatin (Ibraimov 2003, 2004).

If this analogy is appropriate, then it is not difficult to imagine that EO cells are the micro engines capable to transfer surplus heat into intercellular space, the same way as internal-combustion engines do into cooling jackets of cylinders. As it is known, the heat in both systems cannot be used as an energy source for their normal functioning and therefore the surplus heat energy should be transferred in proper time out of cell and engine into circulating liquids.

**Table 18: Principal analogy of physical thermoregulation systems of endothermal organisms and cars.**

| | | | |
|---|---|---|---|
| 1. | The source of heat production. | Metabolically active cells. | Internal-combustion engine. |
| 2. | The place of heat-loss from the source of heat production. | Intercellular space. | Engine cylinder cooling jacket. |
| 3. | The place of heat transfer. | Peripheral layer of CC round the nucleus. | Engine walls. |
| 4. | Cooling system liquid temperature. | Set point and maintained by hypothalamus. | Set point and maintained by thermostat. |

## Possible Role of Cell Thermoregulation in Maintaining Temperature Homeostasis

A change in environmental temperature is one of the most common stresses experienced by a wide range of organisms from bacteria to plants and animals. The response of prokaryotic and eukaryotic systems to heat-shock stress has been investigated widely in a large number of organisms and model cell systems. A sudden temperature upshift poses a serious threat to the integrity of almost all cellular macromolecules. The structure of membrane lipids, DNA, RNA and proteins is altered as the temperature rises. The expression of heat-shock proteins (HSPs) is a universal response found in all living cells. The induced chaperones or proteases constitute a protein quality-control system that either rescues misfolded proteins or promotes their degradation (Gross 1996; Yura et al. 2000). The cellular concentration of heat-shock proteins is regulated primarily at the level of transcription and involves positive control by alternative sigma factors or negative control by repressor proteins (Narberhaus 1999; Yura et al. 2000; Servant and Mazodier 2001; Schumann 2003).

All organisms from prokaryotes to plants and higher eukaryotes respond to cold shock in comparatively similar manner. Generally, cells respond to cold stress by elite and rapid over expression of a small group of proteins, the so-termed CSPs (cold shock proteins). However, unlike HSPs, CSPs do not appear to be as rigorously conserved between prokaryotic and eukaryotic systems. There is sparse information on the molecular mechanisms of the cold-shock response in mammalian cells. What is clear is that the cold-shock response in eukaryotic cells involves a co-ordinated series of responses involving modulation of the cell cycle, metabolism, transcription, translation and the cell cytoskeleton (Ermolenko and Makharadze 2002; Al-Fageeh and Smales 2006).

Apart from protein-mediated transcriptional control mechanisms, translational control by RNA thermometers is a widely used regulatory strategy. It is becoming increasingly clear that certain messenger RNAs (mRNAs) are not simply a substrate for ribosomes but contain control elements that modulate their own expression in a condition-dependent fashion. Structural changes in such sensory RNAs are induced by specific environmental changes (reviewed in: Narberhaus et al. 2005).

A theory advanced in recent years is a conduction or temperature gradient theory (Golden and Hervey 1977; Webb 1986). It is based not on blood flow but on physical conduction of heat in tissue. When the tissue surface is cooled, a temperature gradient is established between the cooler superficial and warmer deep regions. Each layer of tissue eventually cools, with the temperature at any given layer being cooler than the layer immediately beneath it. When the surface is rewarmed, the gradient starts to reverse. However, the temperature at any given depth continues to decrease until the layer just superficial becomes warmer than it is. This phenomenon has been demonstrated in inanimate objects such as spheres of water, dead pigs (Golden and Hervey 1977), legs of beef (Webb 1986), and cylinders of gelatin (Webb 1986), and has been proposed to be at least partly (Savard et al. 1985; Romet 1988) or even totally (Golden and Hervey, 1977; Webb 1986) responsible for the afterdrop seen in humans after removal from cold expose (Giesbrecht and Bristow 1997).

The role of the circulatory system (CS) has been discussed above in maintaining temperature homeostasis of endothermal organisms. However, the CS cannot influence directly the temperature inside the cells, as those are linked with the CS indirectly - through the intercellular space. Thus, the CS influence on inner cellular temperature homeostasis is limited and its effect, in general, comes to transferring surplus heat from the intercellular space. That is why it seems that the problem of maintaining the inner cellular temperature homeostasis is solved by cells themselves, and we call it the cell thermoregulation (CT) (Ibraimov 2003).

Apparently, the physiological organ-based thermoregulation functions relatively independently from CT as evolutionally new adaptive system (Ibraimov and Tabaldiev 2007). From our point of view, CT can be the missing link, which should fill the "gap" between the thermoregulation systems, functioning at the molecular level (see above) and the whole organism. It is likely that we faced with physiological problem which is a new and alien for classical courses of physiology.

**Possible Role of BHC in Human Adaptation to Various Temperature Conditions**

Unlike many animal species, man is unstable to live in an extreme cold environment. He is basically a tropical homeotherm. However, due to various reasons, human populations have to live under conditions of low or high environmental temperature *(T)* where maintaining the temperature homeostasis is especially difficult. Naturally, all three effector thermoregulating systems mobilize: heat production, heat loss and thermoregulatory behavior. Though being important, they cannot be effective at long-term perspective.

We suppose that *H. sapiens*, besides those inherent in all mammals possesses an additional but very fine and simple mechanism of thermoregulation. In the present case, in order to preserve temperature homeostasis under different environmental conditions, in addition to physiological, behavioral and biochemical mechanisms such as wide intra population variability by BHC was used (Ibraimov 1993, 2003, 2004; Ibraimov and Tabaldiev 2007). Possibly, for the *H. sapiens*, BHC diversity is necessary because no single genotype can possess a superior adaptadness in all environments.

As we suppose the level of heat conductivity peripheral layer of CC influences the speed of heat energy transferring inside the cells and then into intercellular space (see above). Evidently, in conditions of hot climate a high level of intracellular heat conductivity is important in order to take out metabolic surplus heat from the cell, whereas in conditions of cold climate it is important to retain some heat energy by slowing down its transfer into intercellular space. (Ibraimov 2007 b; Ibraimov and Tabaldiev 2007).

On the whole, we see efforts for maintaining temperature homeostasis under conditions different from climate of the Eastern Africa as follows:

1) an individual with less chromosomal Q-HRs in the North (where cold is the main harmful physical environment factor limiting human life) maintain more effectively temperature homeostasis in organism because of low BHC, permitting to preserve additional amount of produced heat in organism longer and slow down the body cooling rate from external cold;

2) an individual with high BHC in the North, constantly loosing additional amount of metabolic heat through conduction which is necessary for organism in terms of cold climate and exposing to relatively fast cooling because of cold, has to produce larger amount of heat and/or consume more high-calorie food for heat production, which is not always simple and healthy, because hunger and vice versa overweight reduce his chances to survive;

3) an individual with low BHC in the South (where environment temperature is higher than body temperature) besides his own internal heat production receives additional heat from environment by means of conduction, which, as it is known, is not used in useful physiological work. That is why these individuals' bodies overheat faster and they have to return heat surplus (through sweating, polypnoe, forced rest, behavioral reactions and etc.) to environment at the cost of significant decrease of physical and mental activities that finally negatively influences on their adaptation to hot climate;

4) an individual with big amount of Q-HRs in genome in the South having body with high thermal conductivity perhaps adapts better to high temperature of environment, more effectively leveling temperature differences in different parts of the body and faster directing surplus heat flow from organism to environment, including the way of heat radiation.

The example from the modern sport life can better illustrate our understanding of BHC role. More and more countries situated at southern latitudes have started taking part in the world sport movement lately. The most notable in this process is that, natives of this region achieve great success in sports, requiring (in addition to other factors) effective heat-loss (football, professional boxing, stayer and marathon race). While sportsmen from northern latitudes prevail in water and winter sports and also in mountaineering. (Ibraimov et al. 1990,

1991). It is ascertained that natives of southern latitudes have more chromosomal Q-HRs in their genome (Lubs et al. 1977; Ibraimov and Mirrakhimov 1982 b, c, d, 1985; Ibraimov et al. 1997; Kalz et al. 2005). Since their bodies, as we think, have relatively high heat conductivity (Ibraimov and Tabaldiev 2007) it is not surprising, that they are successful in sports, which require effective heat-loss. Indeed, a sportsman with high heat conductivity cannot make much progress in water sports due to the fact that their body cools rapidly. However, this sportsman can be more successful in sports which require effective heat-loss.

Taking into consideration the mentioned all above, it can be explained why the amount of chromosomal Q-HRs is greater in the genome of newborns, then in senior age groups (Buckton et al. 1976; Ibraimov and Karagulova 2006 a), and the same chromosomal material is found in greater quantity in the genomes of infants died during first weeks, months, and years of their life (Ibraimov and Karagulova 2006 b). Prevalence of people with lesser quantity of Q-HRs in the genome in senior people groups, may be connected with negative selection of individuals with greater amount of chromosomal Q-HRs during first years of their life. As it is well-known, infants' ratio of body surface to body capacity is higher than adults' ratio. When one more physical factor (high BHC) superimposes on this, then these infants are more vulnerable to colds and their consequences.

The issues of a possible connection of cellular thermoregulation and BHC with the origin of noncoding DNAs, condensed chromatin, eukaryotic cell, multicellularity, sex and the appearance of nonhairy skin and the big neocortex in human brain were discussed elsewhere (Ibraimov 1993, 2003, 2004, 2007 a,b, 2008, 2009, 2010 b).

## CONCLUSION

Basal metabolic rate could be out of many factors known from physiology being capable of explaining the nature of wide human BHC variability in population. Indeed, as in the present case, its level turns less with human age. But it is known that basal metabolic rate, as a rule, is lower in women and southern latitude natives. Apart from that, basal metabolic rate is influenced by such factors as height, weight, body constitution, pulse rate and environmental temperature, which contradicts our data.

As of possible genetic factors the most appropriate is the amount of chromosomal Q-heterochromatin in human genome. Certainly, the thickness of peripheral layer of CC around cellular nucleus depends on total amount of chromosomal C-heterochromatin in the genome. But as we suppose, packaging density (compactization) of CC itself is basically connected with the amount of chromosomal Q-heterochromatin. The point is that human populations do not differ significantly in the quantity of C-heterochromatin in their genome. Wide quantitative variability at the level of populations is found only in the amount of Q-heterochromatin. Some quantity regularities in distribution of chromosomal Q- heterochromatin in population depending sex, age, ethnical background as well as peculiarities of permanent place residence are determined (Gereadts and Pearson 1974; Müller et al. 1975; McKenzie and Labs 1975; Buckton et al. 1976; Lubs et al. 1977; Yamada and Hasegawa 1978; Al-Nassar et al. 1981; Ibraimov and Mirrakhimov 1982 b,c,d, 1985; Ibraimov 2010 a; Ibraimov et al. 1982, 1986, 1990, 1991, 1997; Stanyon et al. 1988; Kalz et al. 2005; Dècsey et al. 2006; Bhasin 2007). It is notable, that these regularities turned out to be very similar to the wide BHC variability in population. To be exact: the amount of chromosomal Q-heterochromatin turns less with the age; male genome has Y chromosome with the largest block of Q-heterochromatin in human karyotype; the amount of Q-HRs amount proved to be related to features of the ecological environment of the place of permanent residence (see above).

That is why we came to the conclusion that: a) individuals differ in populations on their BHC; b) human BHC is effected by sex, age and ethnic and racial origin; c) human morphophysiological characteristics such as height, weight, body constitution, blood pressure and pulse rate do not influence significantly on human BHC; 4) apparently, human BHC depends mainly on the amount of chromosomal Q-heterochromatin in his genome. As the amount of chromosomal heterochromatin does not change in ontogenesis, it is possible that the level of BHC may be a constitutional sign, the same as the color of skin, eye shape, body constitution, height and other innate physical human peculiarities.

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