Adaptometry: Models of Adaptation and Measurement of Physiological Fitness

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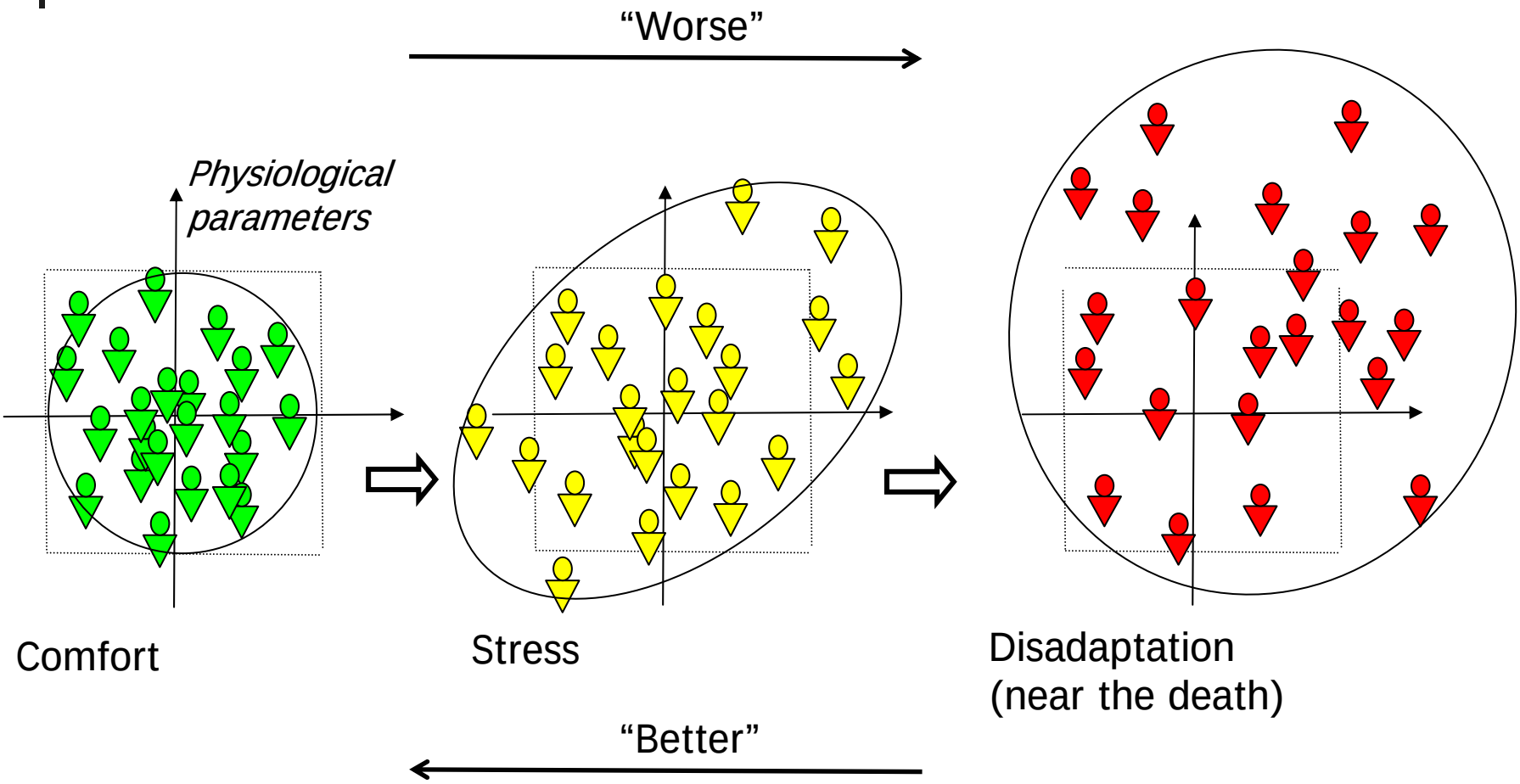
http://adaptometry.narod.ru

Joint work with Elena Smirnova

Plan

- Effect
- Indicators
- Data
- Optimality and Factors-Resources models
- Source of optimality

Effect


“Worse”
Physiological parameters
Comfort
Stress
Disadaptation (near the death)
“Better”

Indicators

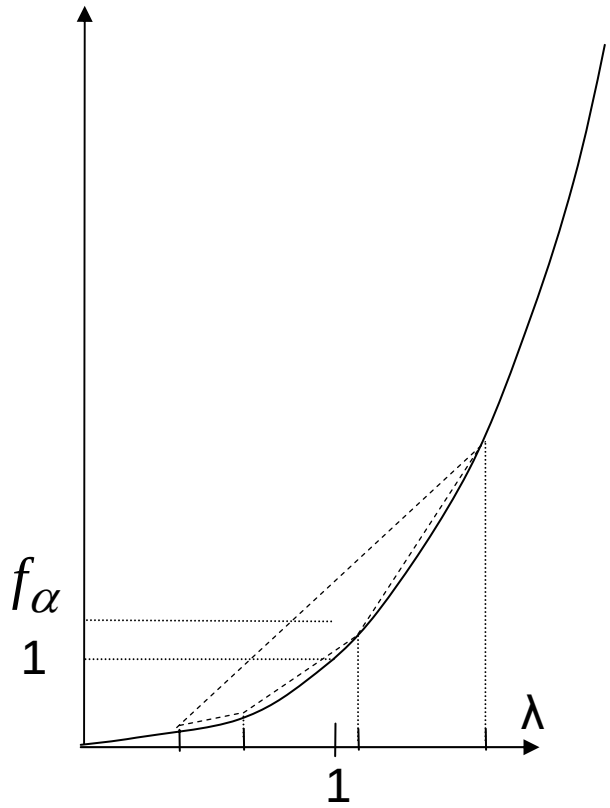
$(r_{ij}) - \text{correlation matrix},$

$\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_n$

$$f_\alpha = \frac{1}{k} \sum_{j=1}^{k} \lambda_j^\alpha \quad (\alpha > 1 \text{ or } \alpha < 0)$$

$$G = \sum_{|r_{ij}| \geq \alpha} |r_{ij}|$$

Indicators



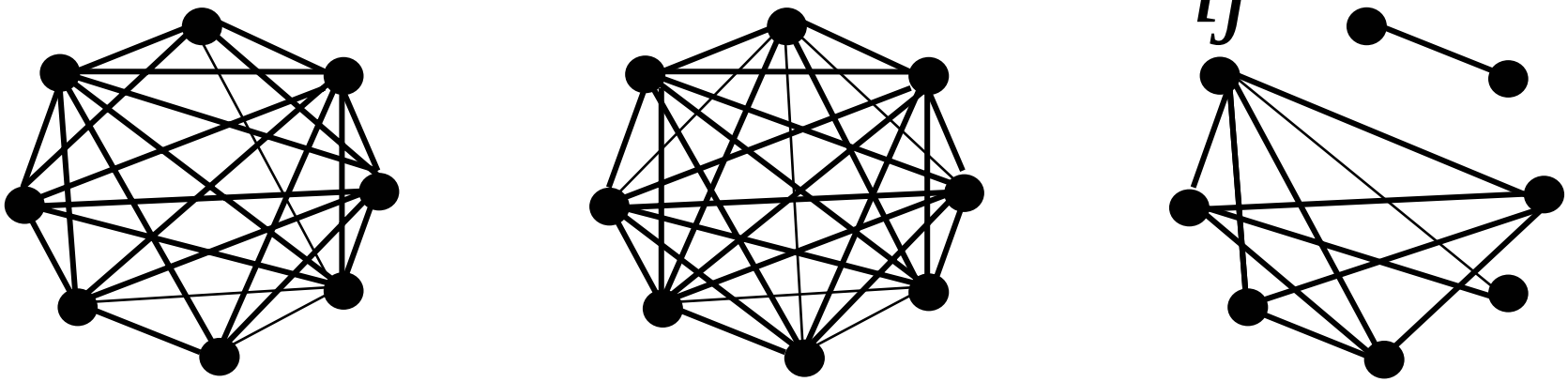
$$f_\alpha \in [1, k^{\alpha-1}] \quad (\alpha > 1)$$

$$G = \sum_{|r_{ij}| \geq \alpha} |r_{ij}| \in [0, k(k-1)/2]$$

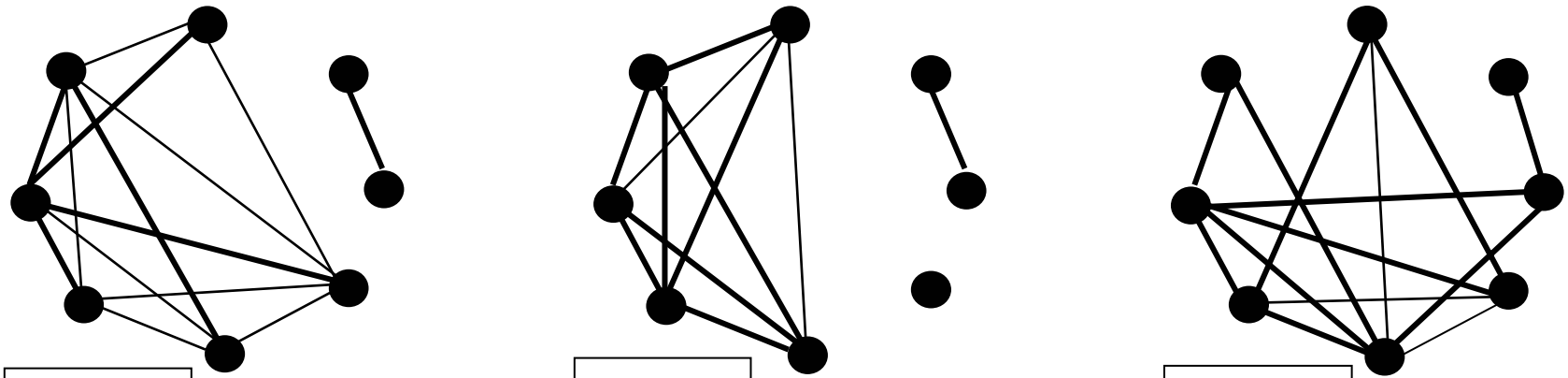
Lipid metabolism: newborn children, Far North

$r_{ij} > 0.5$

Immigrant families



Native population

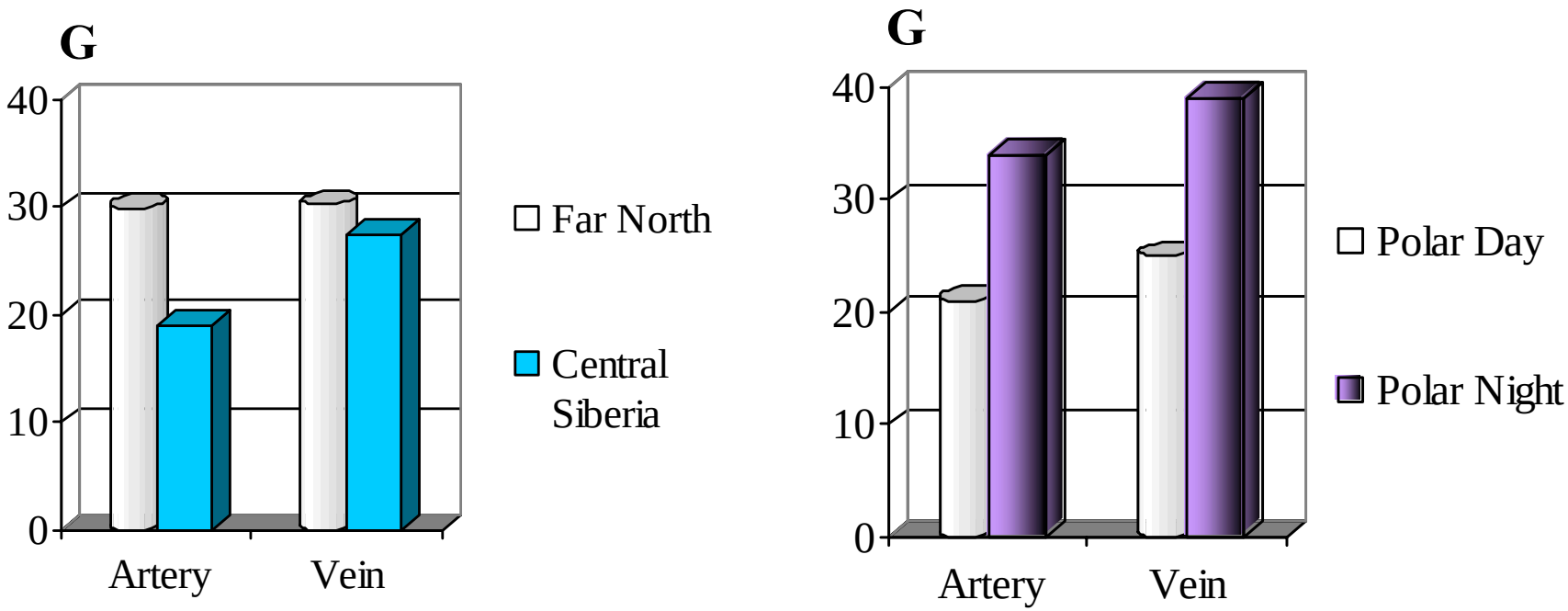


1 – 3 day

4 – 6 day

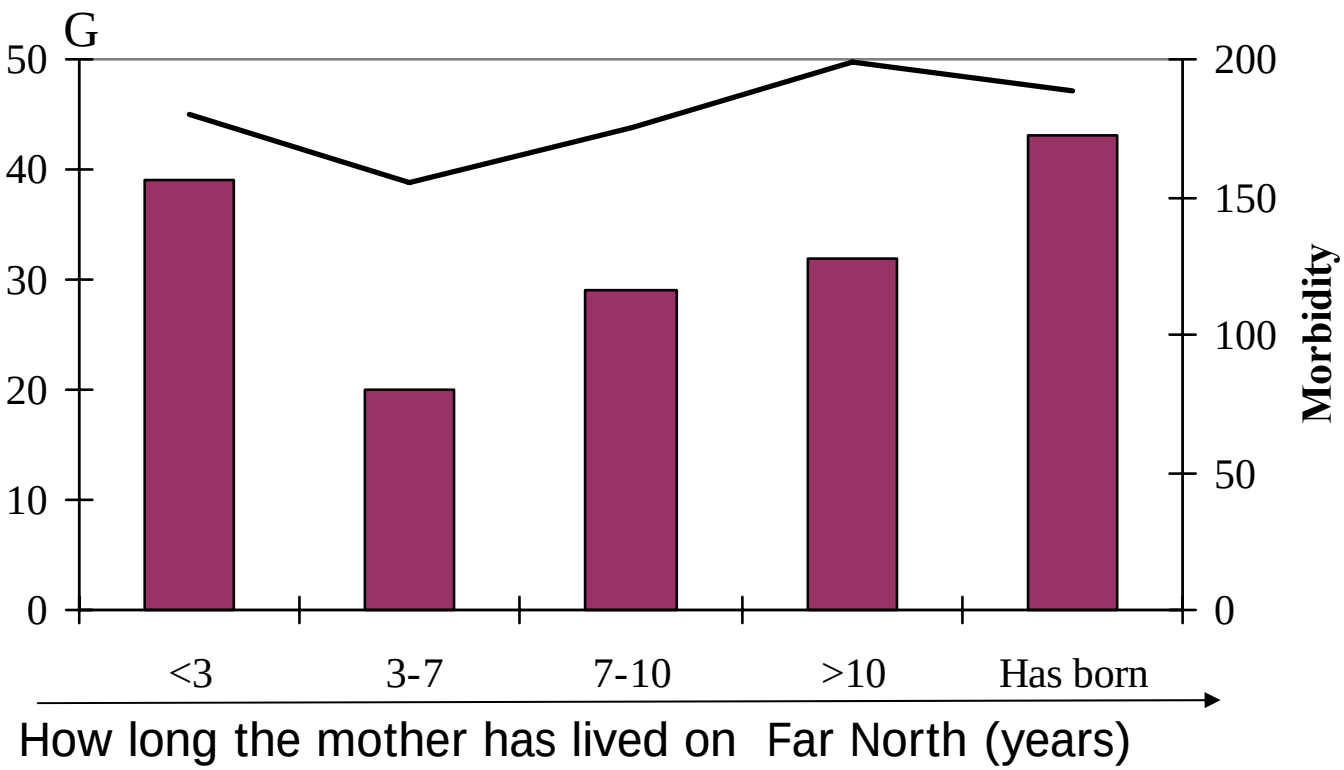
7 – 10 day

Lipid metabolism: newborn children, Far North



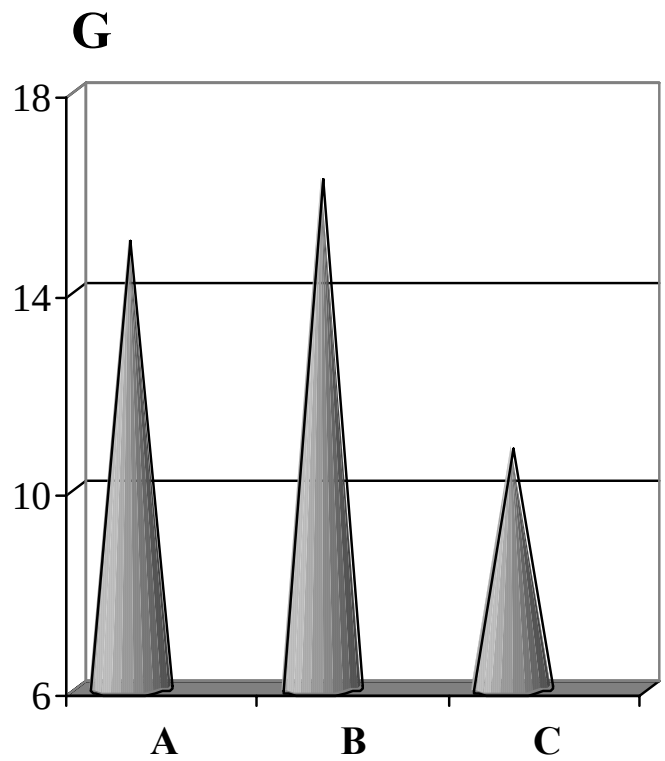
Immigrant families

Lipid metabolism: newborn children, Far North



Immigrant families

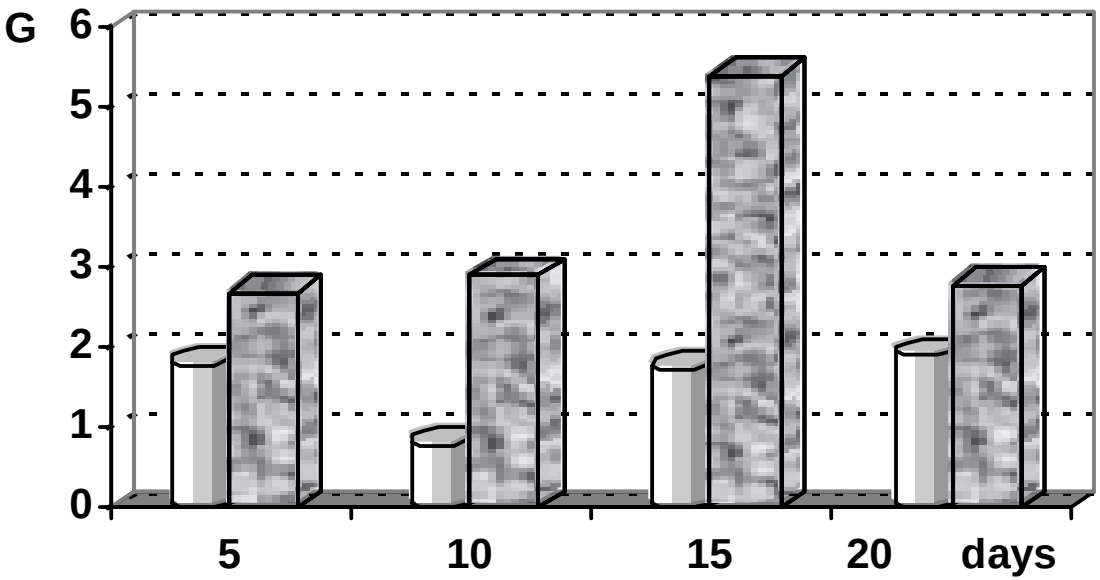
Lipid metabolism: 1-year old children, Far North



A – artificial feeding from the first days,
B – artificial feeding after 6 months,
C – breast feeding.

Immigrant families

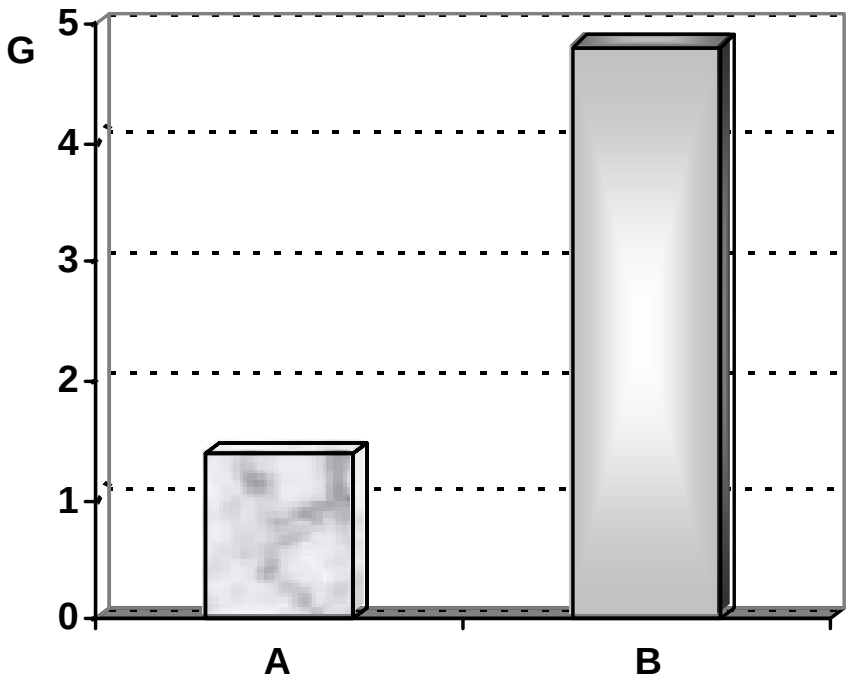
Activity of Lymphocytic Enzymes, Black Sea resort, first 20 days dynamics



People from Far North

People from Central Russia

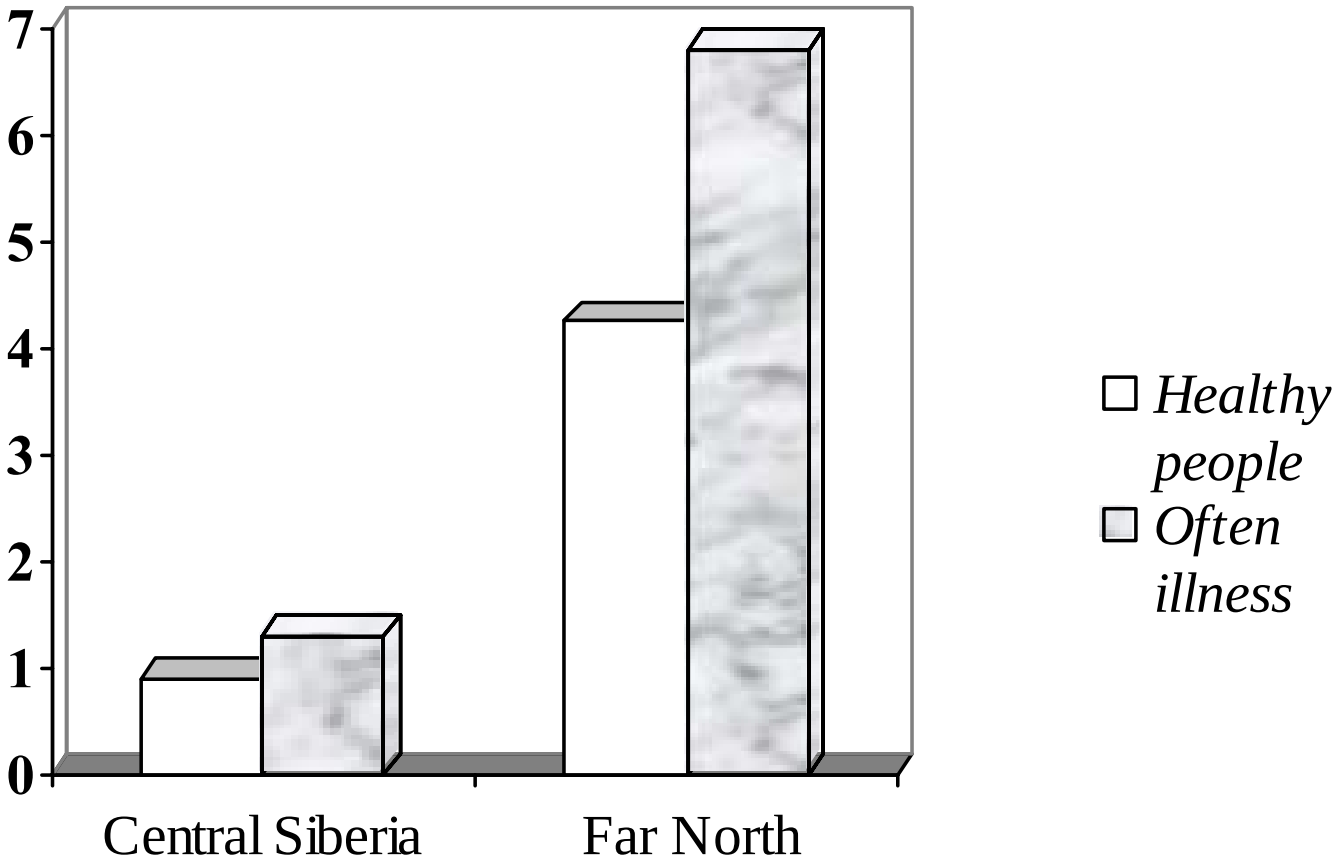
Activity of Lymphocytic Enzymes, Far North, after first 6 months



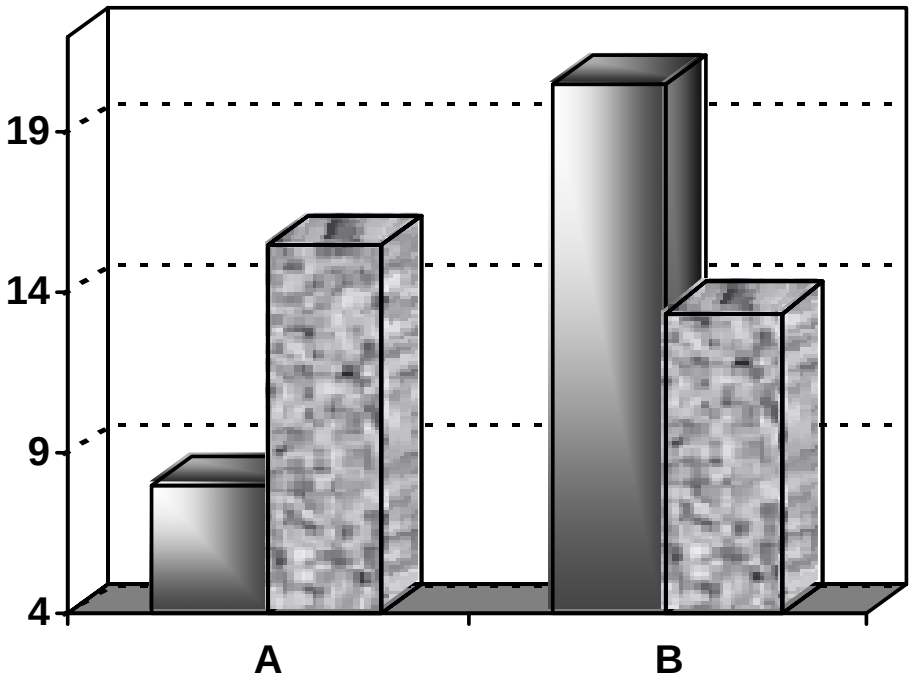
A - People which did not have any illness during 6 months

B - People which have been ill at least once during 6 month

Activity of Lymphocytic Enzymes, Far North, after first 6 months



Activity of Lymphocytic Enzymes, children from primary schools



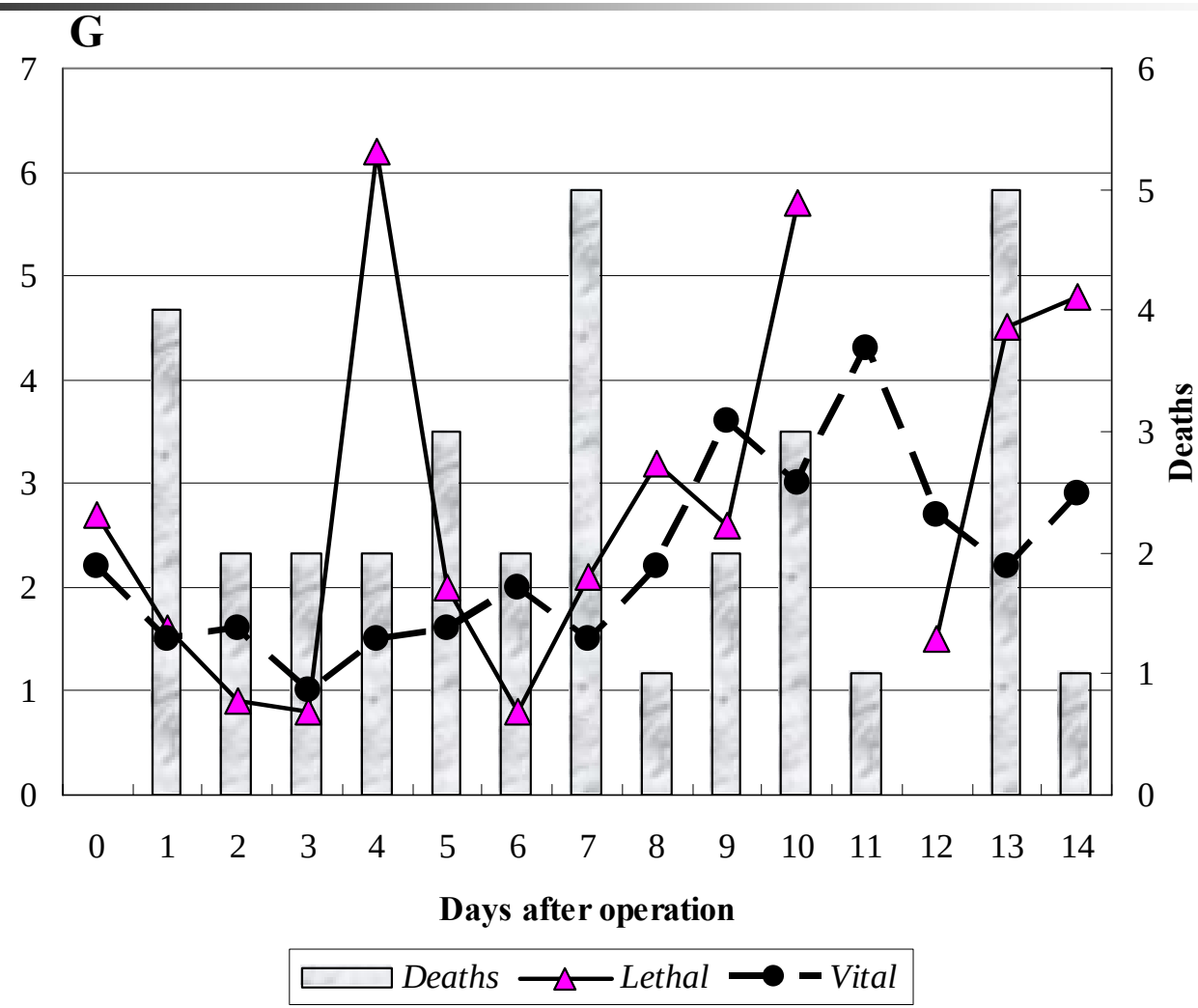
A – Central Russia

B – Far North

Intensive working out (swimming)

No intensive working out (standard control)

Cancer: Disadaptation, decorrelation and death after operation



Adaptation as distribution of a hypothetical nonspecific resource

The adaptation energy (H. Selye)

Many different environmental factors affect living creatures.

$\psi_i \geq 0$ – intensity of ith factor

$r_i \geq 0$ – amount of the adaptation energy assigned for neutralization of ith factor

$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n)$ – the generalized fitness,

$$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n) \xrightarrow[\sum_i r_i = R]{} \max$$ – the redistribution law

Law of the Minimum (1)

The principle behind Liebig's Law of the Minimum is quite simple. It means the rarest necessity an organism requires will be the limiting factor to its performance.

See the "hole in the bucket" illustration. One hole is near the bottom of the bucket, another about midway, and the final hole just below the top. The lowest hole limits the amount of water the bucket can hold. Plugging the upper holes will not help, since water will still pour out the lower hole.

By: Grant R. Woods and Bryan Kinkel

Law of the Minimum (2)

$\psi_i \geq 0$ – intensity of ith factor

$r_i \geq 0$ – amount of the adaptation energy assigned for neutralization of ith factor

$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n)$ – the generalized fitness,

$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n) = \varphi(\max_i \{\psi_i - r_i\})$

Law of the Minimum (3)

$$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n) = \varphi(\max_i\{\psi_i - r_i\})$$

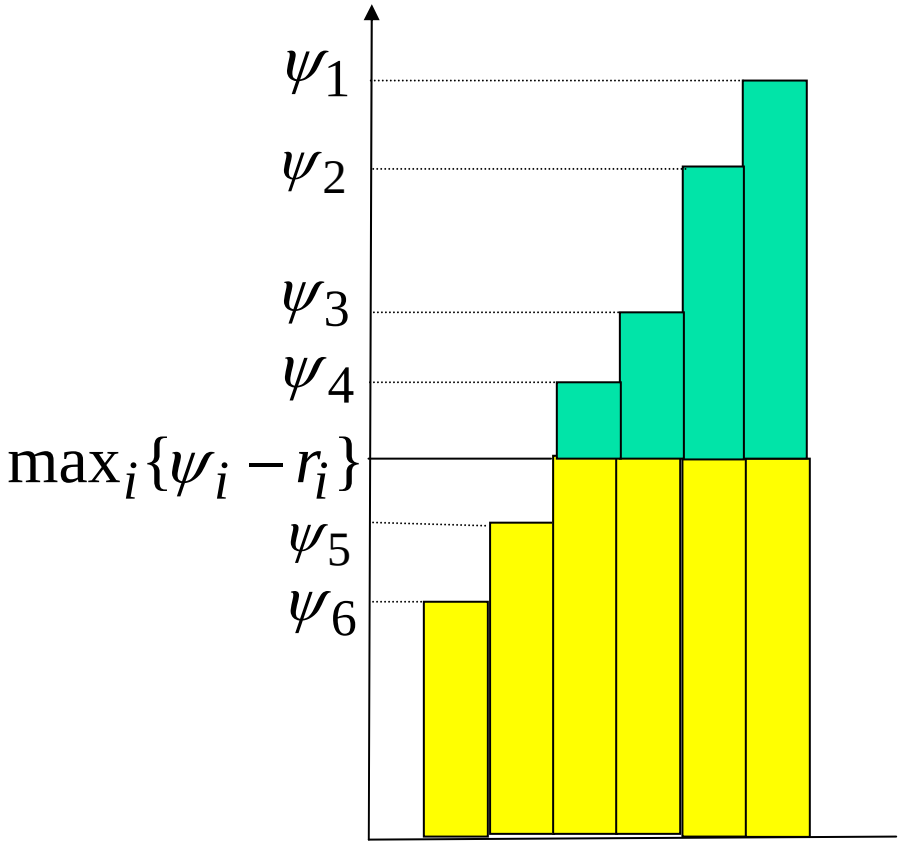
$$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n) \xrightarrow[\sum_i r_i = R]{} \max$$

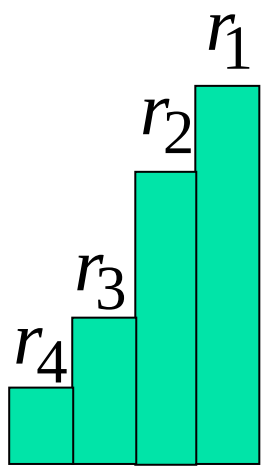
$$\psi_{i_1} > \psi_{i_2} > \ldots > \psi_{i_n}; \quad \Delta_j = \psi_{i_j} - \psi_{i_{j+1}}$$

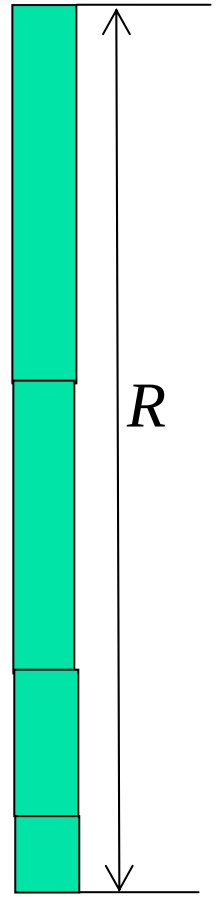
$$\sum_{j=1}^{k} j\Delta_j < R < \sum_{j=1}^{k+1} j\Delta_j;$$

$$r_{i_l} = \begin{cases} \psi_{i_l} - \psi_{i_{k+1}} + \dfrac{1}{k+1}\left(R - \sum_{j=1}^{k} j\Delta_j\right), & \text{if } l \le k+1 \\ 0, & \text{if } l > k+1. \end{cases}$$

Law of the Minimum (4)







Law of the Minimum
PARADOX

If for a randomly selected pair
“State of environment – State of organism”
the Law of the Minimum is valid (everything is limited by the factor with the worst value),

Then, after adaptation, many factors (the maximally possible amount of them) are equally important!

Sinergetic interaction of factors

$\psi_i \geq 0$ – intensity of ith factor

$r_i \geq 0$ – amount of the adaptation energy assigned for neutralization of ith factor

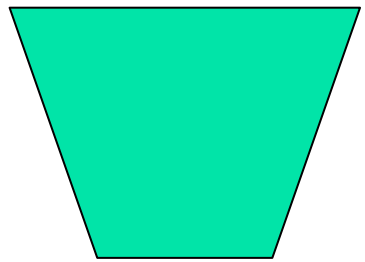
$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n)$ – the generalized fitness,

$$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n) \xrightarrow[\sum_i r_i = R]{} \max$$

$\Phi(\psi_1 - r_1, \psi_2 - r_2, \ldots \psi_n - r_n)$

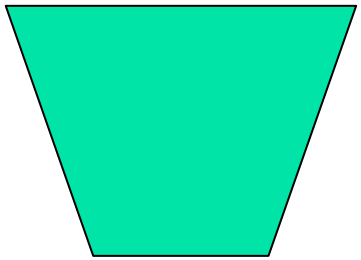
is a strictly convex function of $r_1, r_2, \ldots r_n$

on a plane $\sum_i r_i = R < \sum_i \psi_i$.



Maxima in vertices

Sinergetic interaction of factors



Maxima in vertices of the polyhedron:

$$\sum_i r_i = R; \quad r_i \geq 0; \quad \psi_i - r_i \geq 0$$

Each vertex of this polyhedron corresponds to a set of indexes:

$$\{i_1, i_2, \ldots i_l\}: \quad l \leq n, \quad \sum_{i=1}^{l-1} \psi_i \leq R, \quad \sum_{i=1}^{l} \psi_i > R,$$

$$r_i = \psi_i \ (i = i_1, i_2, \ldots i_{l-1}), \quad r_i = 0 \ (i \notin \{i_1, i_2, \ldots i_l\})$$

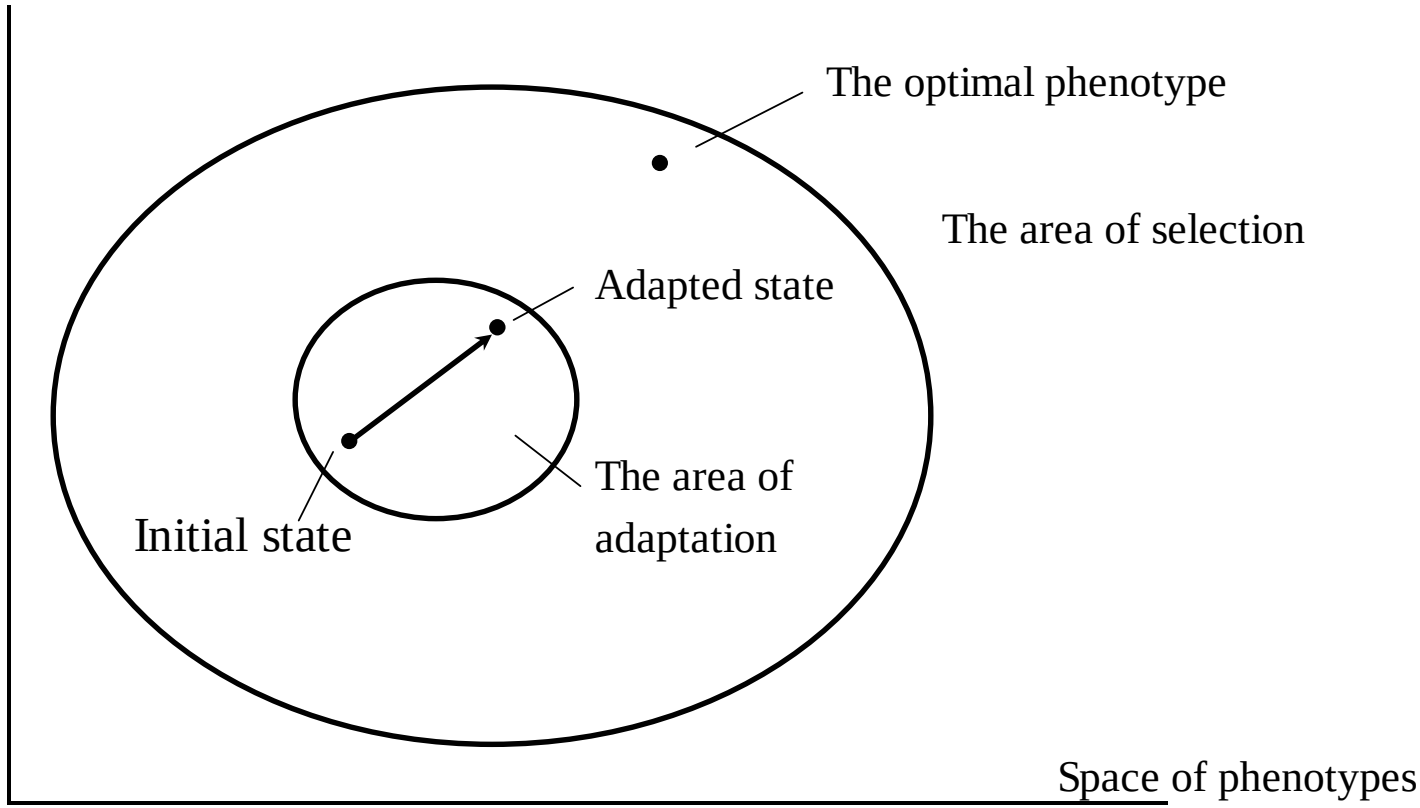
This means that factors $\psi_i \ (i = i_1, i_2, \ldots i_{l-1})$ **are neutralized, and resource is not assigned for factors** $\psi_i \ (i \notin \{i_1, i_2, \ldots i_l\})$

Law of the Minimum
INVERSE PARADOX

If for a randomly selected pair
“State of environment – State of organism” many factors are equally important and superlinear amplify each other (the generalized fitness is a convex function),

Then, after adaptation, the Law of the Minimum is valid (everything is limited by the factor with the worst non-compensated value)!

The source of optimality



Adaptation as a result of selection on a restricted set of possibilities.

Additional verification

- Stress in experimental populations of rats and mice;
- Stress in grassy plants;
- Industrial emission impact (phenolic compounds) on Scots Pine
- ...

Conclusion: we have

- The effect;
- The explanation
- The verification
- And many applications...

Bibliography:

http://adaptometry.narod.ru