

**Bioenergetics  
and  
cultural physiology**

**Stanley Ulijaszek**

# Bioenergetics

**Molecular: energy involved in making and breaking of chemical bonds in molecules of biological organisms**

**Ecological: food and energy as key interface between organisms (humans) and their environments**

**Evolutionary: energy budgets associated with reproduction, development, and foraging behaviour that lead to survivorship**

# Bioenergetics

**Molecular:**

**Saks et al, 2009**

**Ecological:**

**Ulijaszek, 2005**

**Evolutionary:**

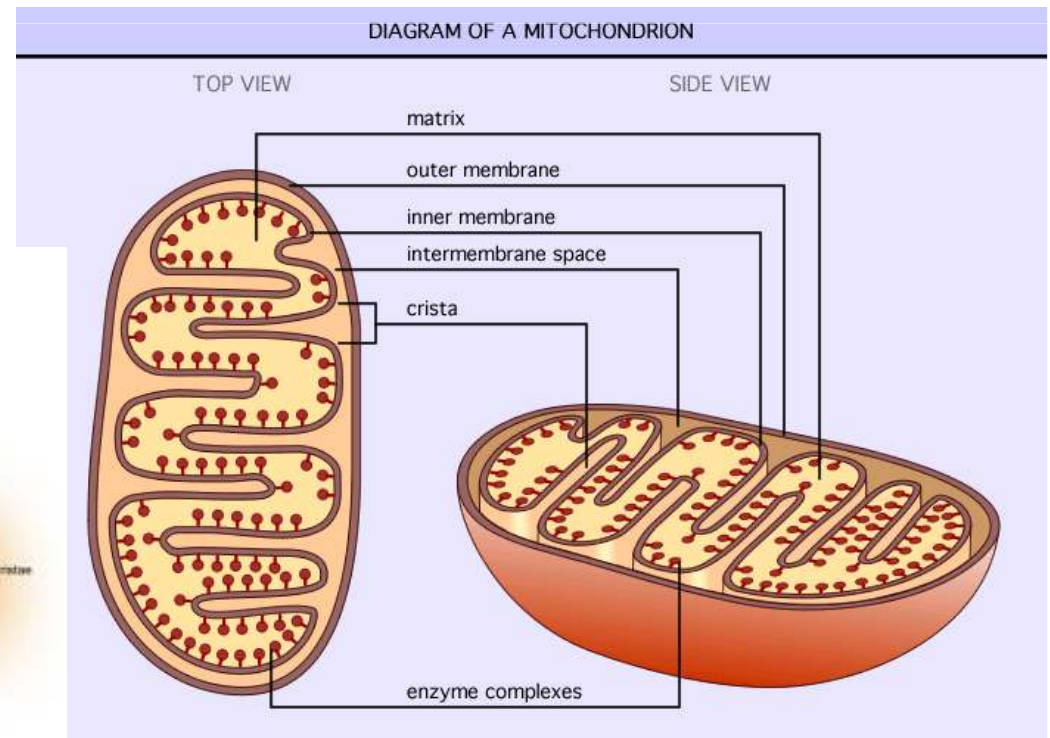
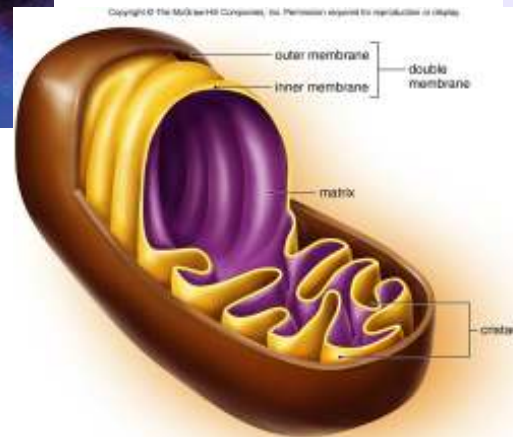
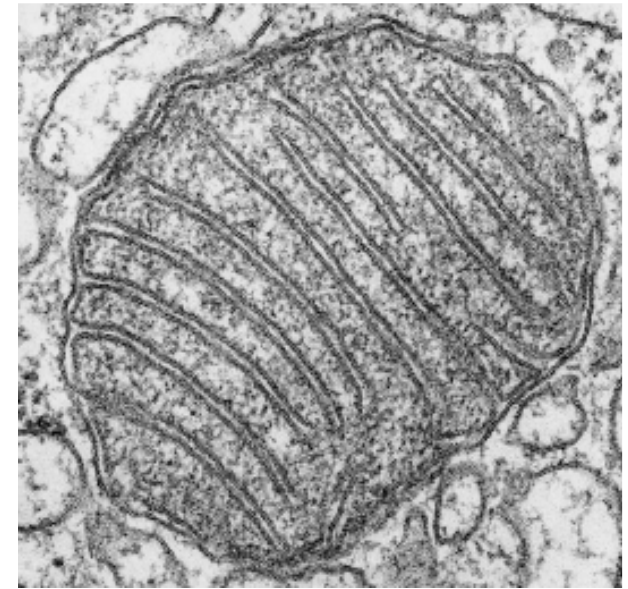
**Leonard &Ulijaszek, 2002**

**Saks, Monge and Guzun (2009). Philosophical Basis and Some Historical Aspects of Systems Biology: From Hegel to Noble - Applications for Bioenergetic Research. International Journal of Molecular Science 10: 1161-92**

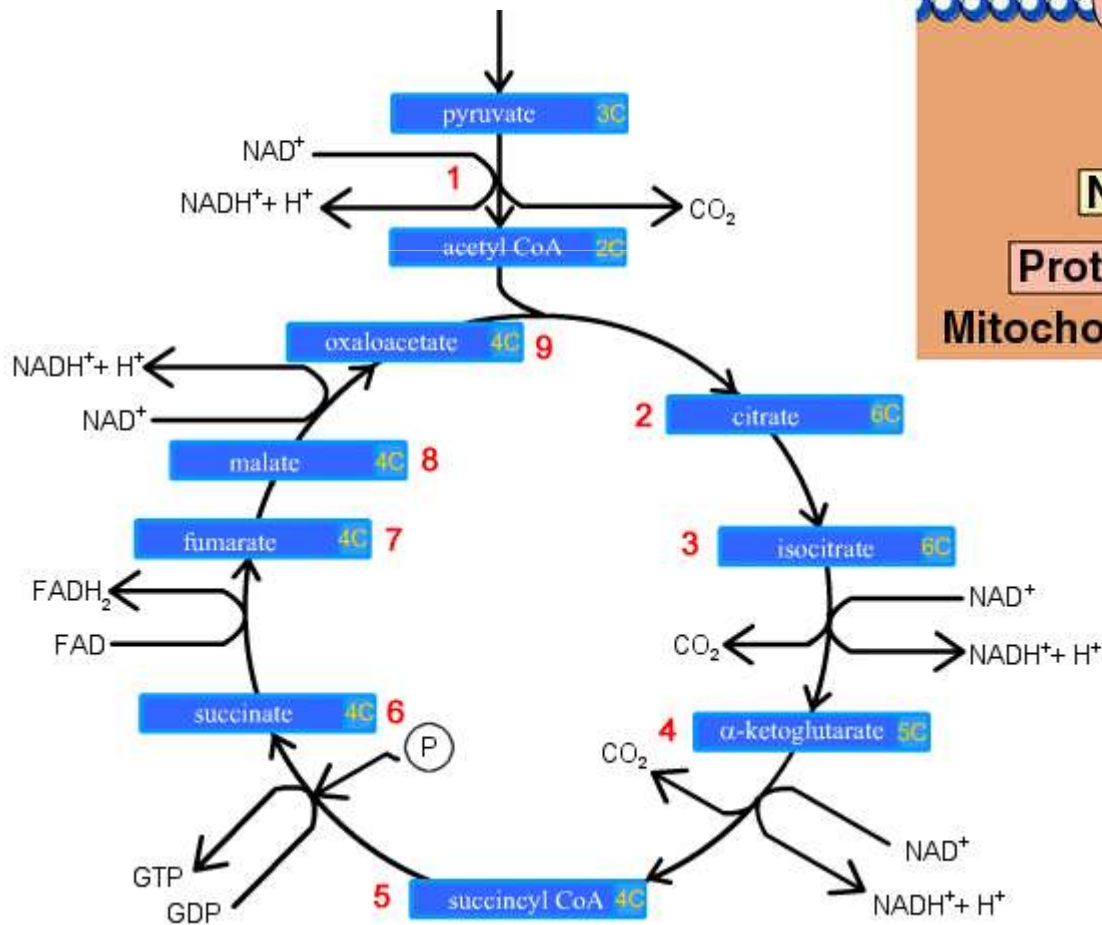
**Wherever there is movement,  
wherever there is life, wherever  
anything is carried into effect in the  
actual world, there Dialectic is at  
work. It is also the soul of all  
knowledge which is truly scientific.**

**Hegel's Logic**

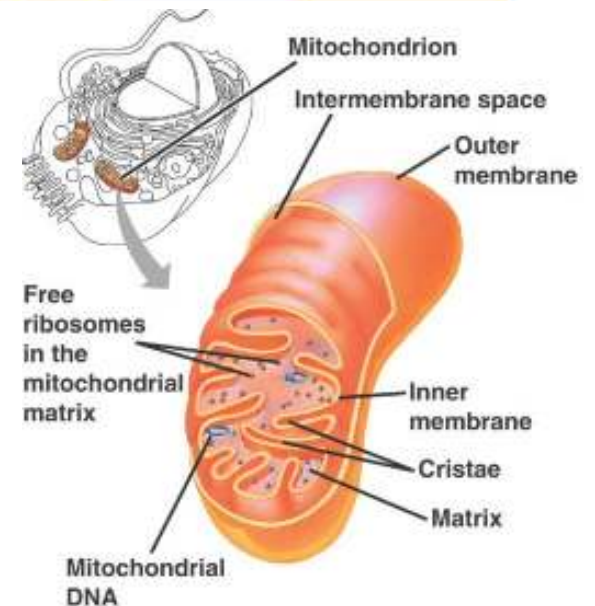
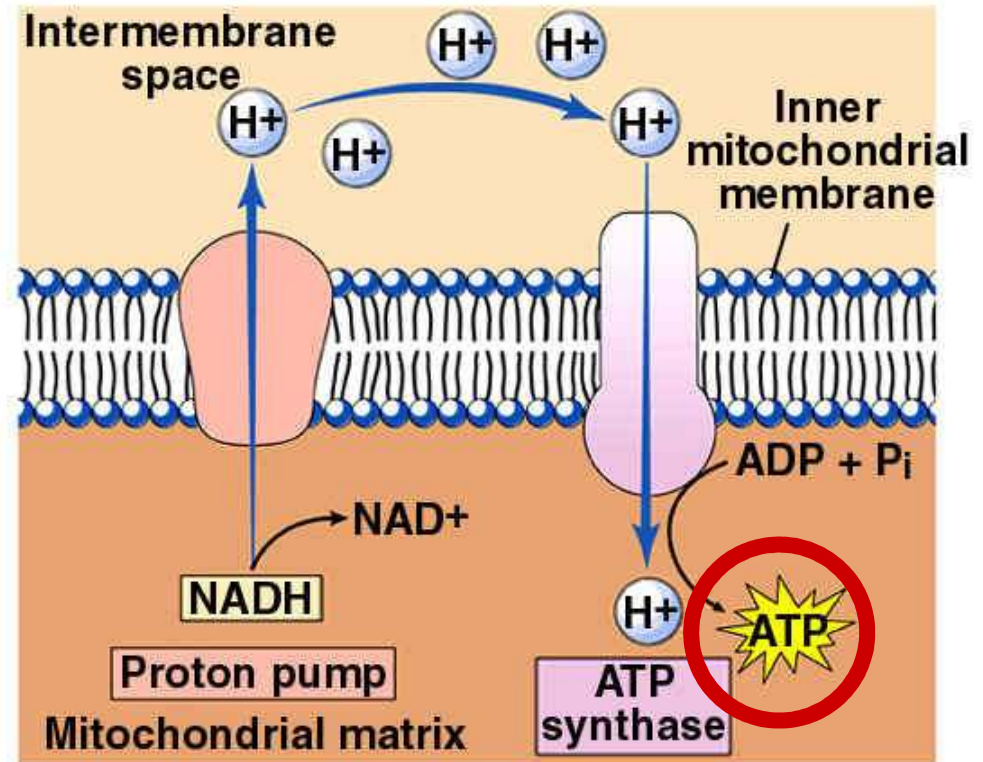
**Mitochondria are cellular organelles that generate ATP (energy currency) from breakdown of carbohydrates and other food molecules**



# Mitochondrial biochemistry, and how chemical energy is made (Penelope a cow and some farmer made out...)



## Chemiosmosis

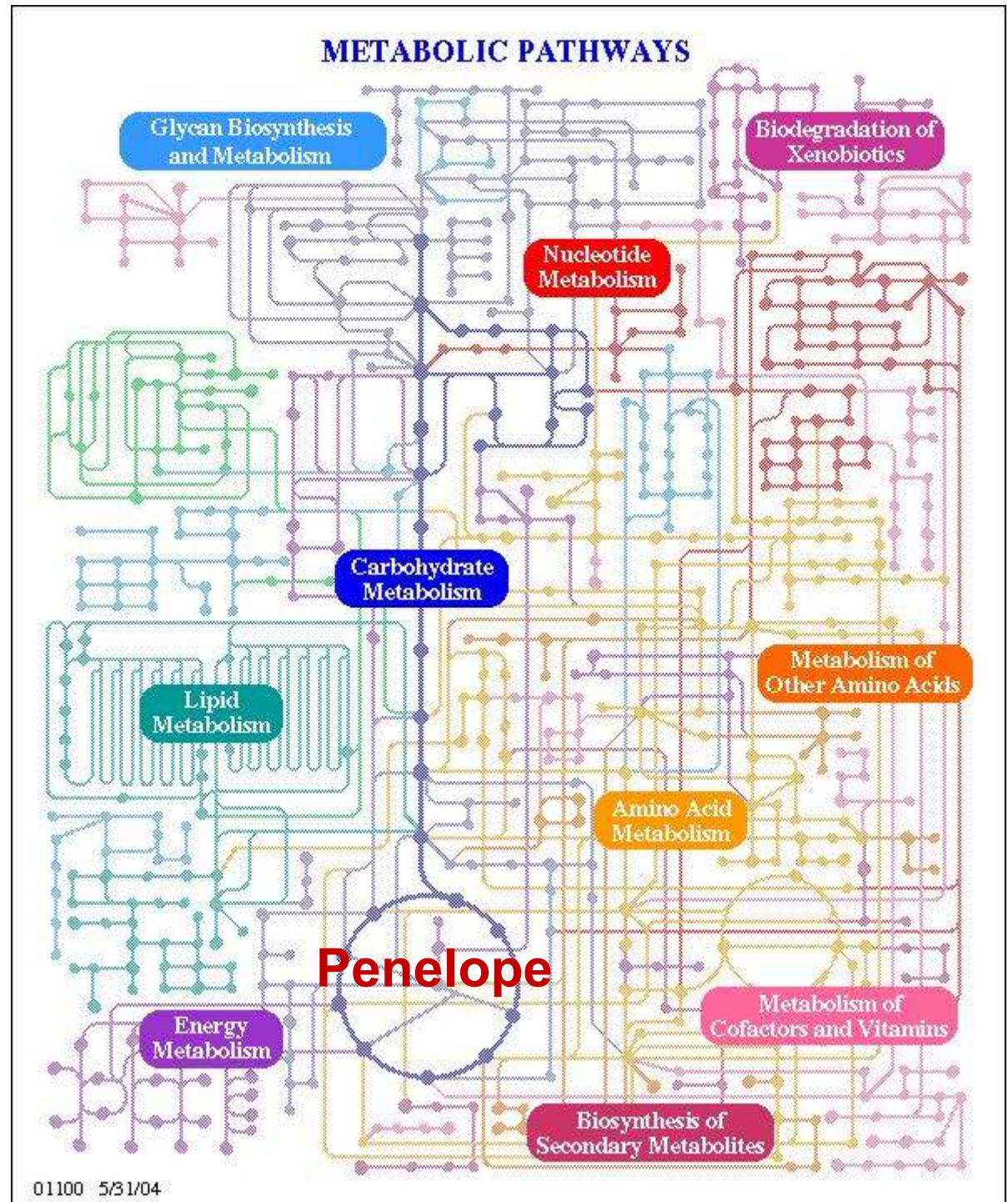


# How is molecular bioenergetics changing?

## According to Saks et al (2009):

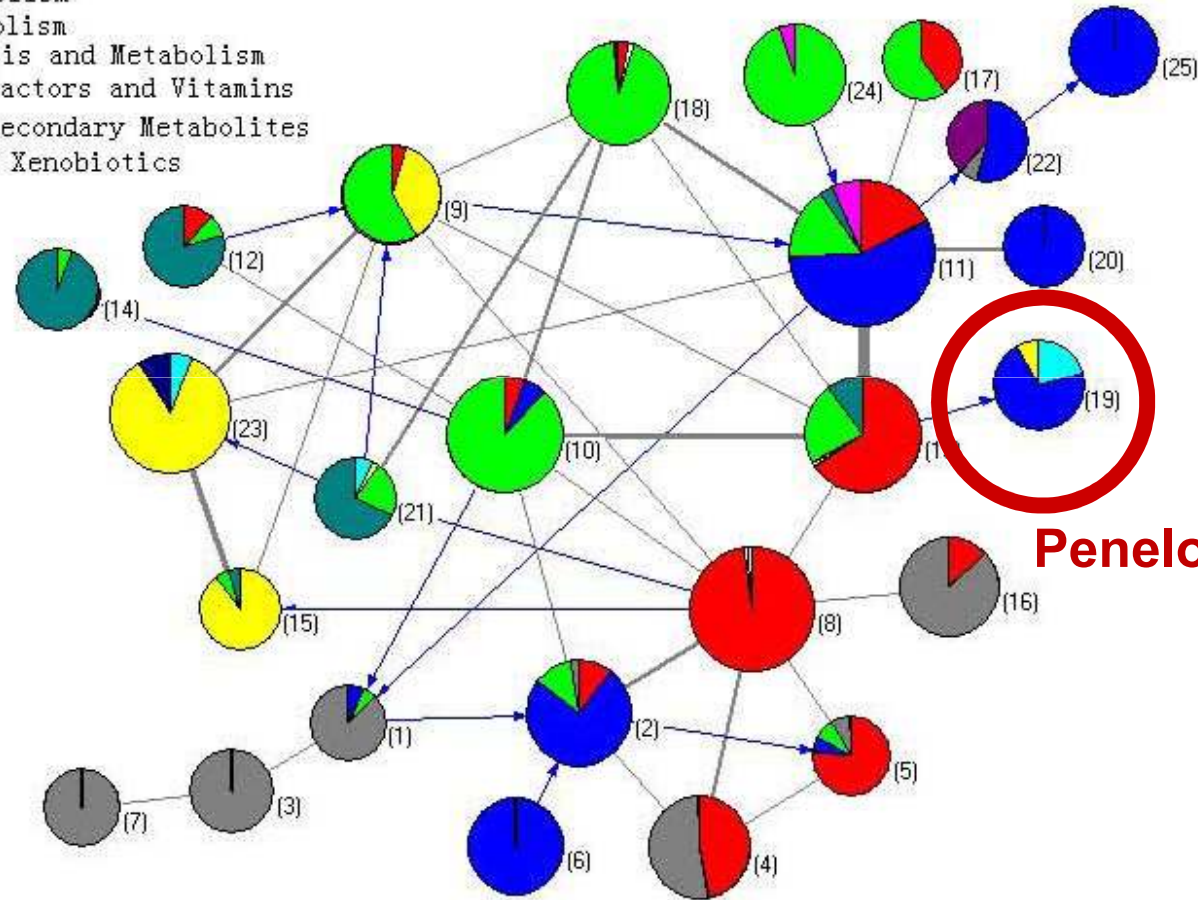
- **Within last decade, biological sciences have witnessed a radical change of paradigms**
- **Reductionism, which used to be a philosophical basis of biochemistry and molecular biology when everything – from genes to proteins and organelles – were studied in their isolated state is giving way to Systems Biology, which favours the study of integrated systems at all levels: molecular, cellular, organ, organism, and population**

- **Classical dynamic view of metabolism,**
- **or how bodies get built and maintained**
- **House-building (cells) and chemical engineering (substances needed to build and maintain them) is the model**
- **Problem: the building blocks ‘talk’ with each other, as do the genes that code for their production, while building and maintenance happen**

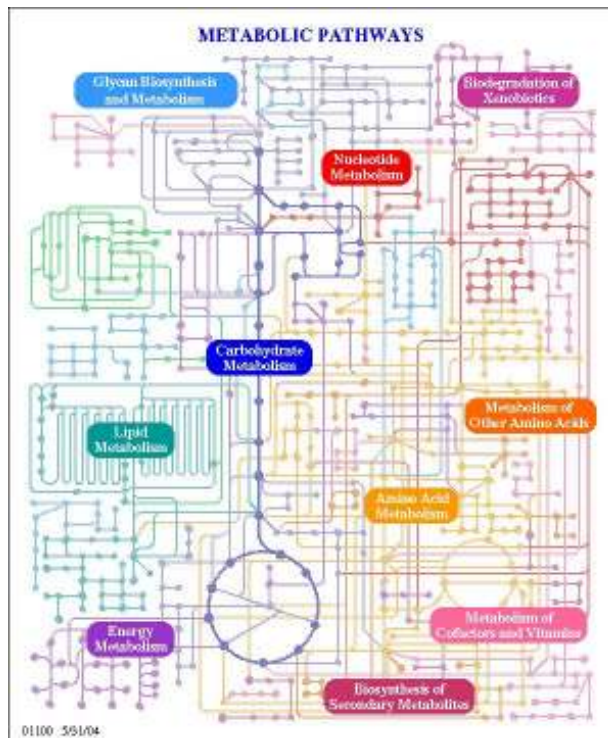


# Metabolic network, based on genetic relationships that code for its components (Zhao et al 2007)

- I. Carbohydrate Metabolism
- II. Energy Metabolism
- III. Lipid Metabolism
- IV. Nucleotide Metabolism
- V. Amino Acid Metabolism
- VI. Glycan Biosynthesis and Metabolism
- VII. Metabolism of Cofactors and Vitamins
- VIII. Biosynthesis of Secondary Metabolites
- IX. Biodegradation of Xenobiotics



**Penelope**



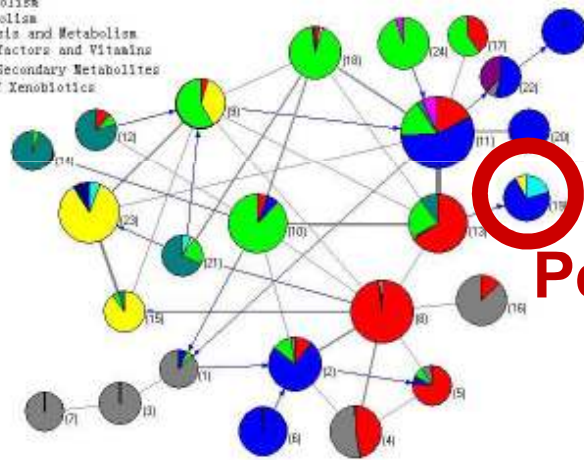
Each circle represents a module and is coloured according to the Kyoto Encyclopedia of Genes and Genomes pathway classification of the reactions belonging to it, while the arcs reflect the connection between clusters. The area of each colour in one circle is proportional to the number of reactions that belong to the corresponding metabolism. The width of an arc is proportional to the number of reactions between the two corresponding modules. For simplicity, bi-directed arcs are presented by grey edges.

# Evolution of metabolic modules found in humans (Zhao et al 2007)

Table 2: Evolutionary ages of topological modules for *H. sapiens* network

Evolutionary age	Module	Percentage of enzymes in this age	P-value	Inter-module degree
6	3	82.35 %	$9.26 \times 10^{-6}$	4
6	6	68.75 %	$2.46 \times 10^{-4}$	1
6	7	71.42 %	$6.19 \times 10^{-3}$	2
6	19	63.16 %	$3.02 \times 10^{-4}$	1
6	25	85.71 %	$1.58 \times 10^{-6}$	1
4	24	30.00 %	$2.22 \times 10^{-3}$	1
3	20	40.00 %	$4.18 \times 10^{-2}$	5
7	22	33.33 %	$2.34 \times 10^{-3}$	2
2	1	36.84 %	$1.89 \times 10^{-2}$	5
2	5	40.00 %	$6.82 \times 10^{-3}$	5
1	8	69.09 %	$4.27 \times 10^{-5}$	22
1	9	84.38 %	$3.5 \times 10^{-6}$	17
1	12	65.22 %	$2.53 \times 10^{-2}$	4
1	13	65.31 %	$6.48 \times 10^{-4}$	25
1	15	64.00 %	$2.65 \times 10^{-2}$	11
1	18	68.57 %	$1.61 \times 10^{-3}$	17

- I. Carbohydrate Metabolism
- I. Energy Metabolism
- II. Lipid Metabolism
- IV. Nucleotide Metabolism
- V. Amino Acid Metabolism
- VI. Glycan Biosynthesis and Metabolism
- VII. Metabolism of Cofactors and Vitamins
- VIII. Biosynthesis of Secondary Metabolites
- X. Biodegradation of Xenobiotics



Penelope

Evolutionary age is defined as: 1. Prokaryota; 2. Protists; 3. Fungi; 4. Nematodes; 5. Arthropods; 6. Mammalian; 7. Human. See Method part for the detailed definition.

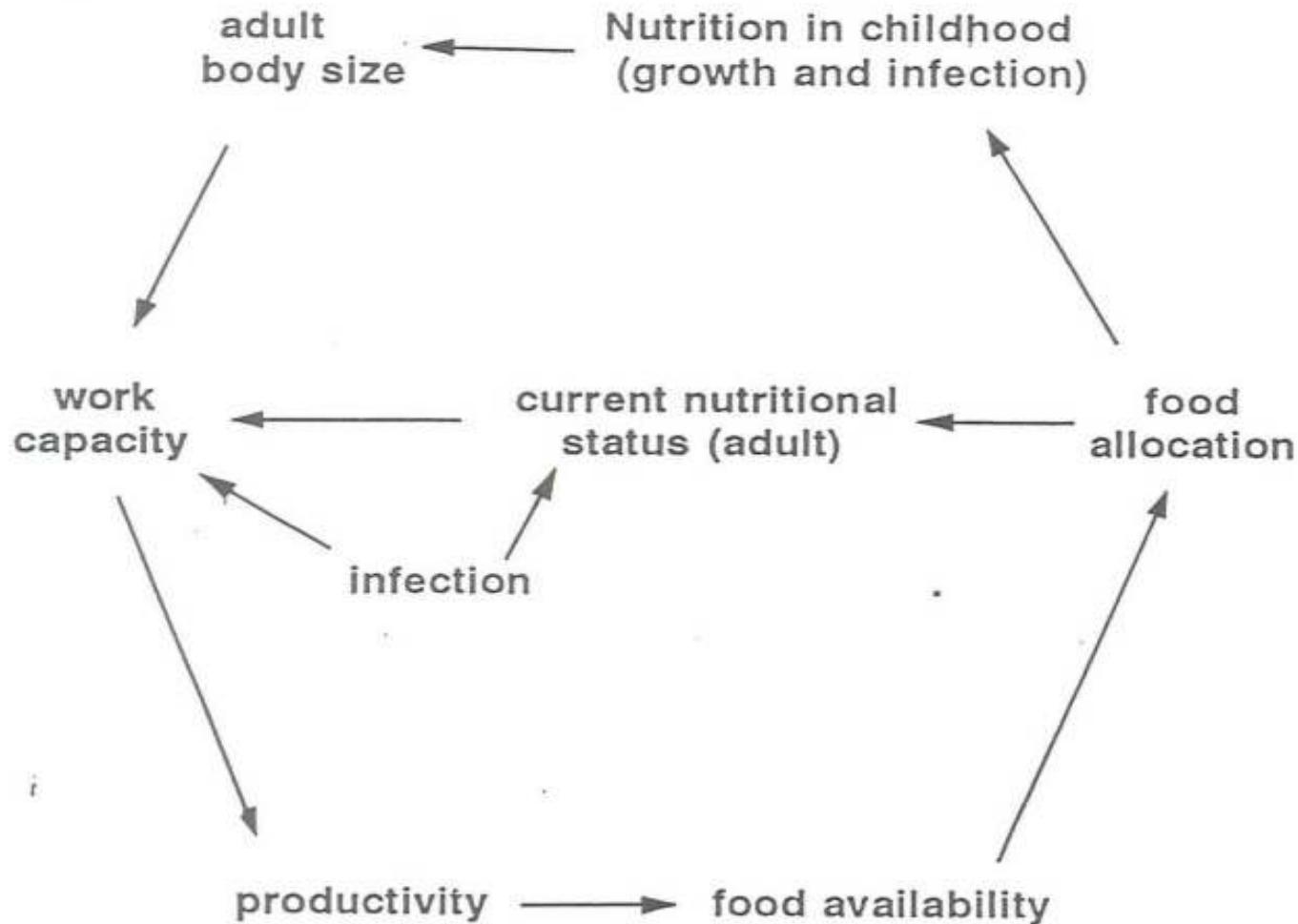
# Molecular System Bioenergetics

- **Higher-level analysis of complex biological systems: focus on relational properties**
- **Using information obtained in studies of isolated components**
- **Applying methods from cybernetics, mathematics, network analysis, nonequilibrium thermodynamics**

# **Ecological bioenergetics (Ulijaszek)**

- **Energy is a force (as is money)**
- **Many aspects of human activity involve energy transfer of one sort or another**
- **A form of biological economics**
- **Tradability of human physical energy for animal and technological force**
- **Tradability of food energy with fossil fuels (and other)**
- **Ecological sustainability**

# Ecological bioenergetics: relational biology of social beings (Ulijaszek 2000)



but the cultural and technological is poorly integrated

# **Human evolution: control of bioenergetic resources and survivorship (Leonard & Ulijaszek 2002)**

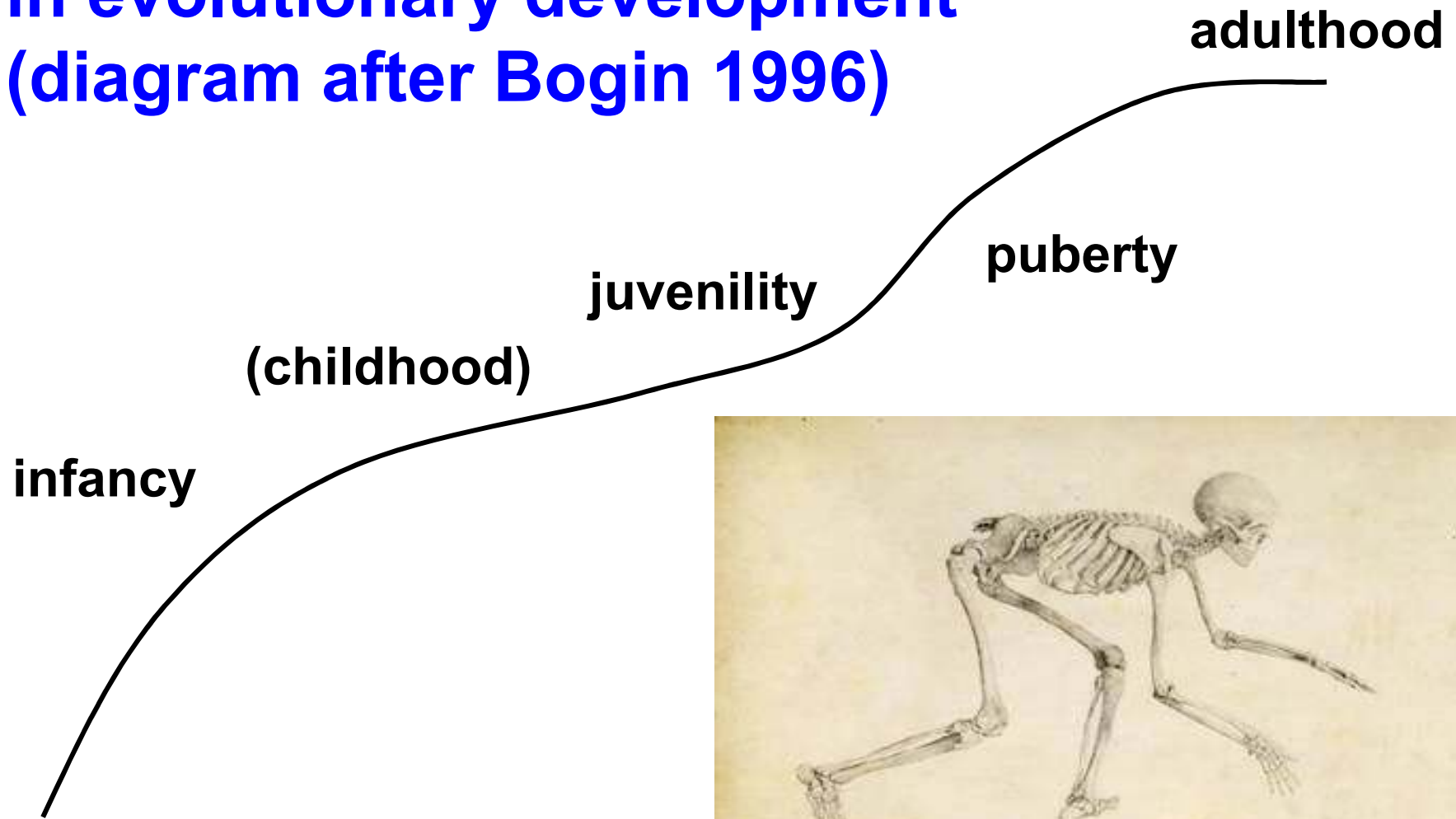
- **Increased body size**
- **Cheaper physical activity schedules**
- **Greater home range**
- **Dominance of food chain**
- **Increased dietary energy capture**
- **No decrease in dietary quality**
- **Small litter size, extended pregnancy**
- **High parental investment**

# Evolutionary bioenergetics

- **Genetics, biochemistry and morphology evolved in ecological context**
- **And they ‘talk’ to each other in evolutionary development**
- **Adaptations get fixed when the design is even marginally successful**
- **Evolution involves bioenergetic trade-offs**

# Bioenergetic trade-offs

- brain, body and parental investment -  
in evolutionary development  
(diagram after Bogin 1996)



# Triangulation of the three bioenergetics

**New scientific synthesis, under negotiation**

**Recent developments in genetics, physiology, medical imaging and network theory offer ways in which human action can be examined anew, linking energies of body and mind**

**Popular engagement with ideas that have bioenergetics at their core – obesity, starvation, sustainability, environmental degradation – suggest that this emerging synthesis carries great resonance which can be tapped to explore the human condition in a new way**

# Toward a cultural physiology

- **Bioenergetics cannot adequately measure energy flows between individual and social bodies**
- **Limited ability to explain intra-societal differences in how individuals mobilize energy resources while under particular cultural constraints**
- **Potentially informative social theory (eg. Bourdieu's 'habitus' (cultural predisposition towards repeating certain thoughts and actions)) absent from bioenergetics discourse**
- **Energized human bodies do not behave as predictably or mechanistically as a physiological understanding of energy flows might suggest.**
- **Bodies as creative agents in responding to and changing societal structures and behavioural conventions**
- **A measure of social energy exchanges needed**