

Environmental Physiology = Ecological Physiology = Physiological Ecology

Definition = the study of physiological adaptation or adjustment to the environment

Adaptation = some characteristic of an organism (structural, physiological, behavioral, etc.) that increases the fitness of the organism possessing it (i.e., increases its likelihood of survival and reproduction)

The basis for adaptation over the *long term* for *populations* is genetic variability.

- Natural selection acts on this genetic variability to preserve favorable traits that increase organismal fitness (these traits are termed adaptive traits)
- Thus, adaptation is a basic process in evolution → changing environments or circumstances result in long-term, or *evolutionary*, alteration of organismal characteristics (including physiology) to meet new demands.
- In this type of adaptive change, the genotype of the organism is modified over time to meet the demands of expected conditions (e.g., organisms native to high altitude show characteristics that are favorable in high altitude situations)

How to detect adaptation?

- 1) Correlation between a character and an environmental gradient or a functional response
 - Problem = correlations do not tell you about actual cause-effect relationships
 - Traits can be linked so that the trait you are measuring actually follows variation in another trait on which selection is acting
 - Correlations also don't tell you which trait is driving the correlation
 - 2) Comparisons of individual differences in a character within a species along an environmental gradient
 - Also provides only correlative evidence, so no cause-effect relationship can be established
 - 3) Experimental alteration of a character, followed by observation of the impacts of that alteration on organismal function (e.g., experimental modification of a phenotypic character, gene knockout experiments).
 - Provides better cause-effect information, but often doesn't measure actual fitness effects of the change
- The difficulty with most studies of “adaptation” is that actual measurements of the effect of the trait of interest on *fitness* are not usually undertaken. To do that requires following populations over time and noting changes in allele frequencies that occur in response to the experimental treatment.
 - Adaptation is usually thought of as a change in response to a long-term change in the environment that an organism faces.

The environment, however, is rarely constant even over the *short-term*.

- 1) Temporal Variation = daily and seasonal variation exist in many environmental factors (e.g., light, energy, temperature, moisture) and animals must respond to this variation in order to survive and reproduce
- 2) Spatial Variation = multitudes of habitats and microhabitats exist, even within a given environment or geographic area. Animals occupy most of the available habitats throughout the world, so they must show a wide variety of physiological adaptations allowing them to inhabit the conditions present.
 - Many of these habitats and microhabitats are potentially stressful to the organism, at least at times

- Stress = any stimulus capable of eliciting a series of stereotyped physiological responses (*stress response*). Environmental stressors may include:
 - low oxygen availability
 - extreme temperatures
 - low humidities (dehydration)
 - toxins

How do animals respond to changing environments?

I. Compensators vs. Regulators

- a. Compensators = allow internal environment to change along with the external environment, yet are able to compensate for these changes and *function in spite of them*. Compensators generally show a *wide range of internal conditions* that allow survival. However, *function may not be optimal over the entire range that is tolerated*.
- b. Regulators = maintain the internal environment within a narrow range of conditions, even in the face of changing external conditions. Regulators generally show (or tolerate) only a *narrow range of internal conditions* over which function is possible. *Function is optimal, or near optimal, over this narrow range*.

II. Tolerant and Resistance

- Tolerance = the amount of change in the internal environment (brought about by changes in the external environment) that an organism can withstand
- Resistance = after tolerance levels are exceeded, an animal can resist changes in the internal environment for a certain period, depending on how greatly the tolerance levels are exceeded, but will eventually succumb → death.

III. Phenotypic Plasticity and Phenotypic Flexibility

- Phenotypic Plasticity = environmental conditions during development fix a particular phenotype from a given genotype. Different environmental conditions during development can fix a different phenotype from the same genotype.
- Phenotypic Flexibility = physiological adjustments within individuals (usually adults) in response to variation in environmental conditions.
 - a. Acclimatization = changes occurring in the *natural environment* that result in changes in the physiology of the animal. Acclimatization usually results in shifts in lethal levels and tolerance zones.
 - b. Acclimation = the *laboratory* equivalent of acclimatization, where an animal is subjected to specific conditions that stimulate certain physiological changes or characteristics (e.g., cold acclimation → better performance in cold temperatures).
- Reaction Norm = profile of phenotypes produced by a given genotype in response to variation in environmental conditions (**Fig 1.5 Willmer et al.**).

(See Fig. 1.2 from Hoar – Animal Responses to Env. Condition and Fig 1.1 Willmer et al.)

Physical Factors of the Environment and Animal Adaptation

I. Energy

Energy (consumed) → Stored + Maintenance (metabolism) + Growth + Reproduction

Metabolism = sum total of biochemical reactions and processes occurring within an animal

- Metabolism is the only fate where energy is lost (as heat) because metabolic reactions do not show 100% efficiency (e.g., aerobic catabolism of glucose is approximately 65% efficient).

Storage = fat (lipids), glycogen (carbohydrates)

Environmental energy varies daily and seasonally, productivity varies with it along with the number of organisms that an environment can support.

II. Temperature

1. Definitions

- a) Ectotherm = depend on external sources for maintenance of body temperature
 - b) Endotherm = generate sufficient heat through metabolic processes to regulate body temperature
 - c) Poikilotherm = body temperature fluctuates with the surrounding environmental temperature (cold-blooded animals is a misnomer ...)
 - d) Homeotherm = maintains a constant body temperature
- Usually, ectotherms are poikilothermic and endotherms are homeothermic, but many exceptions exist.
 - Many ectotherms maintain relatively constant body temperature by behavioral adjustments and some can increase body temperature through muscular activity
 - Hibernating or torpid endotherms become essentially poikilothermic
 - Many other exceptions also exist
2. Internal body temperature change has a striking effect on many physiological processes. For many processes, a 10°C increase in temperature will increase the rate of a process by 2 to 3-times.
- Q_{10} = the change in the rate of a process caused by a 10°C change in body temperature (defined broadly = temperature effects on a process)

$$Q_{10} = (K_2/K_1)^{10/(T_2-T_1)}$$

III. Gaseous Environment

- 1) Oxygen = most important element for animals; aerobic metabolism is the main source of energy and is absolutely dependent of the availability of oxygen
- 2) Carbon Dioxide = very small component of ambient air; produced as a by-product of aerobic metabolism. Has a major effect on blood physiology, so animal must dump CO₂ to the environment.

(SEE HANDOUT ON COMPOSITION OF AIR – Contrast % with partial pressure)

- a. Partial pressure of gases change with altitude, not the composition of air itself, (See Schmidt-Nielsen, p. 9) and partial pressure is what is important for oxygen loading in the blood (actually oxygen volume is what is important, but PP is a good indicator in this case).
- b. Composition of air may change under certain special conditions (e.g., burrows).
- c. Gaseous environment of water is very different than that of air due to solubilities of gases differing (CO₂ 30-times more soluble than O₂) and to different masses of the inert medium. As a consequence a given volume of air contains much more oxygen than a

given volume of water, but the PP of gas in water is equal to the PP of a gas in the air with which the water is in equilibrium. Each gas is dissolved according to its own partial pressure in the gas phase.

- d. The amount of a gas dissolved in water depends on:
- 1) solubility
 - 2) partial pressure of gas in the gas phase
 - 3) temperature (increased temperature reduces solubility)
 - 4) presence of other solutes (saltwater contains less oxygen than freshwater at the same temperature)
- The end result is much more oxygen available in air than in water (about 30-times more at 15°C).

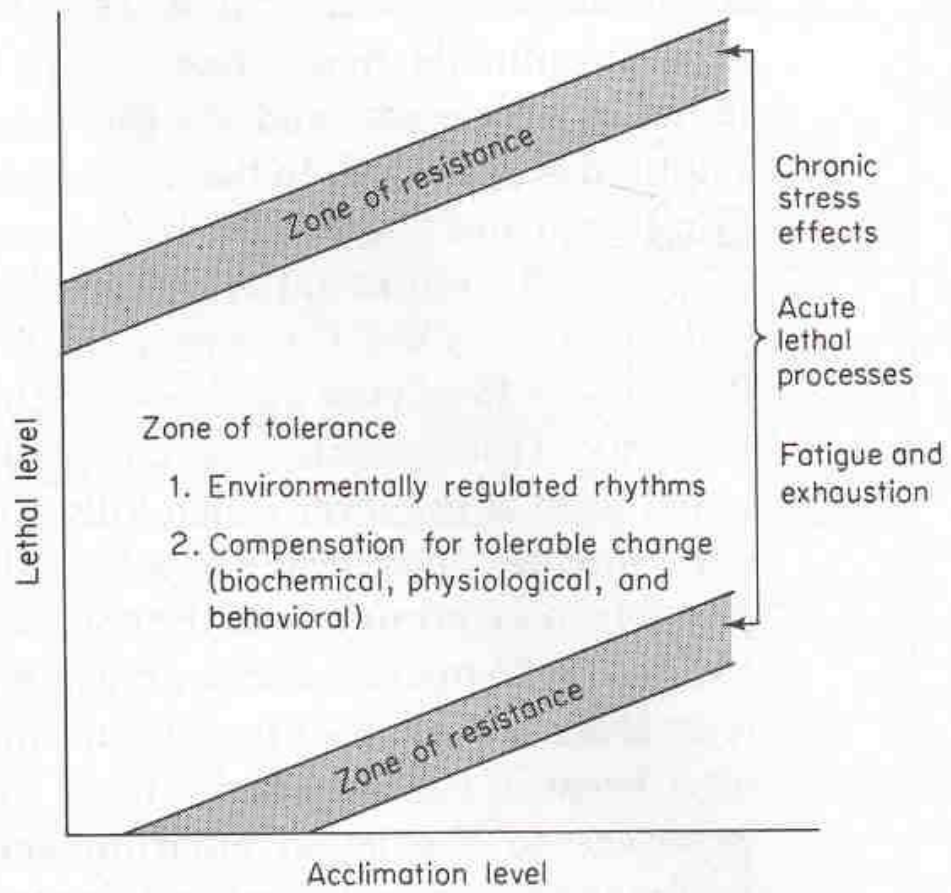
IV. Water Balance

1. Terrestrial animals and saltwater fish face water conservation problems. Saltwater invertebrates (and hagfish) don't, because they are compensators.
2. Freshwater animals face problems with ridding themselves of excess water (unless they adopt compensator strategy).
3. Water loss in terrestrial animals occurs via respiration, cutaneous evaporation, urine and feces. RWL probably the highest component for birds and mammals with high MRs.
 - RWL dependent on *Water Vapor Pressure* of ambient air. WVP at a given relative humidity increases as temperature increases (Low WVP in environment → high RWL).
 - (SEE HANDOUT)

V. Toxins

1. Animals produce endogenous toxins through metabolism that have specific pathways for breakdown and detoxification.
2. These same pathways allow breakdown and detoxification of exogenous toxic compounds (e.g., secondary plant compounds).

TAKE HOME MESSAGE: Environments are extremely variable and animals must exhibit a wide variety of physiological adaptations to cope with this variability

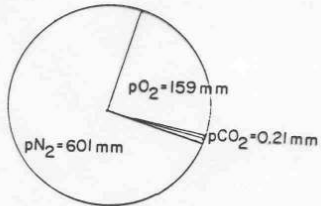
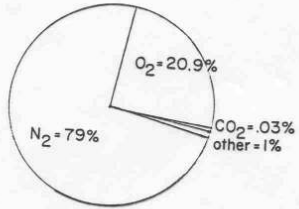


COMPOSITION OF AIR

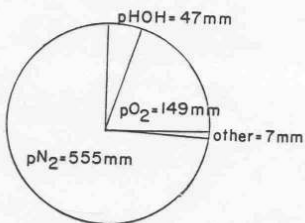
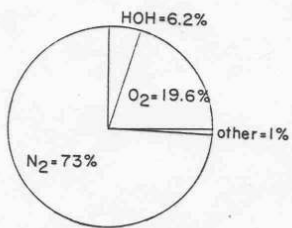
I. Clean dry air at sea level (Barometric Pressure = 760mm Hg).

PERCENT COMPOSITION

PARTIAL PRESSURES (mm Hg)



II. Clean moist air at sea level. Air is saturated with water (R.H. = 100%) at 37°C (eg., mammalian trachea and bronchi).



III. Normal air in the lung of an animal at sea level (pB = 760mm) at a body temperature = 37°C.

