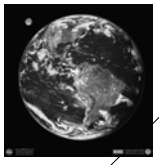
Survival and Adaptation

1926 Byrd and Bennett: first to fly over the North Pole?

Survival "niches"

- How much of the Earth is inhabitable?
  - 2/3 of the Earth is ocean
  - 1/3 is land
    - 1/4 is permanently frozen
    - 1/4 is arid desert
    - high mts, lakes and rivers



- Only about 1/6 of the Earth allows permanent habitation

"Limit Physiology"

- Humans are among the most adaptable animals to their environment
- Critical variables for survival
  - physics of the environment
  - limits of human physiology
  - length of exposure
  - behavioral adaptation
- Physical Diversity (& courage, fitness)
  - allows only temporary and small advantage

Homeostasis Concept

- Claude Bernard (late 1800s)
  - body fluids form an internal environment that provides stable conditions to sustain life at the cellular level (a stability or "sameness")
  - internal and external environments are independent of each other
  - physiological processes (respiration, circulation, heat balance, etc) act to maintain a constant *milieu-interieur*

Walter B. Cannon, 1932

- *It is a failure to maintain homeostasis when exposed to extreme environments that lead to death.*
- *Stability = a dynamic balance*

THE WAY OF AN INVESTIGATOR

A Scientist's Experiences in Medical Research

By

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Stress-Strain

- Stress
  - a threat to homeostasis from the external or internal environment
    - External: temperature, pressure, hypoxia
    - Internal: disease, strong emotions
- Strain
  - the physiological response of the organism
    - altered metabolic rate
    - redistribute blood flow

Shackelton Expedition

- Stressors
  - cold
  - malnutrition
  - fear
- Strain
  - ↑ metabolic rate
  - loss of muscle and fat
  - ↓ immune function

Adaptation

- Adaptation: a survival response to a change in the environment
  - Physiological Adaptation
    - a functional, structural or molecular change
    - slow or fast response
    - reversible or irreversible
  - Genetic Adaptation
    - natural selection
      - a change to the genetic code that favors survival
    - mutation

Mutations: good or bad?

- Scurvy: deficiency of ascorbic acid (Vit C)
  - humans cannot synthesize Vit C
  - Joseph Linde, British seaman, found you can prevent scurvy with fresh fruits and vegees.
- Skin coloration: white skin
  - good in northern climate to process Vit D
  - bad in southern climate: lose protection against UV damage

Acclimatization

- Adaptations that occur over a period of days to months in response to a change in the natural environment. *Usually there are more than one stressor in a natural environment.*
  - Desert: hot and dry
  - Altitude: cold and hypoxia
  - Spaceflight: microgravity, radiation, psychological
  - Diving: cold and hyperbaria

Acclimation

- Physiological changes to the whole body with repeated exposure to an artificial change in the environment. *Usually one specific stressor is induced.*
  - heat chamber
  - altitude chamber
  - pressure chamber
  - bed rest?

Accomodation

- Adaptations that occur in a single cell or tissue to an environmental change
  - increased size of sweat glands--heat
  - decreased sensitivity of peripheral blood vessels to vasoconstrict--cold
  - increased muscle mass--exercise
  - decreased sensitivity of chemoreceptors—hypoxia
  - dark skin—tanning booth
- Changes associated with acclimation

Habituation

- A reduction in response to an environmental stimulus over time
  - less vasoconstriction in the hands with repeated cold water immersion
  - less increase in heart rate with repeated heat exposure
  - less drop in arterial PO_2 with repeated altitude exposure
  - less airways constriction to pollutants
- Responses are often a sign of acclimation

De-acclimation and de-acclimatization

- A reversal of the adaptations with removal of the stressor(s)
- Variable time-courses for different adaptations
- Different temporal relationships to their rate of onset
  - 2 wks to heat acclimate, 4 wks to lose acclimation

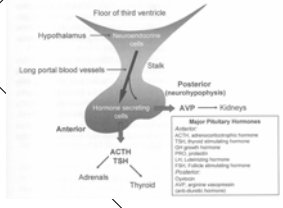
Mediators

- Biological, social or psychological factors that modifies the rate or degree of strain to a stressor
  - age
  - fitness
  - fluid intake (heat acclimation)
  - body fat (cold adaptation)
  - previous experiences
  - personality characteristics

The stress response

- Hans Selye, 1937
  - all types of acclimation invoke a non-specific stress reaction: a general adaptation syndrome
- Stress and adaptation involve interaction between the nervous, endocrine and immune systems

The hypothalamus



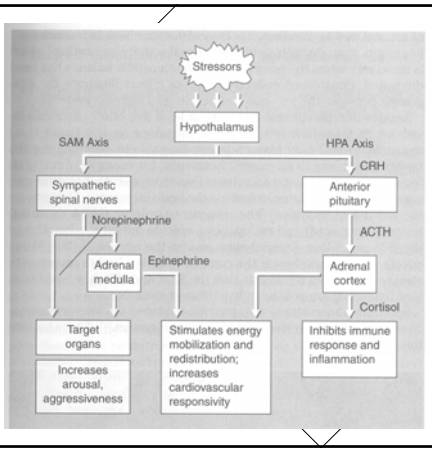
- Regulates body temperature, sleep, appetite
- Connects CSF, higher brain, spinal cord, pituitary
- Secretes neuropeptides that stimulate pituitary to release hormones

Key pituitary hormones for all types of acclimation

- ACTH
  - adrenal corticosteroids (eg. Cortisol)
- TSH
  - thyroid hormone
- AVP

Sympathetic/adrenal/medullary axis (SAM)

- Stress activates SNS (NE)
- Activates the adrenal medulla (EPI)
- Causes the flight or flight response



Neuropeptides that modulate HPA and SAM axes

- serotonin, alters ACTH release
- GABA (gamma-aminobutyric acid) and endogenous opioids, inhibit HPA axis
- acetylcholine, excites release of CRH (corticotropin releasing hormone) ↑HPA axis
- dopamine, precursor of NE

Other hormones altered by environmental stressors

- Initial Stress response: Catabolic
  - growth hormone, prolactin, thyroxine
- Post-stress response: Anabolic
  - insulin, testosterone, estrogen

Molecular Mediators of adaptation

- Different stressors cause the release of over 100 neuropeptides and hormones
  - some influence body temperature
    - thyroid hormone
    - endogenous pyrogen (IL-1)
  - some alter immune function
    - cytokines
    - heat shock proteins (HSP)

Stress Proteins

- 1970s heat shock proteins discovered
  - induced by many stressors
    - Heat, cold, hypoglycemia, ischemia
  - alter protein folding, protein synthesis, or modification
  - Protect the cells against damage
  - Mechanism for thermotolerance?
  - Cross acclimation?

Cross Acclimation

- When humans are exposed to 2 or more environmental stressors,
  - positive interactions
    - humans who adapt positively to one stressor (heat) will respond better to another (hypoxia)
  - negative interactions
    - humans who adapt positively to one stressor (cold) will respond worse to another (hypoxia)

Cross acclimation: example

- What stressors?
- Major risks?
- Interactions?

Environmental Stressors

- Heat
- Dehydration
- Cold
- Altitude/hypobaria
- Hypoxia
- Noise
- Hyperbaria
- Microgravity
- Malnutrition
- Radiation
- Pollution
- G forces