Citation Key
for more information see: http://open.umich.edu/wiki/CitationPolicy

Use + Share + Adapt

- Public Domain – Government: Works that are produced by the U.S. Government. (USC 17 § 105)
- Public Domain – Expired: Works that are no longer protected due to an expired copyright term.
- Public Domain – Self Dedicated: Works that a copyright holder has dedicated to the public domain.
- Creative Commons – Zero Waiver
- Creative Commons – Attribution License
- Creative Commons – Attribution Share Alike License
- Creative Commons – Attribution Noncommercial License
- Creative Commons – Attribution Noncommercial Share Alike License
- GNU – Free Documentation License

Make Your Own Assessment

- Public Domain – Ineligible: Works that are ineligible for copyright protection in the U.S. (USC 17 § 102(b)) *laws in your jurisdiction may differ
- Fair Use: Use of works that is determined to be Fair consistent with the U.S. Copyright Act. (USC 17 § 107) *laws in your jurisdiction may differ

Our determination DOES NOT mean that all uses of this 3rd-party content are Fair Uses and we DO NOT guarantee that your use of the content is Fair.

To use this content you should do your own independent analysis to determine whether or not your use will be Fair.
Body Temperature Regulation

M1 – Cardiovascular/Respiratory Sequence

Louis D’Alecy, Ph.D.

Fall 2008
Tuesday 11/11/08, 9:00
Body Temperature Regulation
(an example of physiological control system)
27 slides, 50 minutes

1. Control System Generalizations
2. Skin blood flow
3. Body Temperature Regulation
4. Control System Competition
5. Adaptation vs. Acclimatization
6. Control Systems Review
CONTROL SYSTEM GENERALIZATIONS

1. Homeostatic control systems cannot maintain complete constancy of controlled variable. (Error signal ***)

2. It is not possible for everything to be maintained relatively constant by homeostatic control systems.

3. Stability of a variable is achieved by balancing inputs (+) and outputs (-).

4. The set point of a homeostatic control system can be reset - raised or lowered.

5. Multiple control systems can operate on the same variable.
Multiple control systems for internal environmental temperature.

STIMULUS

Tb Internal Environment

receptor

integrating center

effectors

RESPONSE

NEGATIVE FEEDBACK

FEEDFORWARD

LOCAL RESPONSE
Summary
Control of Skin Blood Flow

- Primary heat exchange of body
- Large venous plexus = large blood volume
- **Alpha adrenergic vasoconstriction dominant**
- Sympathetic-cholinergic vasodilation-sweat*
- Local cooling = vasoconstriction (then VD!)
- Triple response (historical ?Boards?)
  - red line, red flare, wheal
- CO$_2$ and O$_2$ minimal effects
- Autoregulation assumed unimportant
Image of set point mechanism removed
SET POINT

Image of set point operator removed
Changes in internal body temperature

37°C

Set point

Body temperature

20°C

External environmental temperature

5°C

Error signal
Multiple control systems possible
For same variable.

INTERNAL ENVIRONMENT

NEGATIVE FEEDBACK

FEEDFORWARD

LOCAL RESPONSE
HOMEOSTATIC REFLEX PATHS CONTROLLING BODY TEMPERATURE

INTEGRATING CENTER

ASSERENT PATHWAY

RECEPTORS

STIMULUS ↓ BODY TEMP

NEGATIVE FEEDBACK

SPECIFIC NERVE CELLS IN BRAIN

NERVE FIBERS

TEMP-SENSITIVE NERVE ENDINGS

SMOOTH MUSCLE IN SKIN BLOOD VESSELS

BLOOD VESSEL CONSTRICITION

HEAT LOSS

SHIVERING ↑ HEAT PRODUCTION

SKELETAL MUSCLES

Blood vessel constrictions increase body temperature. 

INTEGRATING CENTER receives sensory information and provides control signals.

Affenent Pathway (stimulus to integrating center) is mediated by temperature-sensitive nerve endings and nerve fibers.

Efferent Pathway (control signals to effectors) involves integrating center to skeletal muscles and smooth muscle in skin blood vessels.

Body temperature control involves both positive and negative feedback mechanisms.

J. McReynolds
skin thermal receptors

spinal cord thermal receptors

suprachiasmatic nucleus (circadian rhythm)

Central thermal receptors in the hypothalamus

HYPOTHALAMUS

temperature integrating center
NON-SHIVERING THERMOGENESIS

Epinephrine

uncouple oxidative phosphorylation in brown fat mitochondria

Thyroxine

futile cycle due to increased Na+ Permeability in cells

Both processes greater in infants than in adults
Thermoneutral zone - range of environmental temperatures in which body temperature can be maintained by adjustment of skin blood flow alone.

Nude human thermoneutral zone 25°- 31°C (77°- 88° F)

Below thermoneutral zone - increased metabolic rate and vasoconstriction

Above thermoneutral zone - sweating
AV Anastomosis
cold environment  warm environment

core 37°C
32°C
shell 28°C
34°C
31°C

cold environment  warm environment
LOCAL RESPONSES TO SKIN BLOOD FLOW

Local heating or cooling of skin produces spinal reflex increases or decreases in skin blood flow by changing the degree of alpha adrenergic activation.
SKIN BLOOD FLOW

sympathetic AP

Normal Resting \( \alpha \) tone

\( \alpha \) adrenergic receptors - contract vascular smooth muscle

vasoconstriction below Ta 75 ° F

max vasodilation above Ta 115 ° F
Sweat gland

1. Precursor fluid similar to plasma but no protein. $\text{Na}^+ \sim 142\text{meq/L}$

2. At low flow most $\text{Na}^+$ reabsorbed $\sim 5\text{ meq/L}$

3. In unacclimatized person high flow $\text{Na}^+ \sim 50\text{ meq/L}$ less $\text{Na}^+$ reabsorbed.

4. Training increases aldosterone and $\text{Na}^+$ reabsorption, Better evaporation, Better cooling.

Source Undetermined
Thermoreceptors

vascular smooth muscle

baroreceptors

temperature
temperature

blood pressure

VD or VC?

sweat glands

fluid loss

sweating

COMPITITION

$T_b$

D'Alecy
Adaptation - a biological characteristic that favors survival in a particular environment.

  e.g. sweating in response to hot environmental temperature

Acclimatization - environmentally induced increase in the capacity of system to adapt

  e.g. increased volume of sweat production after weeks of exposure to hot environment
Hypothalamic Set Point

Aspirin

Prostaglandins

Cyclooxygenase

Arachidonic Acid

Interleukins 1, 6

Tumor Necrosis Factor

Endogenous Pyrogens

Interleukin 1

Inflammation

Bacterial Lipopolysaccharide

Macrophages and Monocytes
FEVER raises the hypothalamic set point for $T_b$. 

---

*Source Undetermined*
HEAT EXHAUSTION (excess compensation)

Weakness and fainting in warm environment
Little change in core body temperature
Hypotension - due to loss of fluid (sweat) and decreased total peripheral resistance due to vasodilation of skin vessels

HEAT STROKE (failed compensation)

Medical emergency - core temperature rises to point that hypothalamic integrating center ceases to function.
Sign - absence of sweating.

MALIGNANT HYPERTHERMIA

Triggered by some anesthetic agents or genetic defect in Ca release in skeletal muscle. Increased release of calcium turns on muscle contraction.
Control System Review
CONTROL SYSTEM

Integrating Center

Afferent Pathway

nerves & hormones

Receptor

Efferent Pathway

nerves & hormones

muscle & glands

STIMULUS

RESPONSE

feedback

D'Alecy
Feedforward - system anticipates change in a controlled variable before it occurs by monitoring changes in the external environment.

Examples:
1) Skin temperature receptors alter the body’s heat production and heat loss mechanisms before there is a change in core body temperature.

2) Glucose receptors in GI tract increase insulin secretion before glucose absorption has raised blood glucose.
HOMEOSTATIC CONTROL SYSTEMS

• REFLEX Involuntary, built-in response to a stimulus

• REFLEX ARC Pathway(s) between stimulus and response in a reflex

• NEGATIVE FEEDBACK SYSTEM
  • Responses tend to move variable back in the opposite direction.

• SET POINT The normal value for the variable to be controlled.
  • Set point can be physiologically reset (e.g. fever)

• ERROR SIGNAL
  – Difference between set point and actual value of variable.

• POSITIVE FEEDBACK SYSTEM
  • Response moves the variable further in the same direction.
Additional Source Information

for more information see: http://open.umich.edu/wiki/CitationPolicy

Slide 6: D’Aley
Slide 10: McGraw-Hill
Slide 11: D’Aley
Slide 12: J. McReynolds
Slide 13: D’Aley
Slide 14: McGraw-Hill
Slide 17: Source Undetermined
Slide 18: Source Undetermined
Slide 19: D’Aley
Slide 20: D’Aley
Slide 21: Source Undetermined
Slide 22: D’Aley
Slide 24: D’Aley
Slide 25: Source Undetermined
Slide 28: D’Aley