
بسم الله الرحمن الرحيم

Blood & Immunity Module

Small Group Discussion (SGD)

FIRST YEAR MBBS BATCH 50

Topic

Physiologic Mechanism Of Temperature Regulation:-

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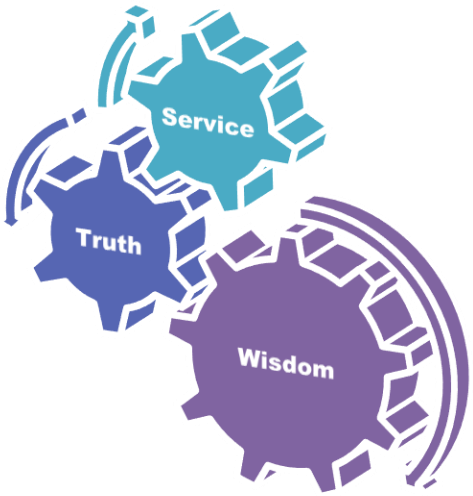
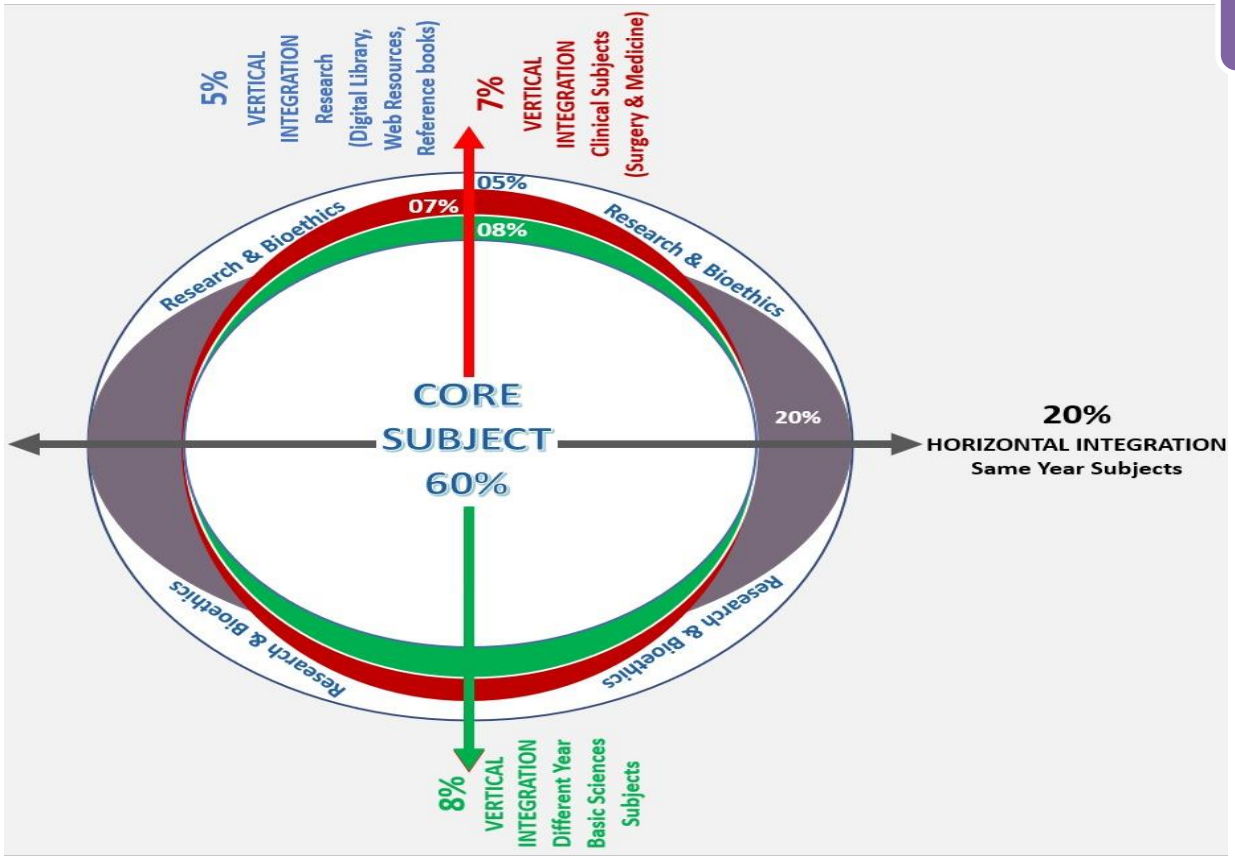
Motto



Vision; The Dream/Tomorrow

- To impart evidence based research oriented medical education
- To provide best possible patient care
- To inculcate the values of mutual respect and ethical practice of medicine

Professor Umar Model of Integrated Lecture



60% CORE SUBJECT

20% HORIZONTAL INTEGRATION Physiology biochemistry

8% VERTICAL INTEGRATION Pathology pharmacology

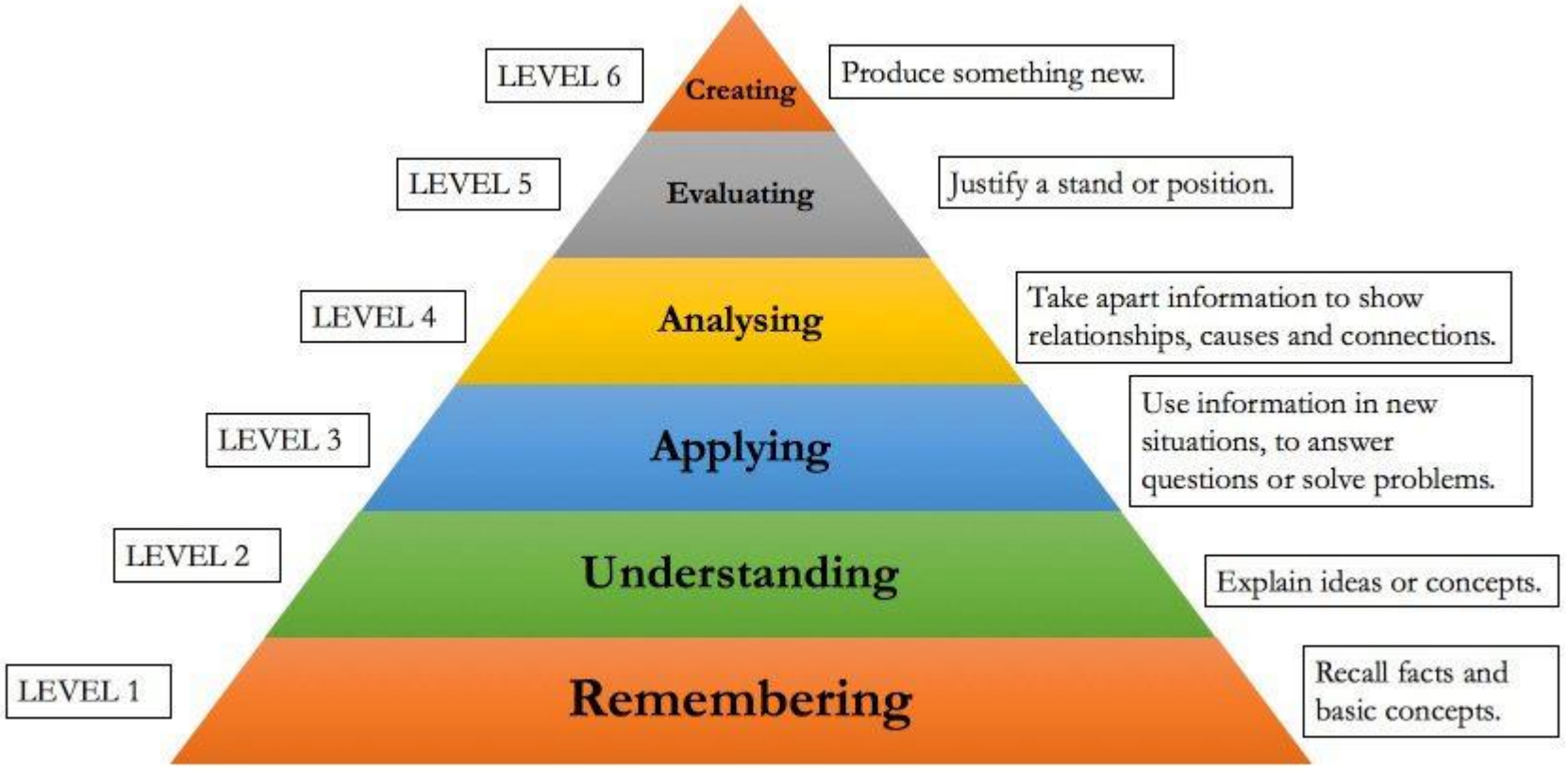
7% VERTICAL INTEGRATION Clinical integration

5% VERTICAL INTEGRATION Research, professionalism Ethics Digital library

BLOOM'S TAXONOMY : DOMAINS OF LEARNING

Sr. #	Domain of learning	Abbreviation	Levels of the domain	Meaning
1	cognition	C	C1	Recall / Remembering
2			C2	Understanding
3			C3	Applying / Problem solving
4	Psychomotor	P	P1	Imitation / copying
5			P2	Manipulation / Follows instructions
6			P3	Precision / Can perform accurately
7	Attitude	A	A1	Receiving / Learning
8			A2	Respond / Starts responding to the learned attitude
9			A3	Valuing / starts behaving according to the learned attitude

BLOOM'S TAXONOMY OF THE COGNITIVE DOMAIN



LEARNING OBJECTIVES

Sr. #	Learning Objective	Domain of Learning
1	To study Regulation Of Body Temperature	C1
2	To Describe Factors affecting body temperature	C2
3	To Recognize Channel of heat loss- radiation, conduction, convection and evaporation	C2
4	To understand Neural Pathway For Sweat Regulation.	C2
5	To relate hypothalamus control and Effector Mechanisms in Temperature Regulation	C3
6	To diagnose and investigate patients with Heat Stroke.	C3
7	To Explain the process fever and hyperthermia.	C2

Horizontal integration

Biochemistry:-

1. Stimulus - Changes in the temperature of our external environment can cause core body temperature to rise or fall

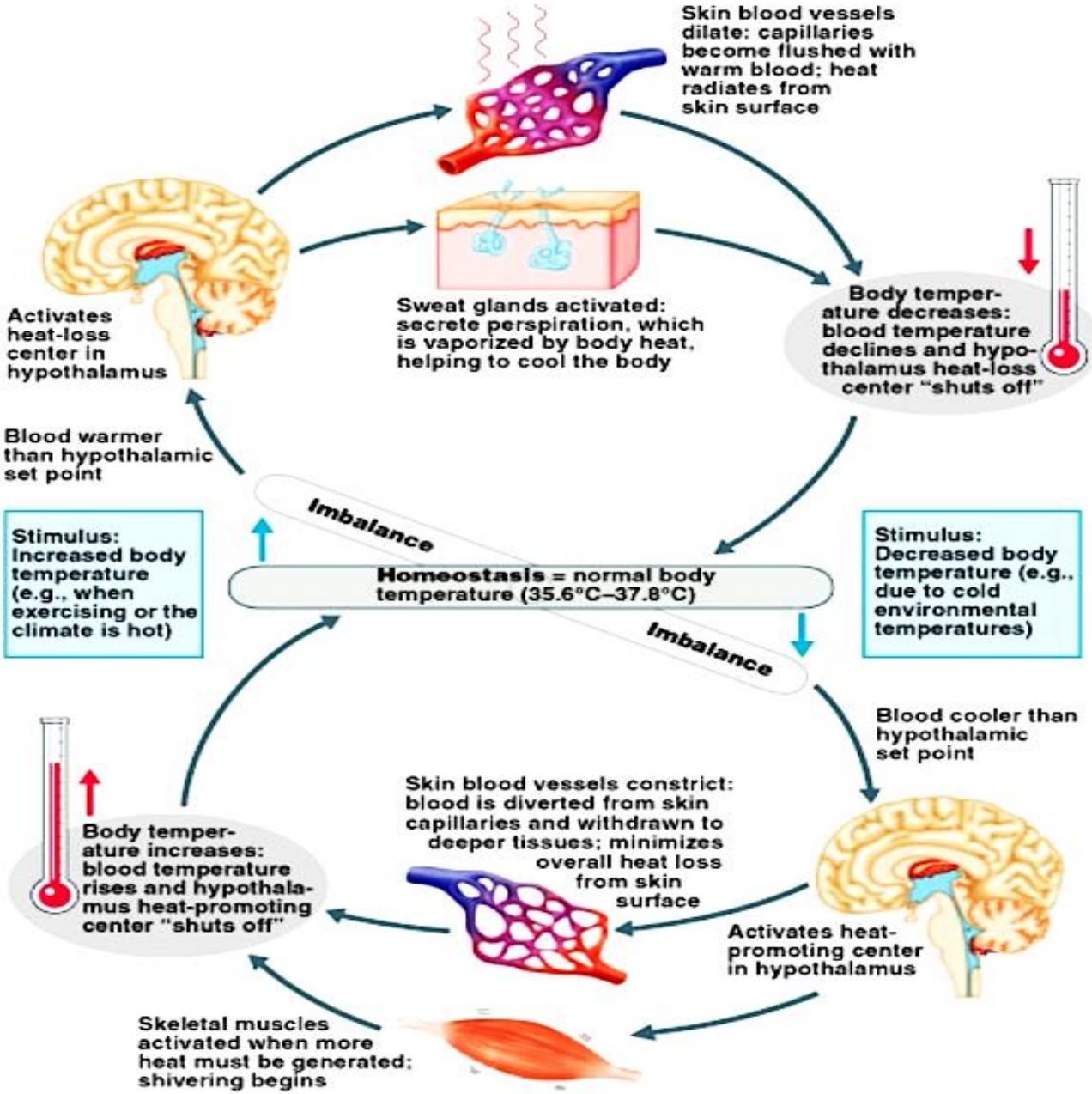
2. Receptors - Nerve endings in the skin and brain (hypothalamus) sense the external and internal body temperature respectively.

3. Control Centre - The hypothalamus (part of our brain) processes signals from the thermoreceptors and signals various effectors that are used to restore the core temperature to its set point (approximately 37°C).

4. Effectors - The following components are used to adjust our core temperature, compensating for the external environment and restoring our core temperature to its set point.

- Skeletal Muscles
- Smooth Muscle Surrounding Blood Vessels
- Thyroid Hormones
- Adrenaline
- Piloerector Muscles
- Sweat Glands

5. Effect - Our core body temperature is raised / lowered back to it's set point of approximately 37°C



Reference: https://www.pathwayz.org/Tree/Plain/THERMOREGULATION

Core Concept

Introduction:-

- **Homeothermic** (WARM blooded)- Humans capable of maintaining their body temperatures within narrow limits inspite of wide variations in environmental (ambient) temperature.
- **Poikilothermic**- (Cold blooded) eg.-fish, reptiles
- **Neutral zone temperature/ Comfortable temperature/Critical / ambient temperature-** at which there is no active heat loss and heat gain mechanism operated by body.
- So it is the lowest ambient temperature at which mammals can maintain its body temperature at the basal metabolic rate.
- Normally it is $27 \pm 2º$ C
- Living tissues can function optimally only within a very narrow range of temperature.
- Therefore accurate regulation of body temperature is a great boon: it enables the animal to be physically active all round the year, and in different geographical locations.

Why Regulation Of Body Temperature Is Required ?

- The enzymes of the body work in optimal temperature
- Speed of chemical reaction varies with temperature
- Very low temperature leads to cardiac fibrillation and failure (Lower lethal core temperature is 26ºC).
- Very high temperature leads to heat stroke (Upper lethal core temperature is 43.5 ºC).

Body Temperature:-

- Temperature can be expressed as ^{0}C or ^{0}F. C = (F - 32) x 5/9 and F = (C x 9/5) + 32
- Normal is 37^{0}C or 98.6^{0}F , Range- 36.3 to 37.1ºC (97.3- 98.8ºF)
- Measured under tongue, axilla or rectum by thermometer.
- Oral temp is 0.5^{0}C less than core body temperature (rectal temp).
- Site for recording core temperature- Rectum, Vagina, Tympanic Membrane.
- The core of the human body includes the organs of the thorax, abdomen and the head.This is where the vital organs are located.
- Their enzyme systems must operate in optimum conditions
- The periphery of the body can withstand some deviation from the core temperature.

Temperature (°C) with Consequences

- 40-44°C -- Heat stroke with multiple organ failure and brain lesions
- 38-40°C-- Hyperthermia (as a result of fever or exercise)
- 36-38°C -- Normal range
- 34-36°C -- Mild hypothermia
- 30-34°C-- Impairment of temperature regulation
- 27-29°C -- Cardiac fibrillation

Factors affecting body temperature

1.Age-

Infant- 0.5ºC more than normal due to irregular activity, brown fat, premature thermoregulatory mechanism.

Old age- subnormal temperature due to decrease activity, low BMR, weak thermoregulatory mechanism.

2.Sex-

Females body temperature is slightly low due to low BMR, more subcutaneous fat. Temperature increases 0.5ºC at the time of ovulation (Progesterone effects)

3.Diurnal variation-

Its up to 1.5ºC. Lowest in early morning and maximum in evening.

4.Diseases-

Increased in hyperthyroidism, malignancy.

Decreased in hypothyroidism.

Factors Affecting Body Temperature:-

5.Exercise-

It can cause increase up to 40-41ºC / 104-106ºF (inability of heat dissipating mechanism to handle that increased amount of heat). The body's rate of heat production can vary from ~70 kcal/hr at rest to kcal/hr during jogging.

6. Emotional factor-

Can increase approx. 2ºC due to unconscious tensing of the muscle.

Heat Production:-

Heat production is the principal by product of Metabolism, its important factors include:-

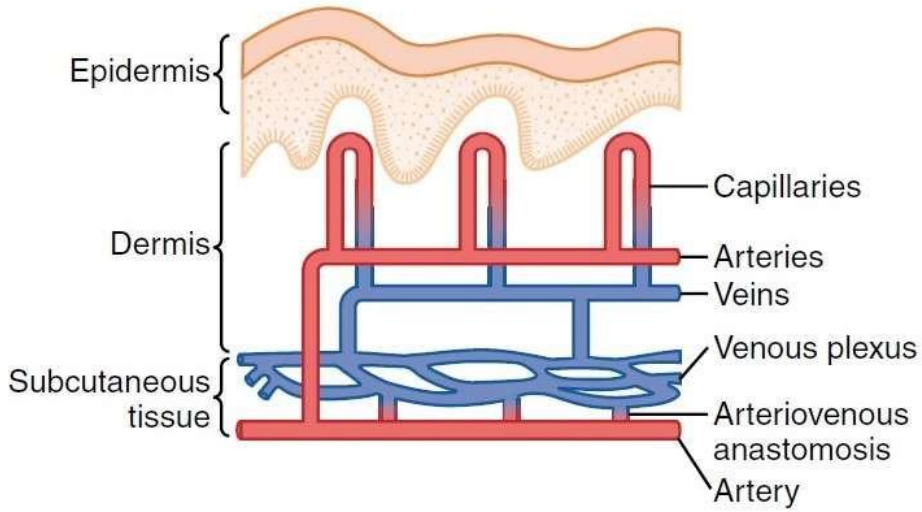
1. basal rate of metabolism of all the cells of the body;
2. extra rate of metabolism caused by muscle activity, including muscle contractions caused by
   shivering;
3. extra metabolism by the effect of thyroxine (growth hormone and testosterone) on the cells;
4. extra metabolism by the effect of epinephrine, norepinephrine, and sympathetic stimulation on the cells;
5. extra metabolism by increased chemical activity in the cells themselves, especially when the cell temperature increases;
6. extra metabolism needed for digestion, absorption, and storage of food (thermo-genic effect of food).

Heat loss:-

- Insulator System of the Body.
- Blood Flow to the Skin from the Body Core Provides Heat Transfer.
- Control of Heat Conduction to the Skin by the Sympathetic Nervous System.
- Channel of heat loss- radiation, conduction, convection and evaporation.
- Sweating and Its Regulation by the Autonomic Nervous System.
- Loss of heat by panting.
- Role of the Anterior Hypothalamic-Preoptic Area in Thermostatic Detection of Temperature.

Insulator System of the Body and Blood Flow to the Skin from the Body Core Provides Heat Transfer:-

- The skin, the subcutaneous tissues, and especially the fat of the subcutaneous tissues act together as a heat insulator for the body.
- Blood vessels are distributed profusely beneath the skin. It's a continuous venous plexus that is supplied by inflow of blood from the skin capillaries.



Insulator System of the Body and Blood Flow to the Skin from the Body Core Provides Heat Transfer:-

- In the most exposed areas of the Body(hands, feet, and ear) blood is also supplied to the plexus directly from the small arteries through highly muscular arteriovenous anastomoses.
- A high rate of skin flow causes heat to be conducted more from the core of the body to the skin.
- Reduction in the rate of skin flow can decrease the heat conduction from the core.
- The skin is an effective controlled “heat radiator” system.

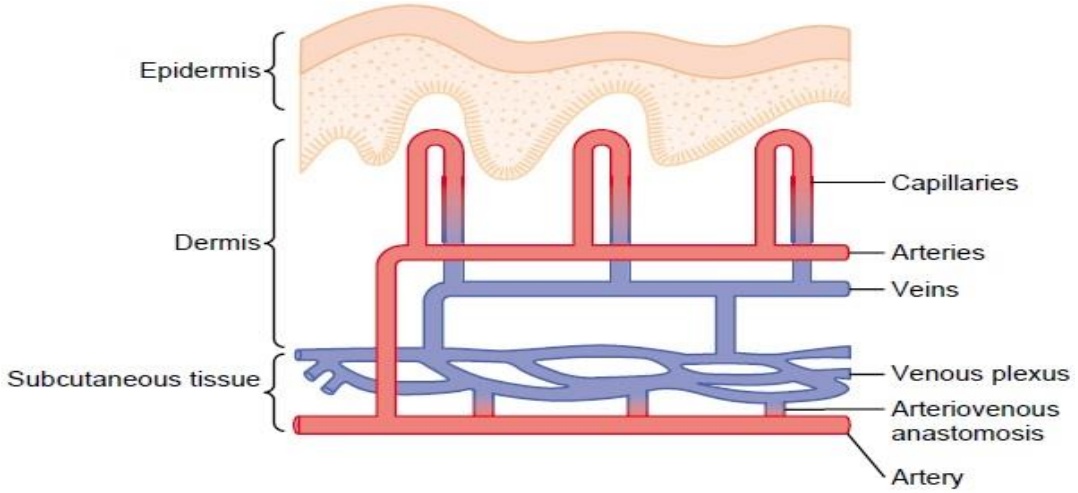


Figure 73–2

Skin circulation.

Channel of heat loss- radiation, conduction, convection and evaporation:-

- Radiation- about 60 percent in the form of infrared heat rays.
- Conduction- about 3 percent, from the surface of the body to solid objects, such as a chair or a bed. About 15 percent loss of heat by conduction to air..
- Convection- removal of heat from the body by convection air currents
- Evaporation- water evaporates from the body surface, 0.58 Calorie of heat is lost for each gram of water that evaporates. water evaporates insensibly from the skin and lungs at a rate of about 600 to 700 ml/day. This causes heat loss at a rate of 16 to 19 Calories per hour..

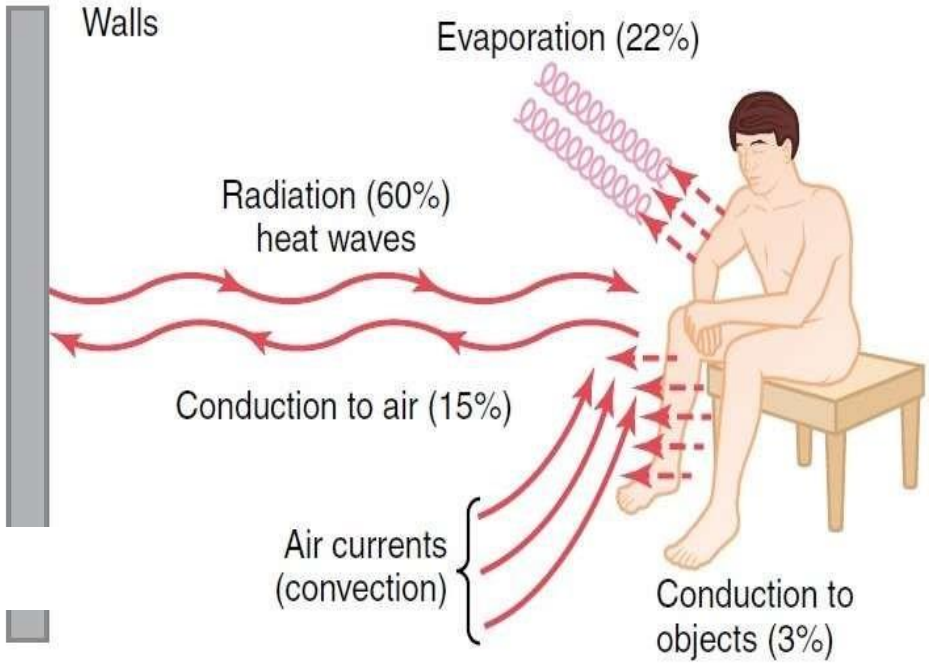
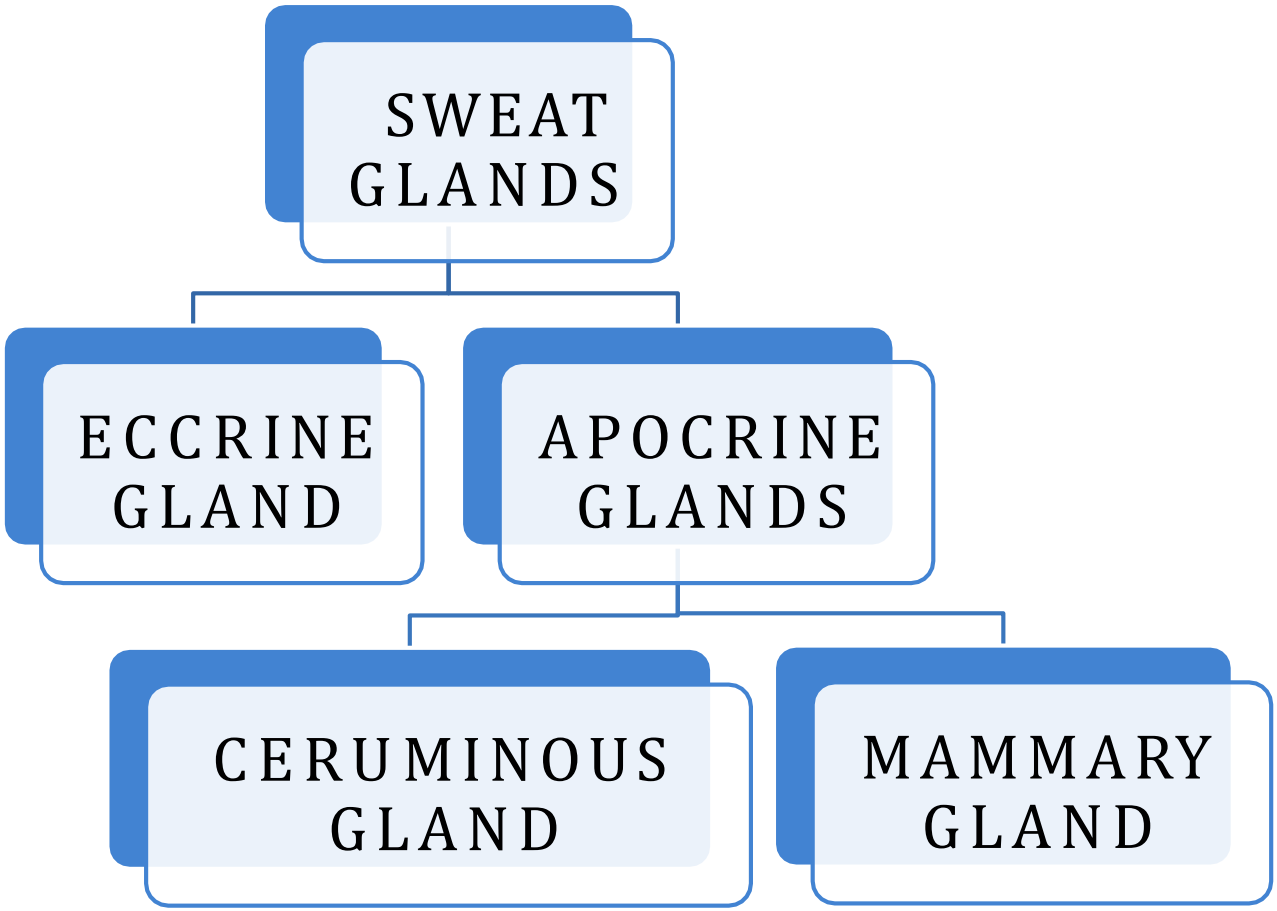


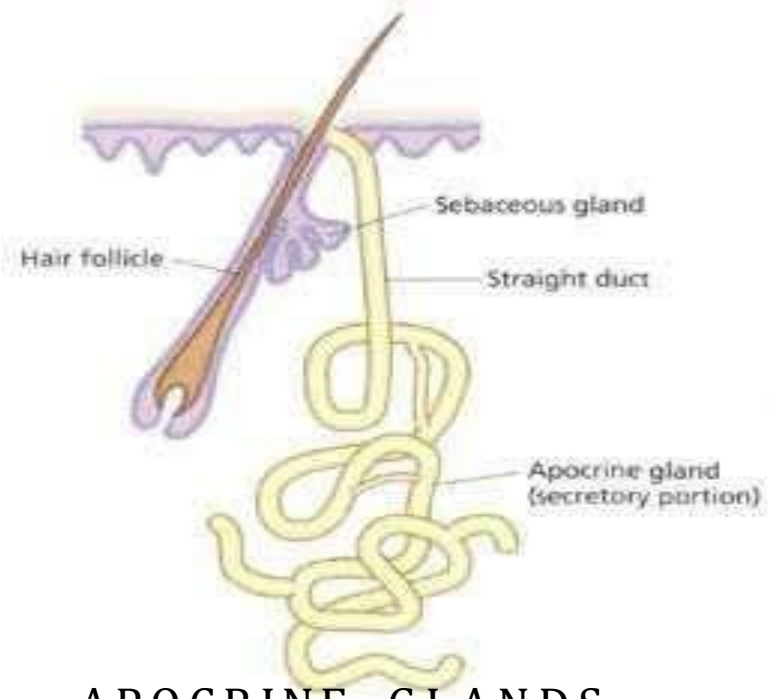
Figure 73-4 Mechanisms of heat loss from the body.

Heat loss by Sweat Glands:-

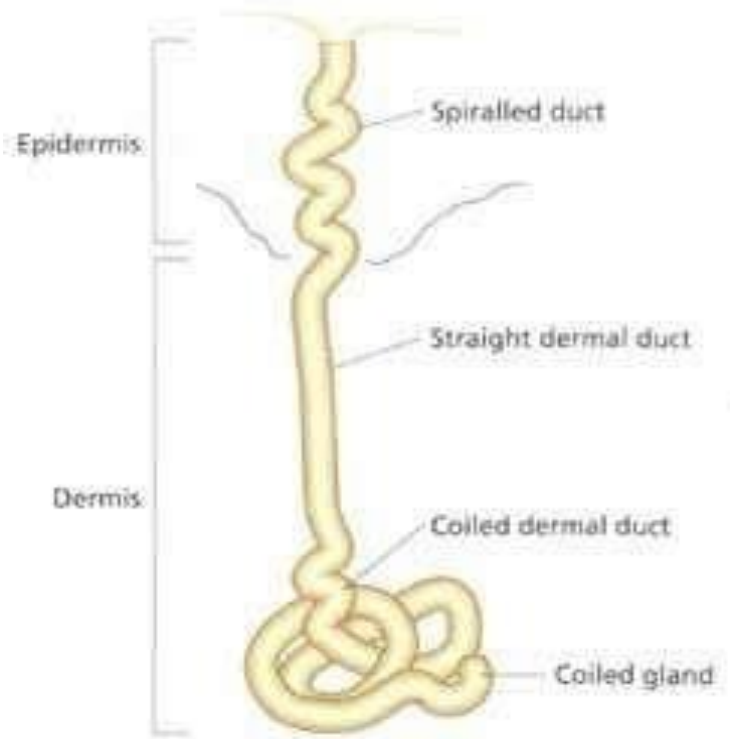


Composition of sweat:-

- 99% Water
- Some salts (mostly Na Cl)
- Vitamin C
- A microbe killing peptide dubbed DERMICIDIN
- Trace of metabolites (urea, uric acid, ammonia)
- Lactic acid



APOCRINE GLANDS



ECCRINE GLAND

Sweat Formation:-

When the sweat gland is stimulated ; the cells secrete a fluid (Primary secretion) . It is mostly water and it has high concentrations of Sodium and Chloride and low concentration of Potassium; but without the proteins and the fatty acids.

The source of fluid is the space between the cells (interstitial spaces); which get the fluid from the blood vessels in the dermis. This fluid travels from the coiled portion up through the straight duct.

Primarily Sweat Glands are controlled by a central thermoregulatory centre in brain and modulated by mean skin temperature.

Regulation of sweat:-

Regulated by the sympathetic division of the autonomic nervous system.
Major is to prevent overheating of the body

Two kind of sweating-

1. HEAT INDUCED SWEATING

Begins on the forehead; then spreads inferiorly over the remainder of the body.

2. EMOTIONALLY INDUCED SWEATING

Also called cold sweating

Brought on by fright ; embrrassment or nervousness

Begins on the palms, soles,and axillae and then spreads over the entire body

Neural Pathway For Sweat Regulation:-

1. Efferent signals from the pre optic area travels via the tegmentum of the pons and the medullary raphe region to the intermedio-lateral cell column of the spinal cord.
2. In the spinal cord, neurons emerges from the ventral horns, pass through the white ramus communicans and the synapse in the sympathetic ganglia.
3. Postganglionic non mylinated c fibres pass through the grey ramus communicans , combine with the peripheral nerves and travel to the sweat gland, with these nerve fibres , entwinded around the perglndular tissues of the eccrine gland

Temperature – Regulating Reflexes:

- Thermoreceptors detect changes in the balance between heat loss & production.
- **Two types-**
  1. Peripheral on Skin (free nerve ending)
  2. Central in hypothalamus (integrating center), spinal cord, abdominal organs.

Output from hypothalamus is sent to effectors via-

1. sympathetic nerves to sweat glands,
2. skin arterioles & adrenal medulla.
3. Motor neuron to skeletal muscles.

- Core temp is maintained relatively constantly.
- Peripheral thermoreceptors help identify heat & cold.

Thermo-neutral zone(TNZ)

- 25^0C to 30^0 C or 75^0F to 86^0F is known as a Thermo-neutral zone.
- At temperature lower than this TNZ - Vasoconstriction cannot prevent heat loss from exceeding heat production & this requires the body to increase heat production.
- At temperature above this TNZ - Vasodilation cannot eliminate the heat as fast as it is produced & this requires another heat loss mechanism 'SWEATING'

Control Mechanisms of Temperature Regulation:-

Nervous Mechanisms

> Thermoregulatory centers

Direct Action

Reflex Mechanisms

Efferent Nerves

> Endocrine and Temperature Control

Adrenal Medulla

Adrenal Cortex

Thyroid

Behavioral Control.

Voluntary control.

Hypothalamus control

1. Receptors - warmth & cold receptors from skin, deep tissues, spinal cord and hypothalamus
2. Heat loss center – Pre-optic & Anterior hypothalamic nuclei
3. Heat gain center - Posterior hypothalamus
4. Warming of anterior hypothalamus (Heat loss)
   - Vasodilatation
   - Sweating
   - Hyperpnoea
   - Injury abolishes the heat loss responses to hot environment.
5. Stimulation of Posterior hypothalamus (Heat production)
   - Vasoconstriction
   - Injury abolishes responses to cold & interferes with the responses to heat.
6. Preoptic region of Anterior Hypothalamus is regarded as the thermostat.
7. SET POINT is maintained by this region

Hypothalamus control (Contd.)

Direct action:

When environmental temperature-

- **Is high**, warm blood flowing through hypothalamus causes HEAT LOSS RESPONSES.

- **Is low**, cool blood cause HHEAT PRODUCTION RESPONSE.

Hypothalamus control (Contd.)

REFLEX Mechanism:-

Sensitive Thermoreceptors:-

In the skin carry information via cutaneous nerves and hypothalamus.

EFFERENT NERVES:-

1. AUTONOMIC:-

> Sympathetic Adrenergic vasomotor nerves (cutaneous vasoconstriction & vasodilatation)

> Sympathetic cholinergic nerves to sweat glands

2. SOMATIC:-

Nerves to skeletal muscle (tone, activity, shivering)

Nerves to respiratory muscles

Endocrine control

Adrenal medulla-

Immediate adrenaline release (Calorigenic)

Exposure to cold leads to-

> Cutaneous vasoconstriction leads to heat loss

> Metabolic rate & heat production

Adrenal Cortex-

> BMR is low in adrenal cortical insufficiency

> Patients do not tolerate cold well & body temp is subnormal.

Thyroid Hormone-

> Calorigenic

> Permissive action on adrenaline calorigenesis

> Hyperthyroidism- Skin is warm

Behavioral and Voluntary Control

- Animals move from warm to cold regions
- Curling up of body in cold conditions
- Clothing in woolens in winter and thin cotton clothing in summer.
- Fans, air conditioners, heaters & central heating

Control Of Heat Production

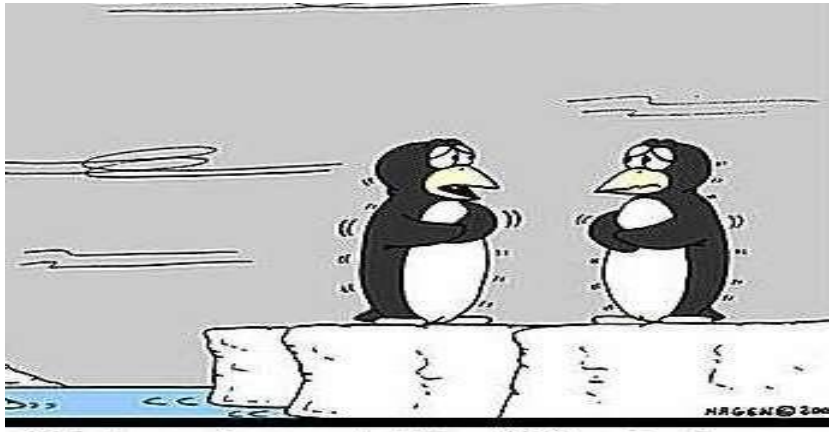
Response To The Cold Exposure:-

❖ Shivering thermogenesis

- This contains rhythmical oscillatory muscle contractions.
- No external work is involved, all the energy liberated by the metabolic machinery appears as internal heat.

❖ Non shivering Thermogenesis

- Increase in (metabolic rate) heat production not due to muscular activity.
- Increased epinephrine, sympathetic activity to adipose tissue & contribution of thyroid hormone.



Effector Mechanisms in Temperature Regulation:-

	STIMULATED BY COLD
Desired Effect	Mechanism
Heat conservation/ Decreased Heat Loss	1. Vasoconstriction of skin vessels 2. Reduction of surface area (curling up) 3. Behavioral responses (warm clothes) 4. Piloerection 5. Abolition of sweating
Increased Heat Production	1. Increased muscle tone 2. Shivering & increased voluntary activity 3. Adrenalin, nor-adrenalin secretion (minimal) 4. Thyroxin production 5. Hunger 6. Increased appetite

Effector mechanisms in Temperature Regulation:-

	STIMULATED BY HEAT
Desired effect	Mechanism
Increased Heat Loss	1. Vasodilation of skin vessels 2. Sweating 3. Behavioral response 4. Insensible perspiration 5.Increased respiration 6.Excretion of urine and feces
Decreased Heat Production	1. Decreased muscle tone 2. Decreased secretion of epinephrine (minimal) 3. Decreased Appetite 4. Apathy 5. Decrease voluntary activities 6.Decrease TSH secretion

Core Concept

When body temperature is high?

Core body temperature >37°C

Thermoreceptors

Ant. Hypothalamus & Preoptic area

Muscles Reduce Activity

Less heat generated

Sweat glands increase secretion

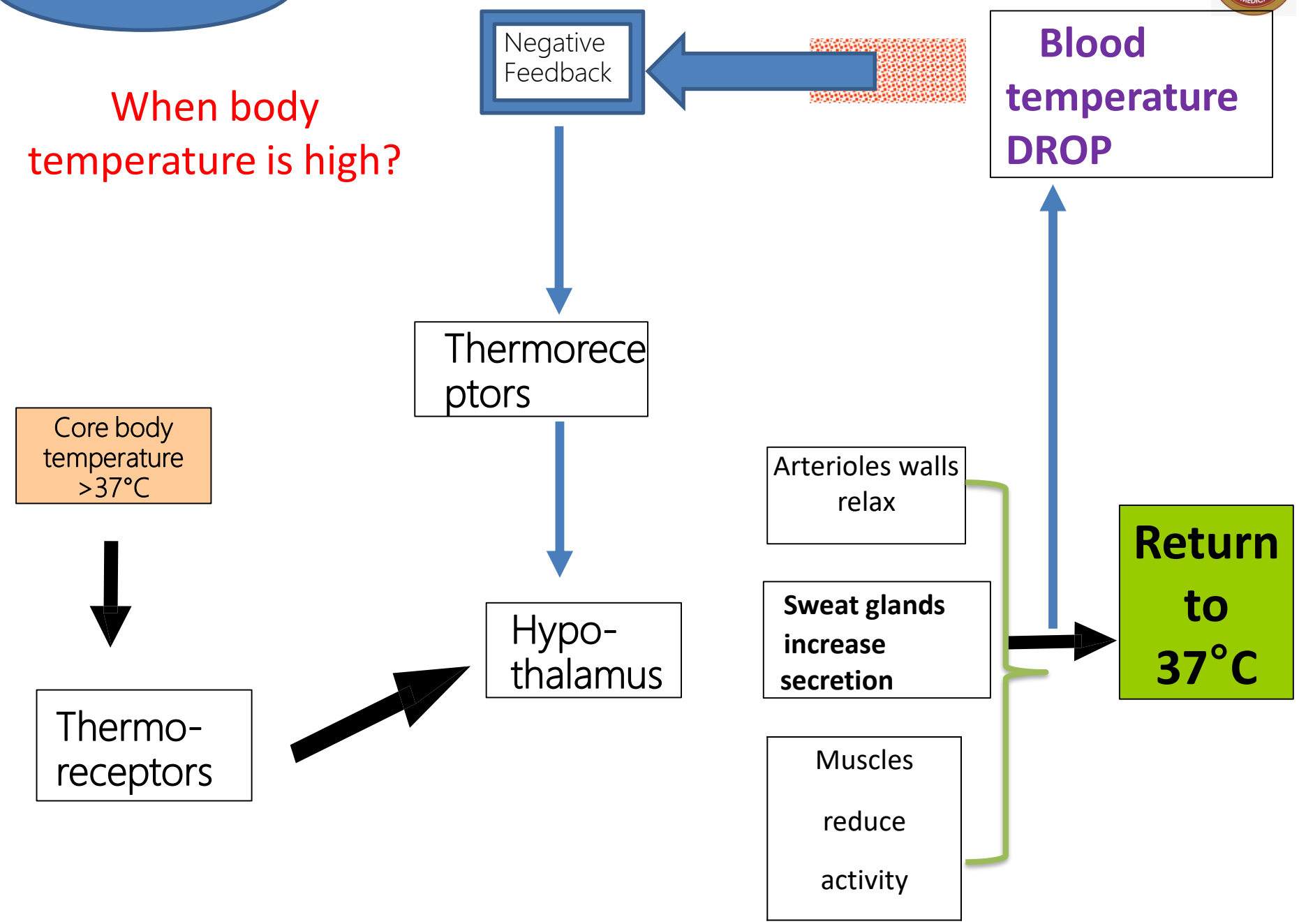
More water covers the skin.
More evaporation

Muscles of arteriole walls of skin relax

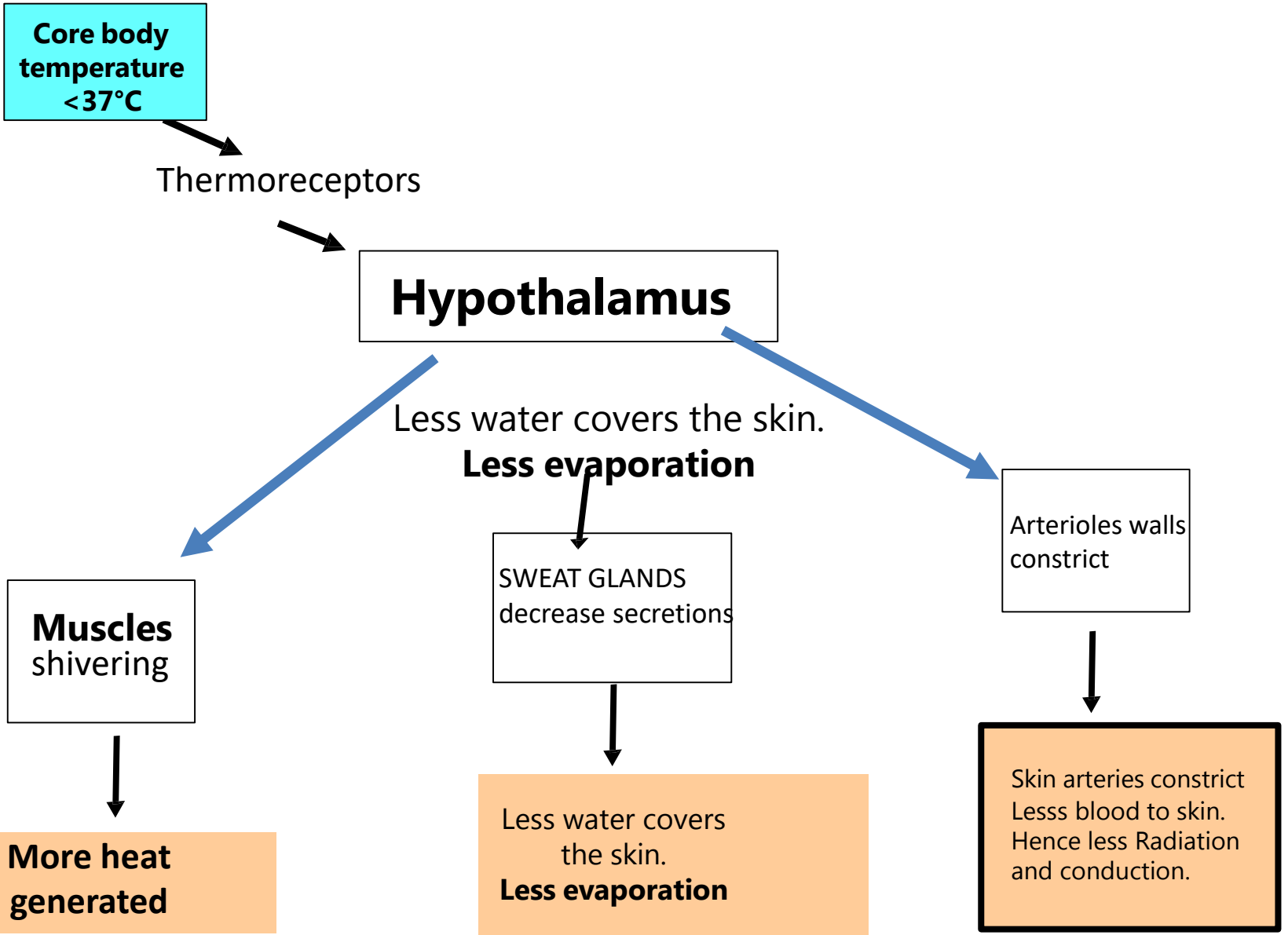
Skin arteries dilate
More blood to the skin.
More radiation & conduction of heat

Core Concept

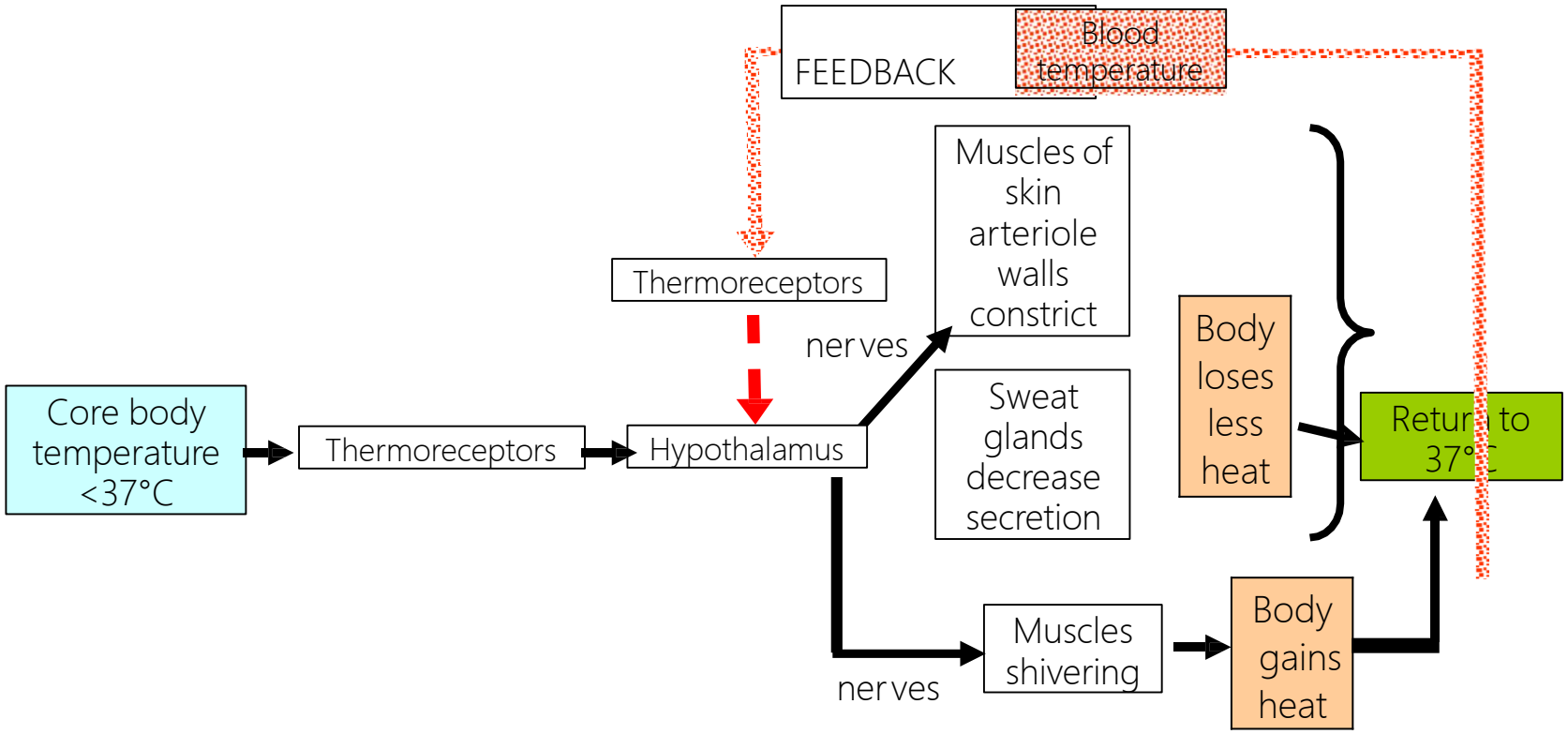
When body temperature is high?



When body temperature is low:-



When body temperature is low:-



Fever & Hyperthermia

- Fever is an elevation of body temperature due to a "resetting of the thermostat > 99^0F
- Bacterial / Viral Infections (Pyrogen), trauma, lesions/Tumor of CNS, exposure to high temperatures & drug induced.

Pyrogen: any substance that rise the set point of hypothalamus

1. Gram negative Bacterial endotoxins , cell membrane proteins & breakdown products
2. interleukin-1
3. Inflammatory mediators: kinin, bradykinin, prostaglandin E_2

- The cytokines are polypeptides.
- They are also produced by cells in CNS when these are stimulated by infection
- They may act directly on thermoregulatory center.
- Fever produced by cytokines is due to local release of prostaglandin in hypothalamus.

Characteristic of febrile condition:-

- Increased heat production by shivering (rigor) & increased metabolism.
- Diminished heat loss by vasoconstriction.
- Skin is warm & flushed
- Subsides by sweating.
- Antibodies production are high in fever.
- Many micro-organism are destroyed by fever.
- Hyperthermia slows the growth.

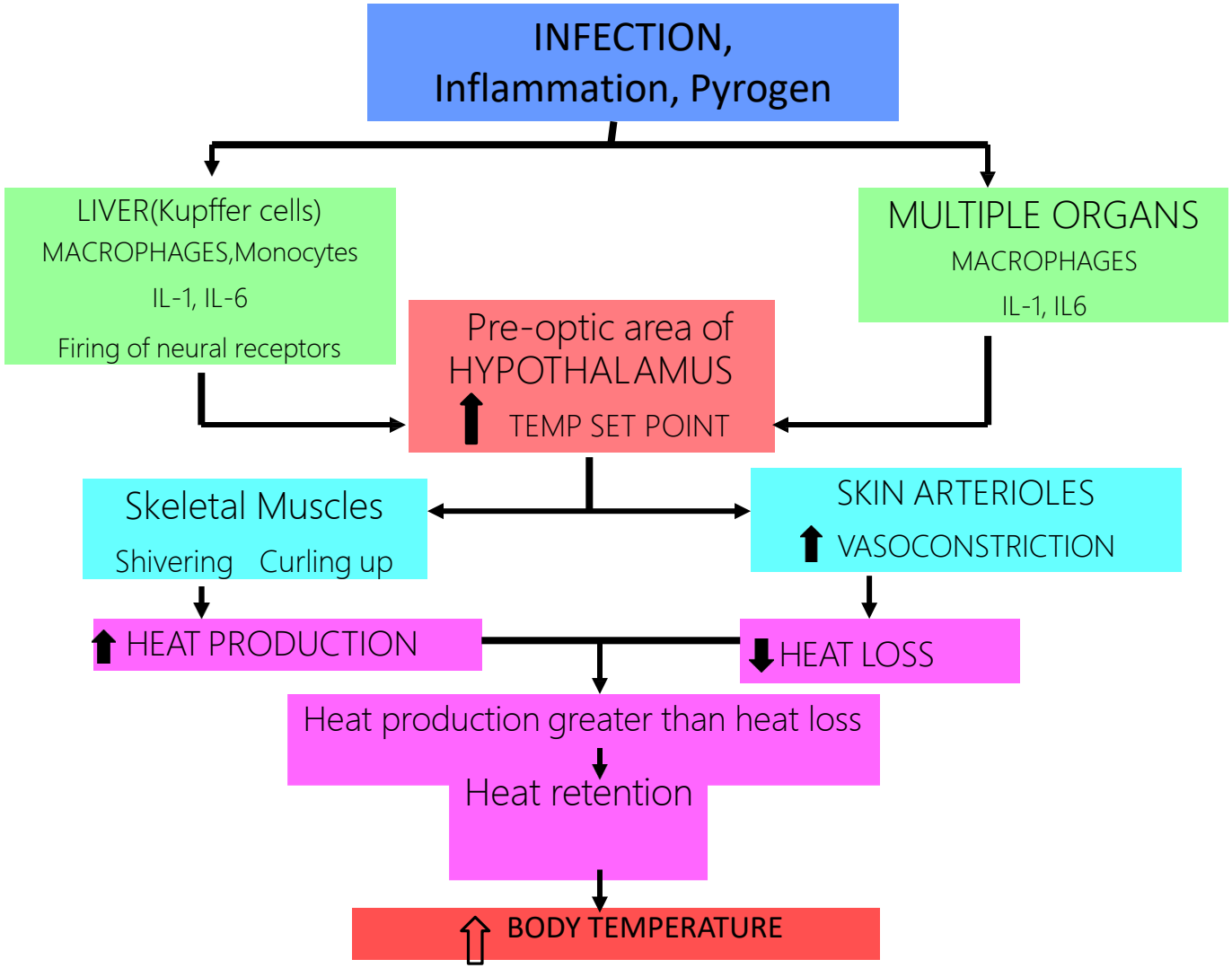
Treatment:-

Tepid Sponging

Antipyretic agents- Aspirin, Paracetamol

Aspirin blocks PG-E_2

Treatment of specific causes like antibiotics etc.


INFECTION,
Inflammation, Pyrogen
LIVER(Kupffer cells)
MACROPHAGES,Monocytes
IL-1, IL-6
Firing of neural receptors
MULTIPLE ORGANS
MACROPHAGES
IL-1, IL6
Pre-optic area of
HYPOTHALAMUS
TEMP SET POINT
Skeletal Muscles
Shivering Curling up
SKIN ARTERIOLES
VASOCONSTRICTION
HEAT PRODUCTION
HEAT LOSS
Heat production greater than heat loss
Heat retention
BODY TEMPERATURE

Vertical integration

Heat Stroke

- Serious Condition, high environmental temperature
- Overheating of body, impaired sweating
- Hyperpyrexia (41^0C or 106^0F)
  - Death results if untreated
  - Temperature to be brought down to 102^0F with ice packs
- Symptoms-

  Headache,

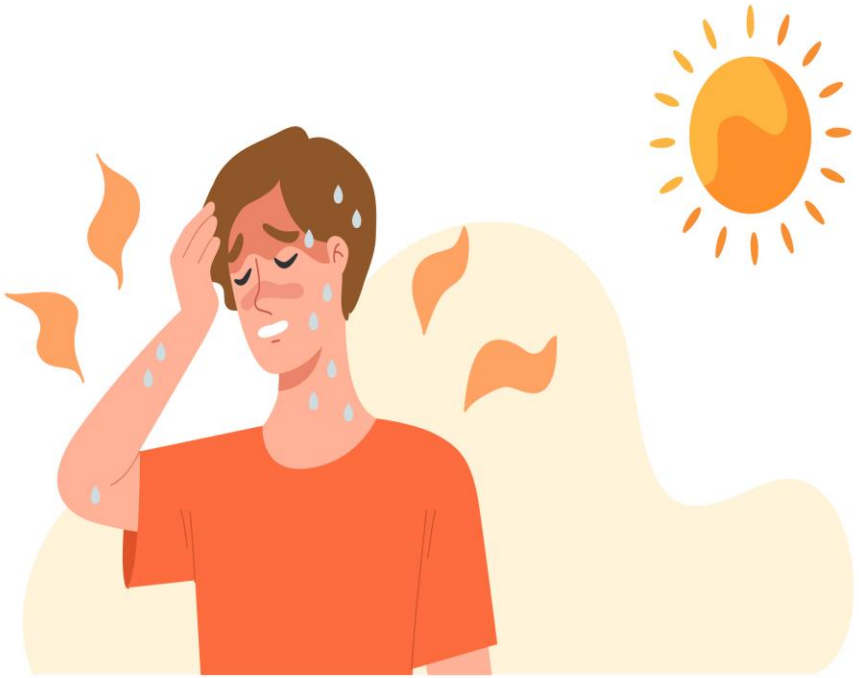
  Restlessness

  Mental confusion /Delirium,

  Convulsions,

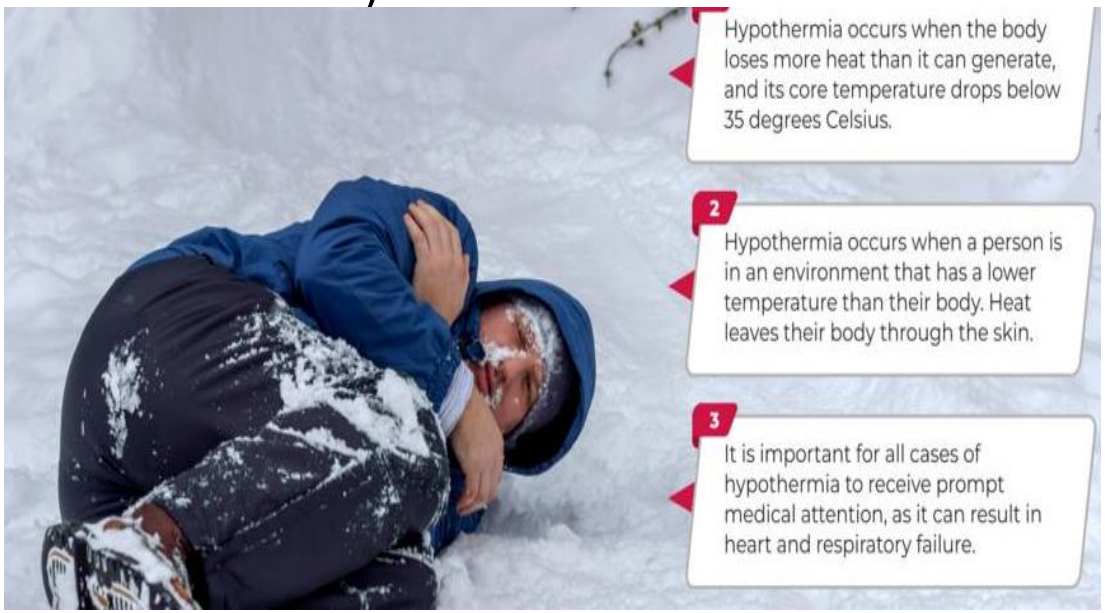
  CV collapse &

  COMA.



Hypothermia

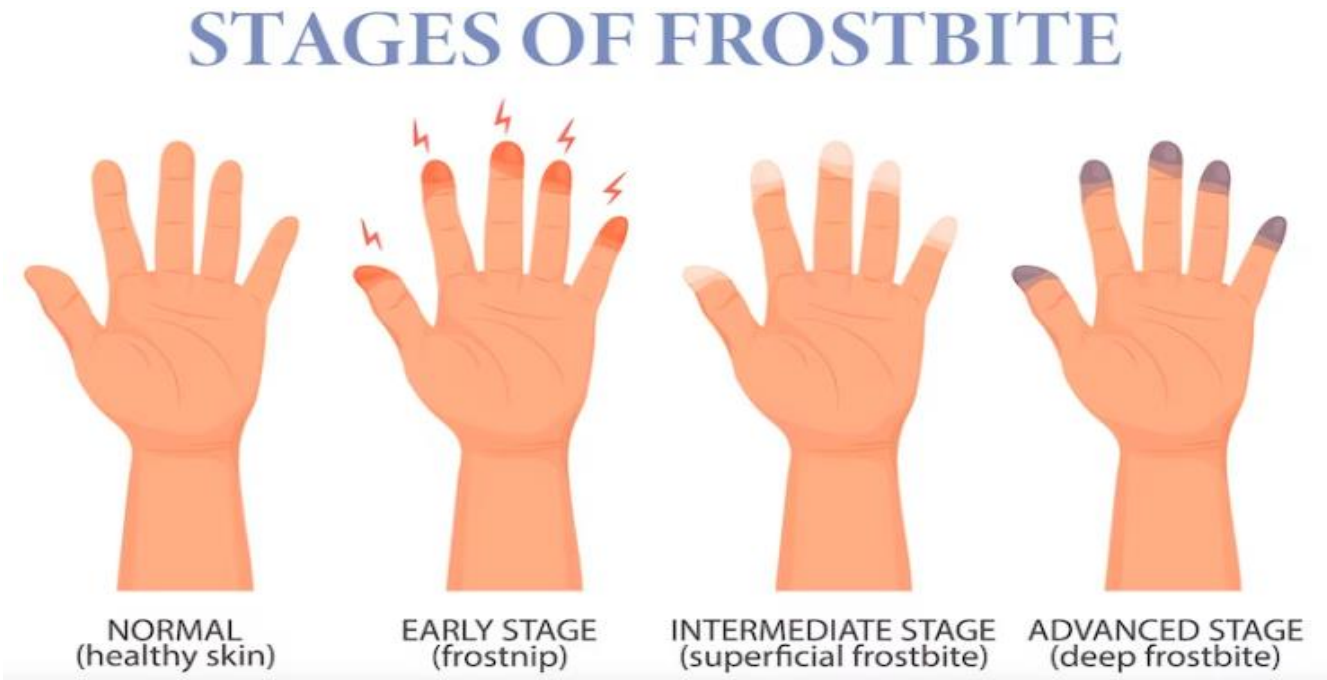
- ✓ Reduction in temp < 35^0C
- ✓ The body temperature has fallen below 28ºC / 85°F, the ability of the hypothalamus to regulate temperature is lost.
- ✓ At 27^0C the metabolism is greatly reduced.
- ✓ Person exposed to ice water for 20 to 30 minutes ordinarily dies because of heart fibrillation. (Death in RMS Titanic disaster)
- ✓ Symptoms-
  - HR,BP & RR are decreased
  - Unconscious state
- ✓ Cause-
  - Exposure to low temperature
  - Cardiac surgery



Reference:- https://www.australiawidefirstaid.com.au/resources/first-aid-for-hypothermia

Frostbite

- When the body is exposed to extremely low temperatures, surface areas can freeze; the freezing is called frostbite.
- Especially in the lobes of the ears, tip of nose and in the digits of the hands and feet.
- It is mainly mountaineering hazards.



Biomedical Ethics

BREAKING BAD NEWS:-

The aim for any health-professional is to use their skills to deliver bad news clearly, honestly and sensitively in order that patients can both understand and feel supported.

6 STEPS STRATEGY:-

(BREAKING BAD NEWS)

Setting up and starting. Mentally rehearse and arrange for privacy.

Perception. Elicit the patient's perspective.

Invitation. Ask the patient what they would like to know.

Knowledge. Provide information in small pieces.

Emotions. Recognize and empathize with the patient's emotions.

Strategy and summary. Set out a medical plan of action.

Step 2> Assessing the Patient's PERCEPTION:-

Finding out how much the patient knows. In particular how serious he or she thinks the illness is, and/or how much it will affect the future.

* What have you made of the illness so far?
* What did doctor X tell you when he sent you here?

The style and emotional content of the patient's statements provide you with information.
Terms that are used or avoided and tone of voice will give information about the patient's level of understanding and whether the implications of the information have been taken in.
It is important to learn the patient's level of understanding.

Brain Storming

Question & Answer

Brain Storming

Clinical Scenario

A 28-year-old male presents to the emergency department during a hot summer day after participating in a strenuous running match. He complains of dizziness, confusion, and nausea. On physical examination, his skin is hot and dry to the touch, and he appears disoriented. His heart rate is elevated at 120 beats per minute, blood pressure is 100/70 mmHg, and his body temperature is 104.5°F (40.3°C). He is sweating minimally, and his urine output is decreased. The patient's past medical history is unremarkable, and he denies any drug use or significant medical conditions.

Question Related to Scenario

Question 1 : What is the most likely diagnosis for this patient's presentation?

Answer:

The most likely diagnosis for this patient's presentation is heat stroke.

Question Related to Scenario

Question 2 : What are the key pathophysiological mechanisms underlying heat stroke?

Answer:

Heat stroke occurs when the body's thermoregulatory mechanisms fail to control temperature, resulting in a dangerously elevated core body temperature. There are two main types of heat stroke:

Exertional heat stroke: Usually occurs during intense physical activity, like sports, and is often seen in young, healthy individuals. It's characterized by high metabolic heat production and impaired heat dissipation.

Non-exertional (classic) heat stroke: Typically occurs in the elderly, infants, and those with chronic medical conditions. It's often associated with environmental exposure to high temperatures and humidity.

Both types lead to impaired hypothalamic thermoregulation, causing a breakdown of cellular membranes, protein denaturation, and multi-organ dysfunction.

Question Related to Scenario

Question 3 : What are the immediate and definitive management strategies for heat stroke in an emergency setting?

Answer:

Immediate management of heat stroke involves:

Rapid cooling

Intravenous fluids: Aggressive fluid resuscitation with isotonic fluids to correct dehydration and support blood pressure.

Monitoring: Continuous monitoring of core body temperature, cardiac rhythm, electrolytes, and renal function.

Airway support: Ensure airway patency and provide supplemental oxygen if needed.

Definitive management includes:

Transfer to an intensive care unit (ICU) for continued monitoring and treatment.

Correction of electrolyte imbalances and acid-base disturbances.

Supportive care to manage complications such as acute kidney injury, rhabdomyolysis, and coagulopathy.

Suggested Research Article

Related Research Article

https://onlinelibrary.wiley.com/doi/full/10.1002/ams2.827

Heat stroke management during the COVID-19 pandemic: Recommendations from the experts in Japan (2nd edition)

Jun Kanda, Masahiro Wakasugi, Yutaka Kondo, Satoru Ueno, Hitoshi Kaneko, Yohei Okada, Yuichi Okano, Yuki Kishihara, Jun Hamaguchi, Tadashi Ishihara, Yutaka Igarashi ... See all authors

First published: 11 April 2023 | https://doi.org/10.1002/ams2.827

Working group members (committee members and external committee members) are presented in Appendix 1.

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Abstract

Both coronavirus disease 2019 (COVID-19) and heat stroke have symptoms of fever or hyperthermia and the difficulty in distinguishing them could lead to a strain on emergency medical care. To mitigate the potential confusion that could arise from actions for preventing both COVID-19 spread and heat stroke, particularly in the context of record-breaking summer season temperatures, this work offers new knowledge and evidence that address concerns regarding indoor ventilation and indoor temperatures, mask wearing and heat stroke risk, and the isolation of older adults. Specifically, the current work is the second edition to the previously published guidance for handling heat

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1. Guyton and Hall text book of medical physiology, 14th edition
2. Human Physiology by Lauralee Sherwood, 9th edition
3. Ganong's Review of Medical Physiology, 26th Edition
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5. Davidson Principles and Practice of Medicine.

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