

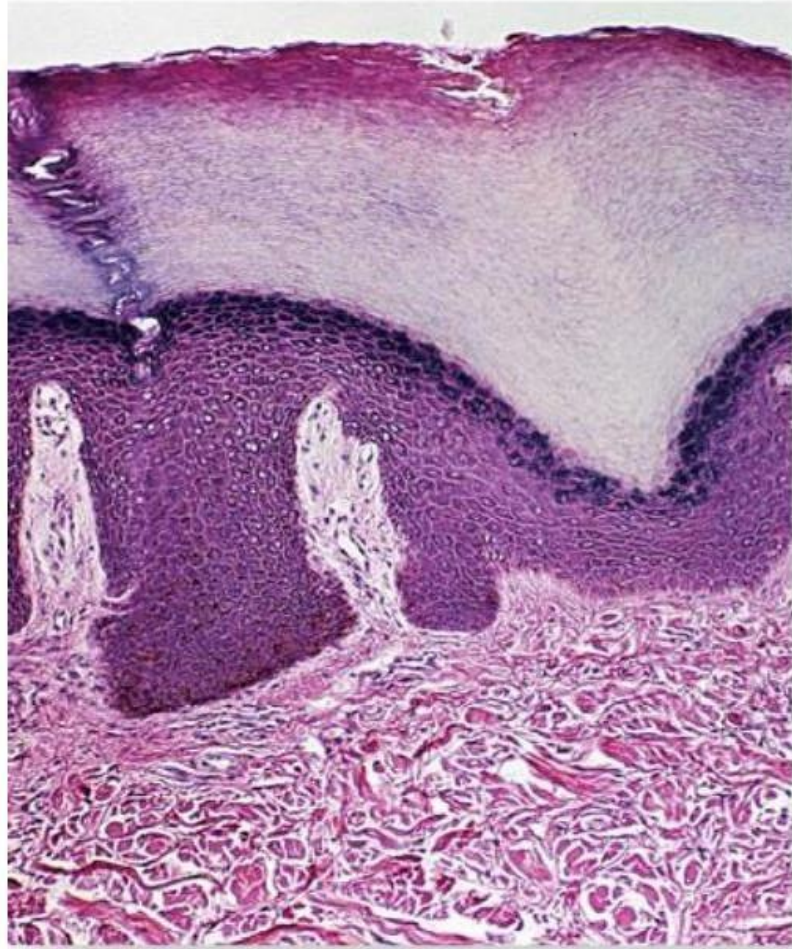
SKIN & TEMPERATURE REGULATION

SKIN

- Skin is considered as the largest organ of the body.
- It acts as a partition between internal milieu and external environment of the body.
- The skin is divided into two main layers:
 1. Epidermis
 2. Dermis

EPIDERMIS

- The epidermis is formed by stratified squamous epithelium.
- It consists of five layers.
- From superficial to deep, they are
 1. Stratum **C**orneum
 2. Stratum **L**ucidum –present only in palms and soles
 3. Stratum **G**ranulosum
 4. Stratum **S**pinosum
 5. Stratum germinativum/**B**asale



a

Stratum corneum

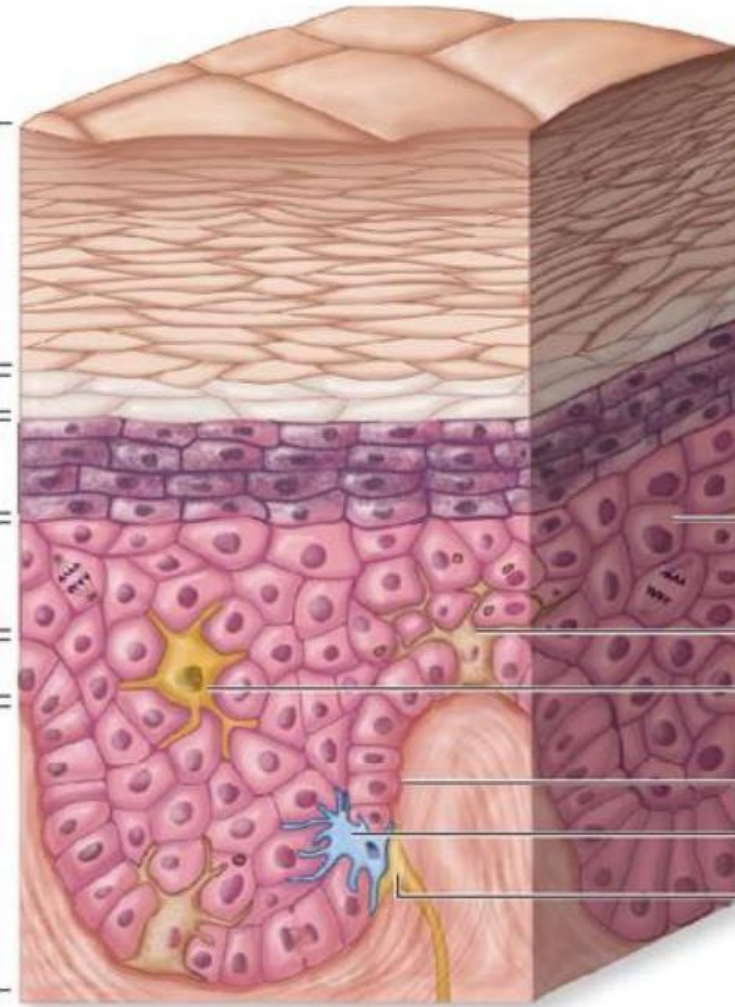
Stratum lucidum

Stratum granulosum

Stratum spinosum

Stratum basale

Dermis



b

Dead keratinocytes

Living keratinocyte

Melanocyte

Epidermal dendritic cell

Basement membrane

Tactile cell

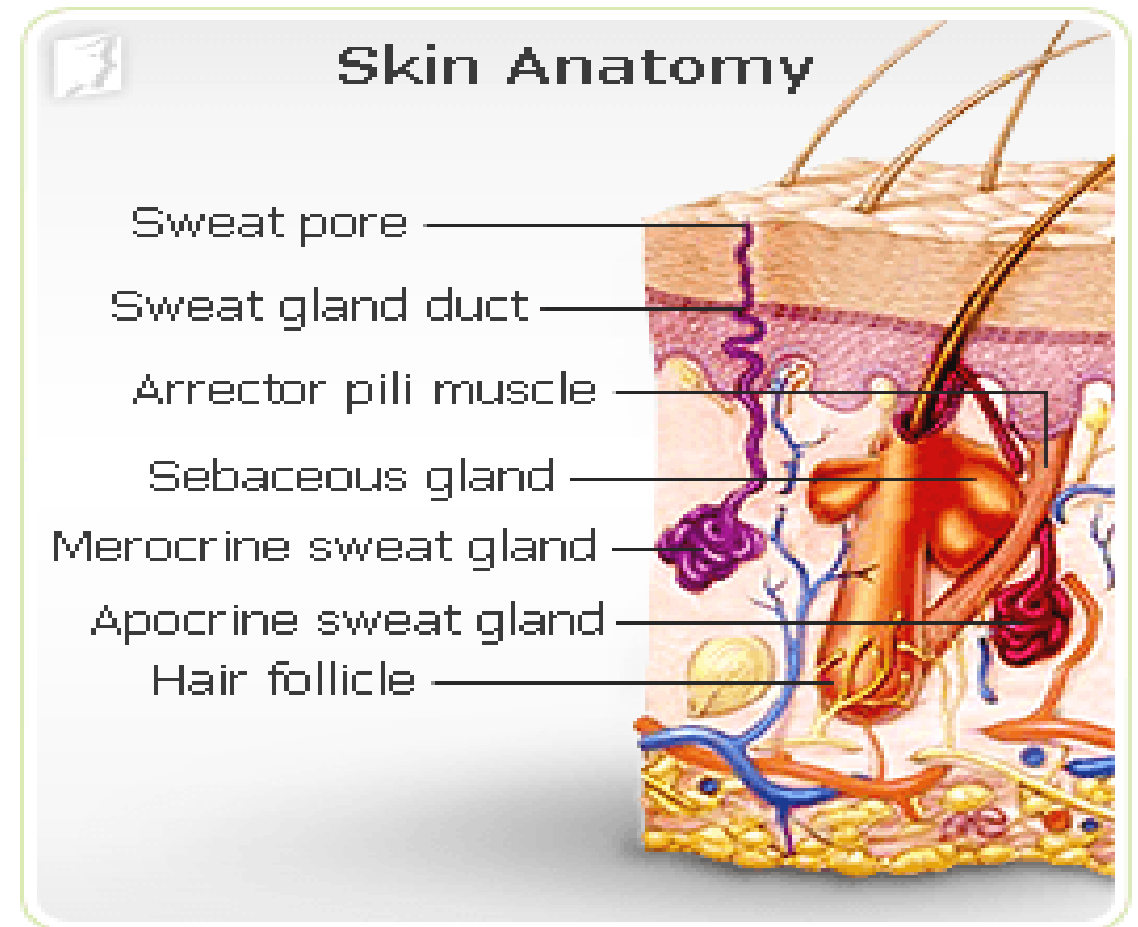
Sensory nerve ending

DERMIS

- Inner layer of skin.
- Many glands, hair follicles and few smooth muscles along with fibroblasts and histiocytes are present in the dermis.
- Composed of two layers:
 1. Superficial papillary layer
 2. Deep reticular layer

GLANDS OF THE SKIN

- The glands in the skin are mainly sweat glands and sebaceous glands.
- Sweat glands are present all over the skin except ear drum, lips and glans penis.
- They are of two types:
 1. Merocrine/Eccrine
 2. Apocrine
- Ceruminous and mammary glands are the modified apocrine glands.



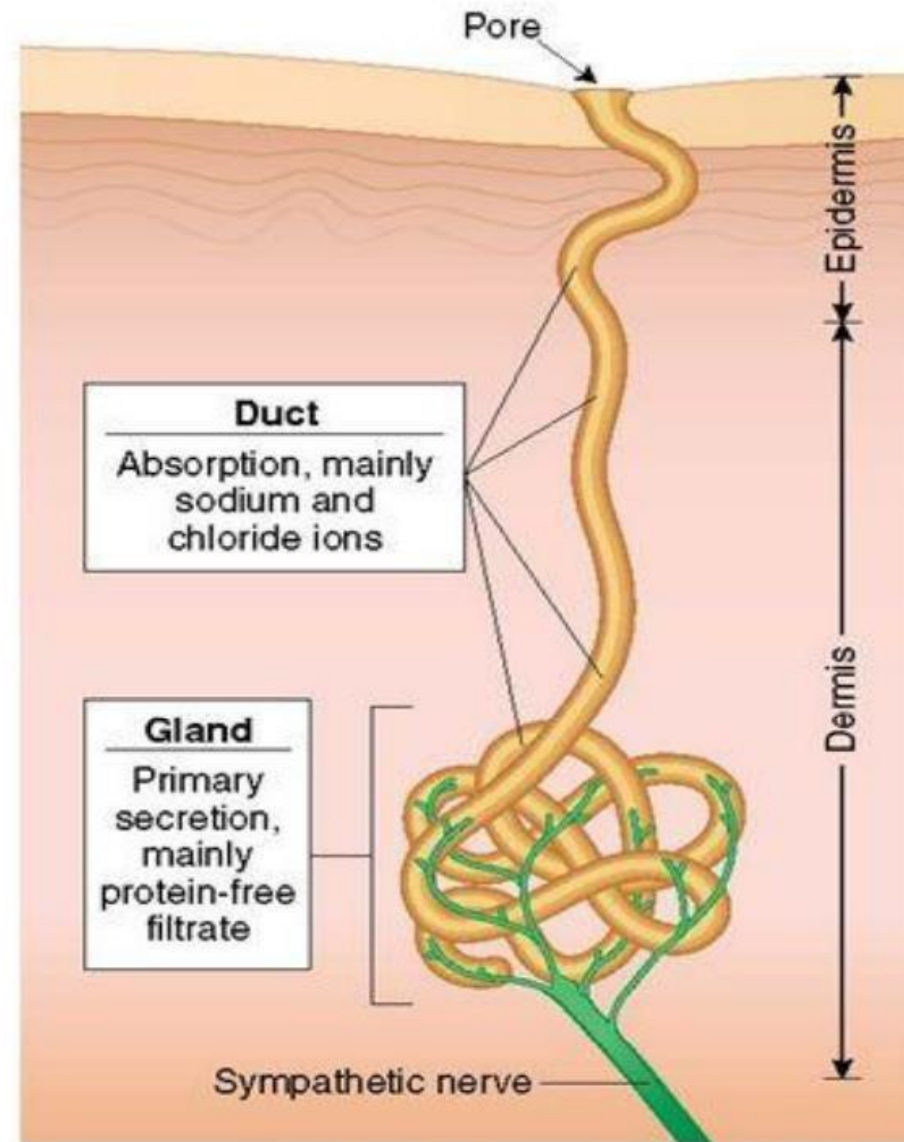
SWEAT GLANDS- 2 types

FEATURE	ECCRINE (MEROCRINE) SWEAT GLAND	APOCRINE SWEAT GLAND
Method of secretion	eccrine	apocrine
Distribution	Throughout the body	Axilla, areola, circumanal
Characteristics of secretion	Watery, clear	Thick
Nerve supply	Sympathetic CHOLINERGIC	Sympathetic ADRENERGIC
Opening	Sweat pore	Into hair follicle

MECHANISM OF SWEATING

- Sweat gland is a tubular structure consisting of two parts
 1. A deep subdermal coiled portion that secrete the sweat.
 2. A duct portion that passes outwards through the dermis and epidermis.
- When stimulated by cholinergic sympathetic fibres, epithelium cells lining the coiled portion begins to secrete.-PRIMARY SECRETION or PRECURSOR SECRETION.

It's composition is similar to plasma except that it does not contain plasma proteins. (sodium 142 mEq/L, chloride 104 mEq/L, with much smaller concentration of the other solutes of plasma)



Anatomy of an eccrine sweat gland that is innervated by a sympathetic cholinergic nerve

- As this precursor solution flows through the duct, it is modified by reabsorption of most of the sodium and chloride ions.
- When sweat glands are strongly stimulated (extreme hot condition), large amounts of precursor secretion are formed and it passes through the duct rapidly.
- So reabsorption is less. Significant loss of sodium chloride occurs in the sweat.
- Also little of the water is reabsorbed.

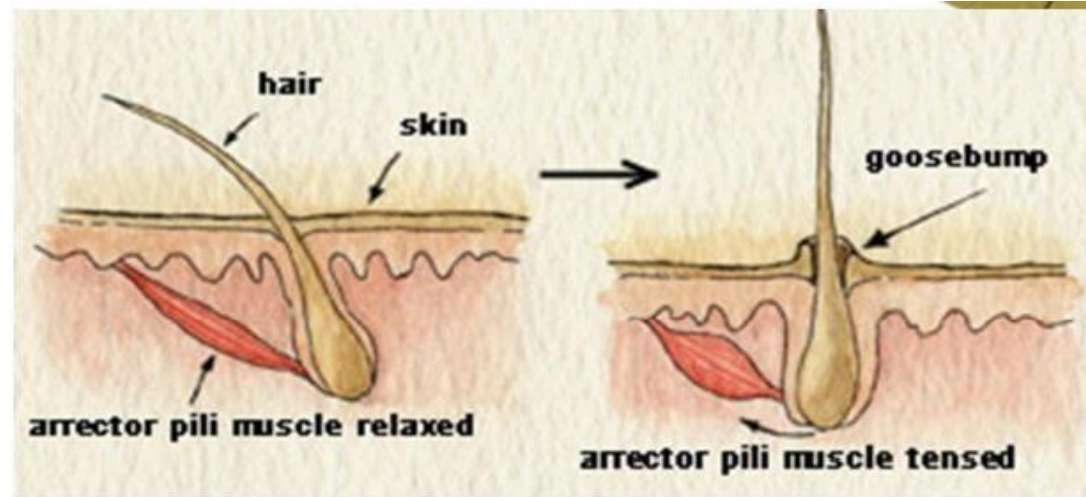
SEBACEOUS GLAND

- Secretion- sebum -it makes skin greasy, prevent the skin from drying.
- Obstruction of secretion from these glands is responsible for acne formation



SKIN APPENDAGES

- Hair
- Nail



- The ARRECTOR PILI muscle is attached to the hair follicle. Contraction of this muscle causes PILOERECTION(hair standing on end or goose skin) during sympathetic stimulation.
- This is seen during exposure to cold or during emotional reaction.

BLOOD SUPPLY TO SKIN

- Blood vessels are distributed profusely beneath the skin.
- Cutaneous venous plexus is supplied by inflow of blood from skin capillaries.
- In most exposed areas (hands, feet), blood is supplied to the plexus directly .(arteriovenous anastomoses).
- Blood flow varies between 1 to 150 ml/ 100 g of the skin/min.
- The skin blood vessels are supplied by sympathetic fibres.
- Rate of blood flow can vary tremendously –from barely above zero to as great as 30% of total cardiac output

FUNCTIONS OF SKIN

1. **Body protection**-Mechanical protection against infections and protection from UV rays.
2. **Immunity**-Skin plays a crucial role in non specific defense of body.
3. **Temperature regulation**-Secretion of sweat contributes significantly to temperature regulation.
4. **Sensory organs**-All types of receptors such as pain,touch, temperature (exteroceptors) etc. are present in the skin.Hairs are more sensitive sensory structures.
5. **Vitamin D synthesis.**

FUNCTIONS



BODY PROTECTION



TEMPERATURE REGULATION

6. Water and electrolyte balance-Hormones like aldosterone affect water and electrolyte excretion from skin.

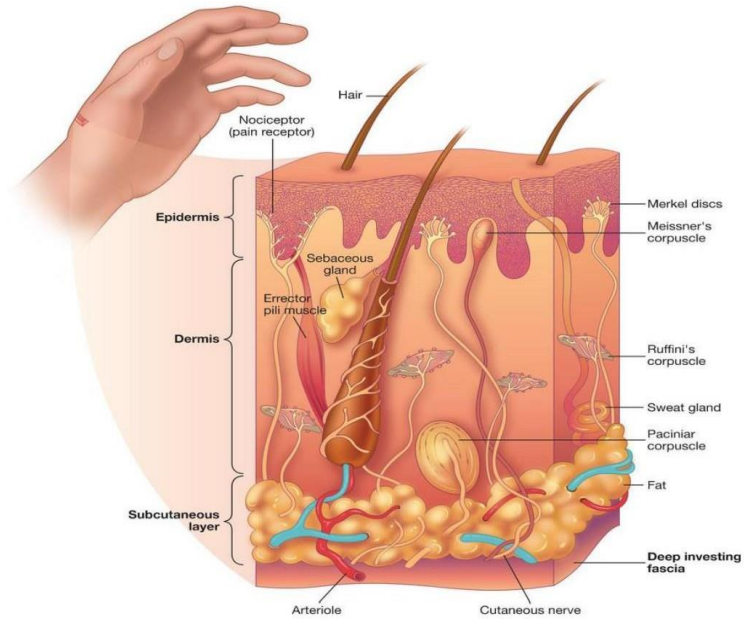
7. Excretory organ-Sweat also acts as a medium for excretion of waste materials from the body.

8. Route for drug administration-

Topical ointments-act locally.

Subcutaneous implants-for example,estrogen- progesterone contraceptive implants.

9. Diagnosis of diseases.



SENSORY RECEPTOR



SYNTHESIS OF VITAMIN D



ROUTE OF DRUG ADMINISTRATION

DIAGNOSIS OF DISEASE



**Systemic Lupus
Erythematosus**



Figure 3: Malarial anaemia—pallor of child's palm with his mother's for comparison



10. Contributes to central blood volume.

- Cutaneous vascular bed accommodates a good quantity of blood volume, from which blood can be diverted to vital organs at times of need.
- Example-In circulatory shock, sympathetic vasoconstriction occurs.



- Blood from cutaneous and splanchnic circulation diverted to cerebral and coronary circulation. Blood flow to brain and heart is maintained.

REGULATION OF BODY TEMPERATURE

- Homeothermic animals like birds and mammals are capable of regulating their internal body temperature.

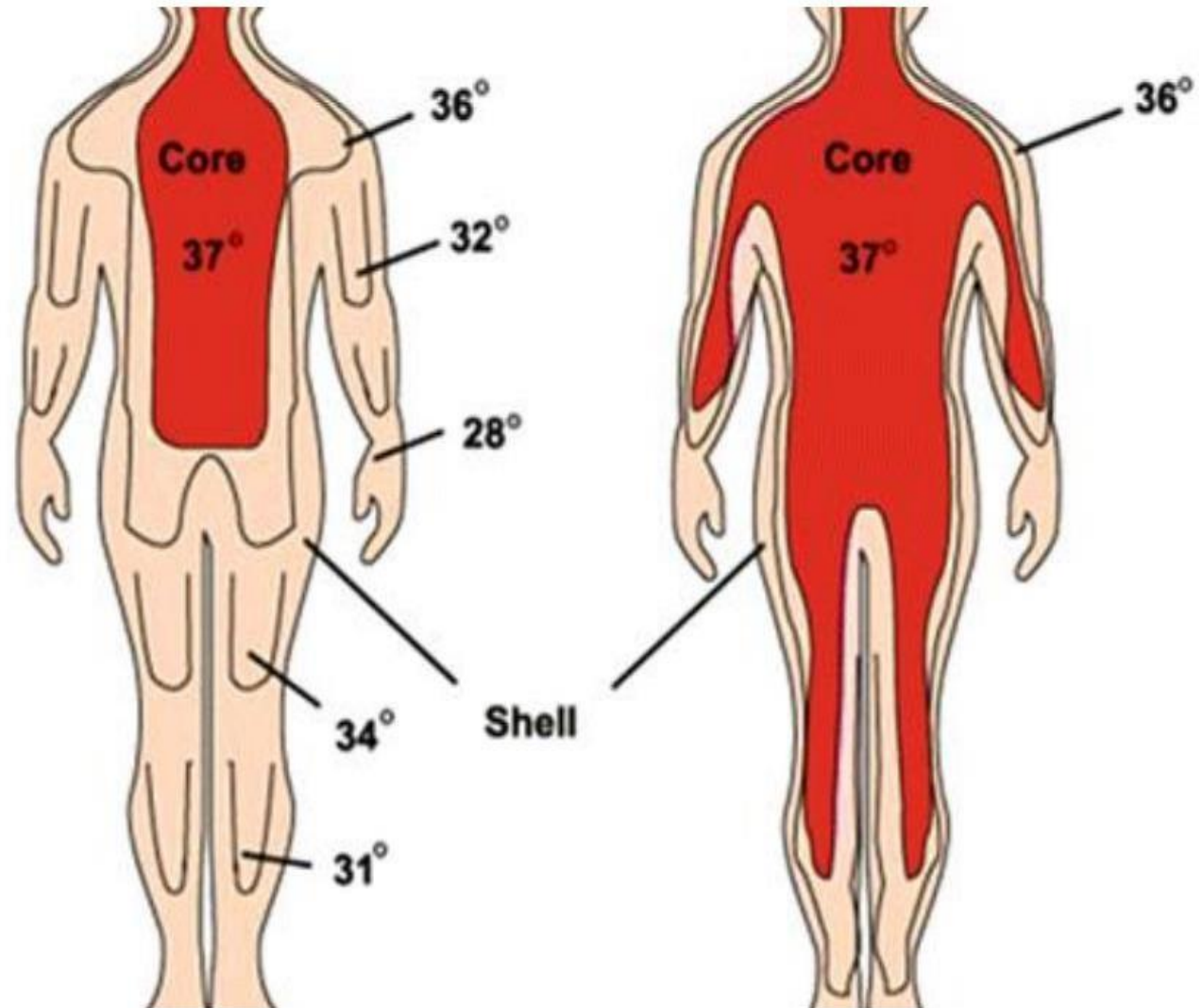


The balance between heat production and heat loss determines the body temperature.

Body function depends on a relatively constant body temperature because:

- ✓ speed of chemical reactions varies with temperature.
- ✓ The enzymes can act optimally only in a narrow range of temperature.

- ✓ Temperature recorded from inner body structures is **CORE TEMPERATURE** (37°C)
- ✓ Temperature recorded from body surface is **SHELL TEMPERATURE** (31°C to 34°C)



- Normal body temperature in an adult is 37°C or 98.6°F , varies from 36.3°C to 37.1°C (97.3°F to 98.8°F) {Morning oral temperature}.
- Axillary temperature is 0.5°C less than oral temperature.
- Rectal temperature is 0.5°C more than oral temperature. (preferred in infants & children). It represents core temperature.
- The temperature of scrotum is carefully regulated at 32°C .

Factors influencing body temperature

1. Diurnal variation- Regular circadian fluctuation of $0.5-0.7^{\circ}\text{C}$, lowest at 6.00AM and highest in the evenings.
2. Age –Newborn, infants and elderly people are less capable of maintaining body temperature especially in an altered state of environmental condition.
 - a) Sweating and shivering are poorly developed in newborns.
 - b) The surface to mass ratio is also high in infant and children.

- Young children have a temperature 0.5°C above that of adults because temperature regulation is less precise in them.

c) Elderly people have

decreased metabolic rate, reduced muscle mass, atrophied sweat gland, decreased cardiovascular reserve to dissipate heat and impaired ability to sense heat and cold.

3. Gender:

- In women during their reproductive life, under the influence of progesterone, body temperature increases by about 0.5 °C following ovulation. This is called rise in basal body temperature.
- Females are less influenced than males by external body temperature due to presence of subcutaneous fat.

4. Physical Activity:

Increased physical activity generates excess heat by increasing rate of metabolism.

Temperature rises as high as 40°C.

5. Emotion and Excitement:

- Due to unconscious tensing of the muscles.

6. Sleep:

- Body temperature is low because heat production is less due to decreased sympathetic and physical activities.
- Decreased sensitivity of thermostat.

7. Meals:

- Animal proteins produce more heat than plant proteins.

8. Type of clothing

METHODS OF HEAT PRODUCTION

1. Basal Metabolic Activity:

- The food substrates are oxidized to produce energy.
- The metabolic energy is utilized in transport of membrane pumps, energy requiring chemical reactions and muscular activity.
- Most of the metabolic energy used in these processes is converted into heat in the body, which is called metabolic heat.

2. Muscular Activity:

During physical exercise, 90% of heat is produced by muscular activity.

- Even during rest, basal muscular activity to some extent contributes to heat production. This is mainly by the activity of respiratory muscle, cardiac muscle and basal tone of skeletal muscle.
- On exposure to cold, skeletal muscle activity increases that increases heat production by several fold. This is called *shivering thermogenesis*.

3. Specific Dynamic Action and Digestion of food:

- The metabolic rate and thus, the heat production increases by about 15% after a meal. This is called specific dynamic action of food or thermic effect of food.
- SDA is maximum for protein.

- Also during digestion and absorption of food from GI tract, increased intestinal motility and secretion increases heat production.

4. Non shivering thermogenesis:

- Hormones such as catecholamines and thyroxine increase body metabolism and thus contributes to basal heat production.

Mechanisms of Heat gain from environment

- Radiation, conduction, convection
- ingestion
- ventilation

- **RADIATION:**Transfer of heat by infrared electromagnetic radiation from one object to another at a different temperature with which it is not in contact.
- **CONDUCTION:**Heat exchange between objects or substances at different temperatures that are in contact with one another.
- **CONVECTION:**Heat transfer when body exposed to a fluid or air with temperature different from the body.It is movement of molecules away from area of contact.
- **INGESTION AND VENTILATION:**Ingestion of hot food and drinks allows heat to enter into the body.Breathing hot air from external environment as in hot climate,increases body temperature.

Methods of heat dissipation

METHOD	% OF TOTAL HEAT LOSS AT 21°C
Radiation, Conduction & convection	70%
Evaporation: 1) sweating 2) Insensible perspiration Diffusion of fluid from the body to epidermis occurs continuously. It is evaporated from the body surface even in the absence of external sweating. It is 50mL/h (400 kcal/day)	27%
Excretory loss : stool and urine coming out of the body are warm. So heat is lost.	1%
Respiration : 1) evaporation of water in expired air (300 mL of water is lost from lungs) 2)warming of inspired air 3) panting	2%

EVAPORATION

Evaporation occurs in two forms:

1. Sweating:Evaporation of 1 g of water from the skin removes about 0.6kcal from the body.
2. Perspiration/Insensible water loss-It is not sensed by the body as sweating does not occur.It usually does not depend on external conditions.
 - The rate of evaporation does not depend upon temperature gradient,rather proportionate to water vapour pressure gradient.
 - When the humidity is high,the water vapour pressure gradient between skin and environment becomes very low,which decreases evaporation and accumulation of heat.

TEMPERATURE REGULATION

- The temperature of the body is regulated almost entirely by nervous feedback mechanisms, and almost all these mechanisms operate through temperature regulating centers located in the hypothalamus.

Feedback reflex system that include:

- Thermal sensors
- Afferent pathway
- Hypothalamic control Centre
- Efferent pathway (autonomic nervous system)
- Thermal effector organs

Thermal sensors

✓ Cutaneous

- Warm receptors-10%
- Cold receptors-90%

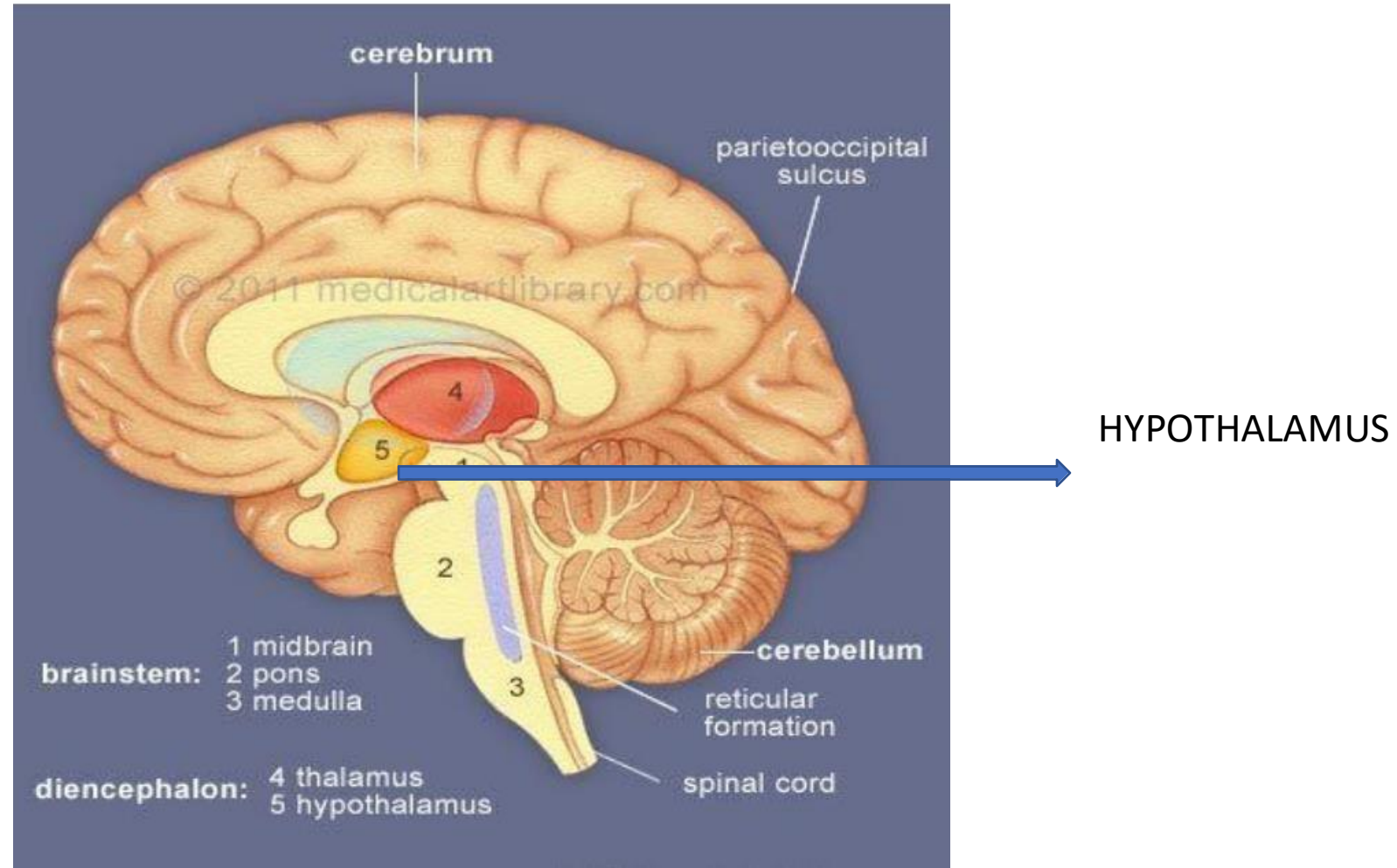
✓ Hypothalamic

- Sensor neurons in Pre-optic area of Anterior hypothalamus.
- Constitute 10% of hypothalamic neurons.
- Warm receptors are more than cold receptor.

There are also heat loss neurons and heat production neurons in anterior and posterior hypothalamus.

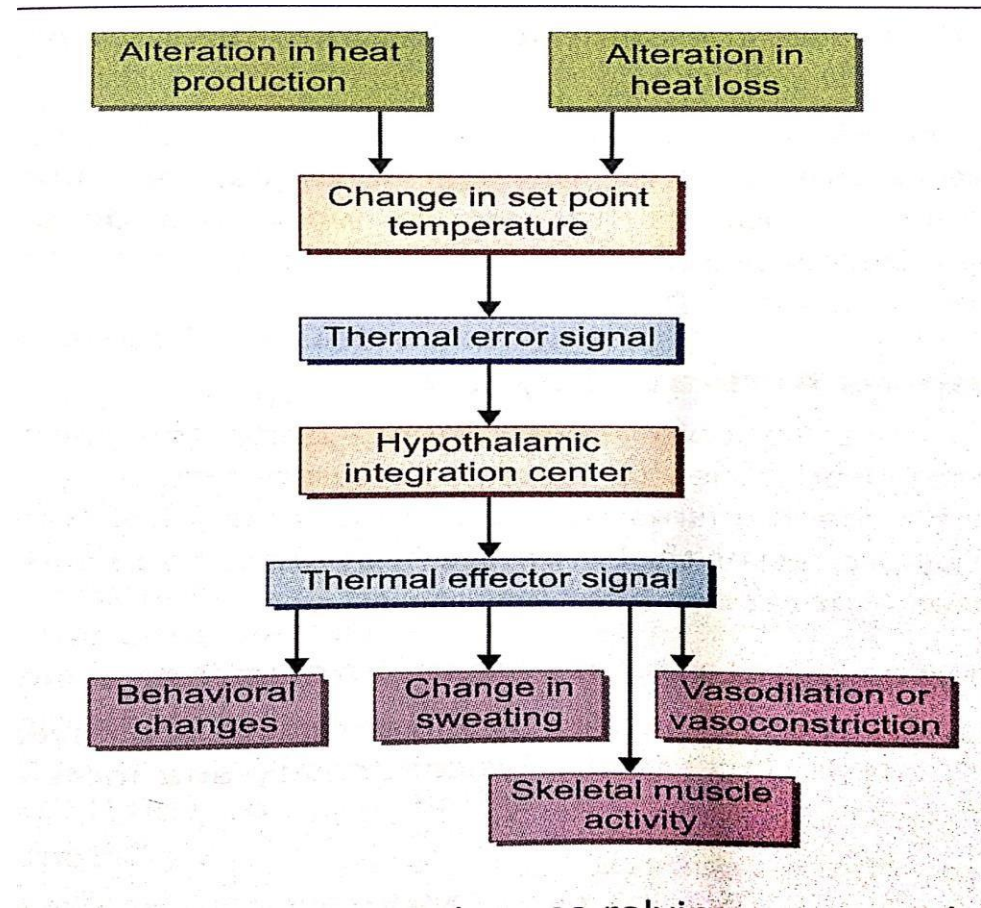
- ✓ **Deep body temperature receptors** are present in spinal cord, abdominal viscera, around great veins etc.

HYPOTHALAMIC CENTRE



- Hypothalamic thermostat has a 'set point' for body temperature- it is a narrow range with average of 98.6°F (37°C).
- Any deviation from this set point is received by thermostat as 'error signal'.
- The impulses generated in the cutaneous thermoreceptors ascend up in the sensory pathway in the spinal cord.
- Through the collaterals, from the ascending pathway, information reaches hypothalamus.
- Hypothalamic integration centers receive and interpret the change in the firing rate from thermoreceptors.
- Appropriate thermal effector signals are generated.

- Neurons that on activation induce loss of heat are located in pre-optic area in Anterior hypothalamus.- HEAT LOSS CENTRE.
- Neurons involved in prevention of loss of heat and production of heat are located in Posterior hypothalamus- HEAT PRODUCTION CENTRE



Responses activated by heat

1. Responses that promote heat loss
 - Cutaneous vasodilation
 - Sweating
 - Increased respiration or panting
2. That reduce heat production
 - Decreased appetite
 - Decreased physical activity



Cutaneous vasodilation

- When temperature increases

1. NEURAL

Stimulation of Heat loss centre
(anterior hypothalamus)



Inhibit sympathetic discharge



2. CHEMICAL

Locally increased kinins from sweat
glands



3. THERMOGENIC

Direct effect of heat



**CUTANEOUS
VASODILATION**

Cutaneous vasodilation

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graph TD; A[Cutaneous vasodilation] --> B["Skin blood flow increases.  
Core heat is transferred to  
surface (heat flow)"]; B --> C[Heat dissipation to  
environment];
```

Skin blood flow increases.
Core heat is transferred to
surface (heat flow)

Heat dissipation to
environment

Sweating

If heat load is high, hypothalamic drive activates AUTONOMIC RESPONSE



Increased discharge in cholinergic sympathetic fibres that innervate ECCRINE SWEAT GLAND



Increased SWEATING

- Sweating may reach 700 ml/hour or more in a very hot weather. It may lead to salt depletion.

Increased Respiration

Increased
heat

Sympathetic &
thermogenic
activation

Respiratory
stimulation

Expired air is
warmer

Remove body heat
to environment



Decreased appetite

- Decreased food intake
- Decreased amount of metabolism
- Decreased SDA of food



DECREASED HEAT
PRODUCTION

Decreased Physical Activity:

In extreme hot weather, physical activities are reduced.

The individual loses interest to work and develops lethargy.

Responses activated by cold

1. Responses that promote heat gain

- Shivering
- Increased physical activity
- Non shivering thermogenesis (chemical thermogenesis)
- Increased appetite

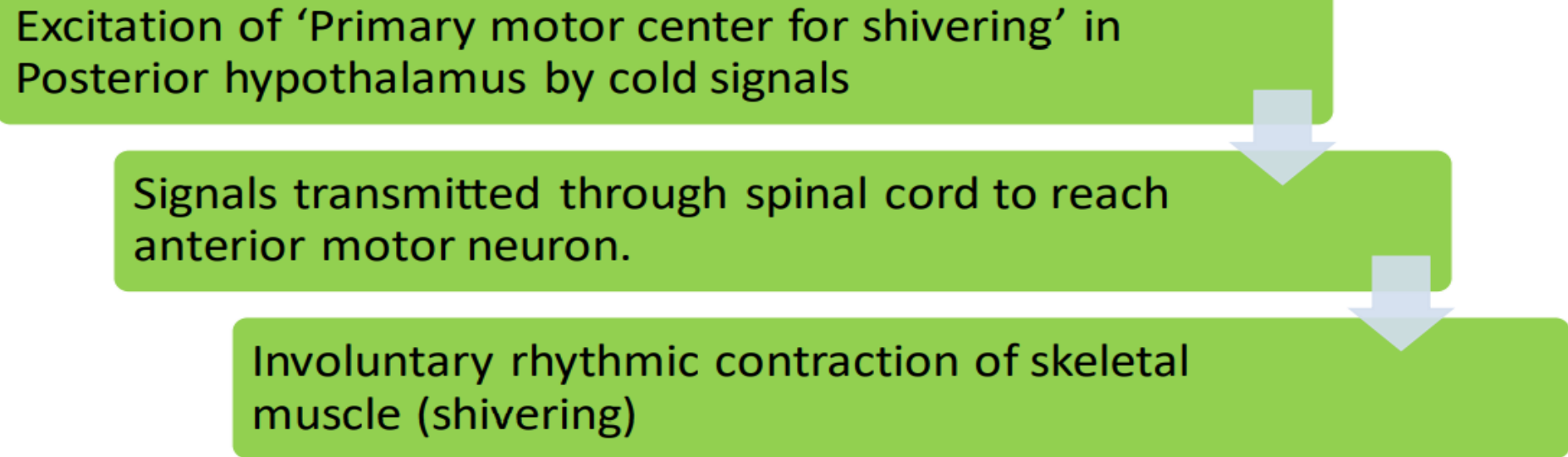
2. That decrease heat loss

- Cutaneous vasoconstriction
- Body attitude change
- Horripilation(piloerection)



Shivering thermogenesis

Excitation of 'Primary motor center for shivering' in Posterior hypothalamus by cold signals



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graph TD; A[Excitation of 'Primary motor center for shivering' in Posterior hypothalamus by cold signals] --> B[Signals transmitted through spinal cord to reach anterior motor neuron.]; B --> C[Involuntary rhythmic contraction of skeletal muscle (shivering)];
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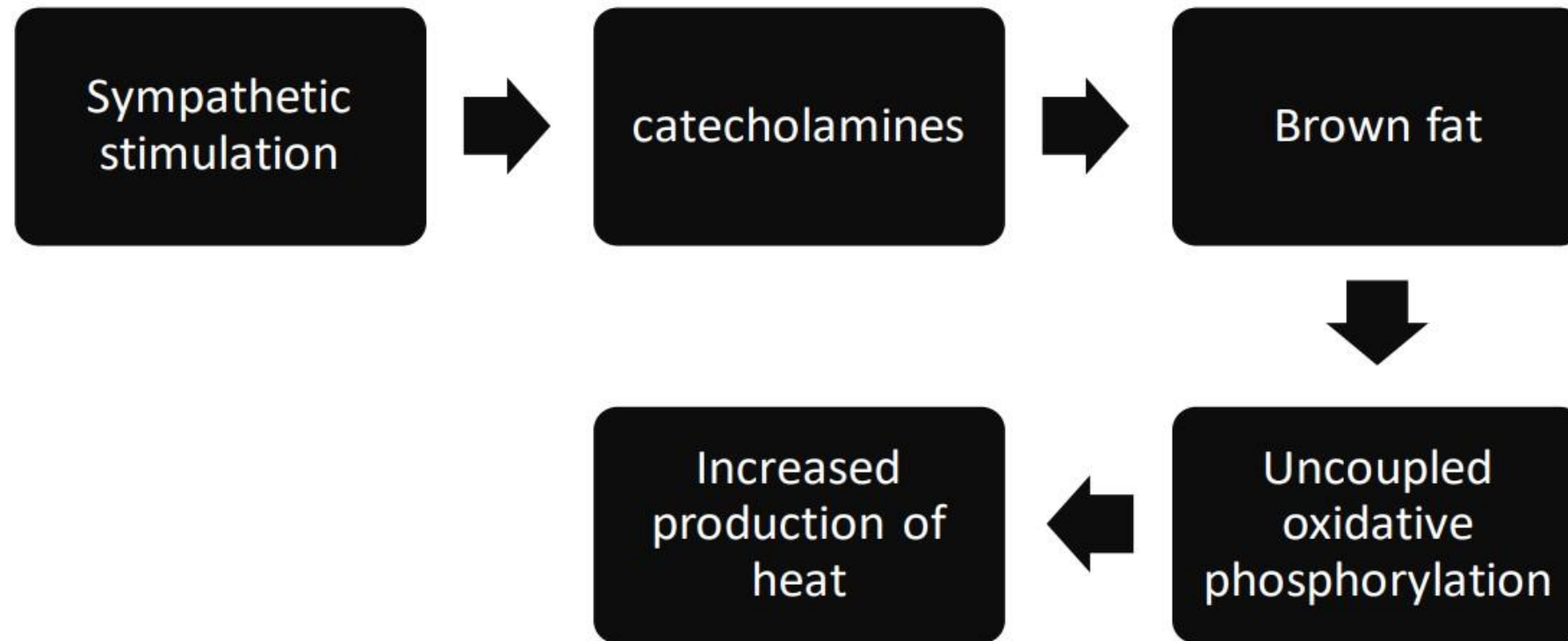
Signals transmitted through spinal cord to reach anterior motor neuron.

Involuntary rhythmic contraction of skeletal muscle (shivering)

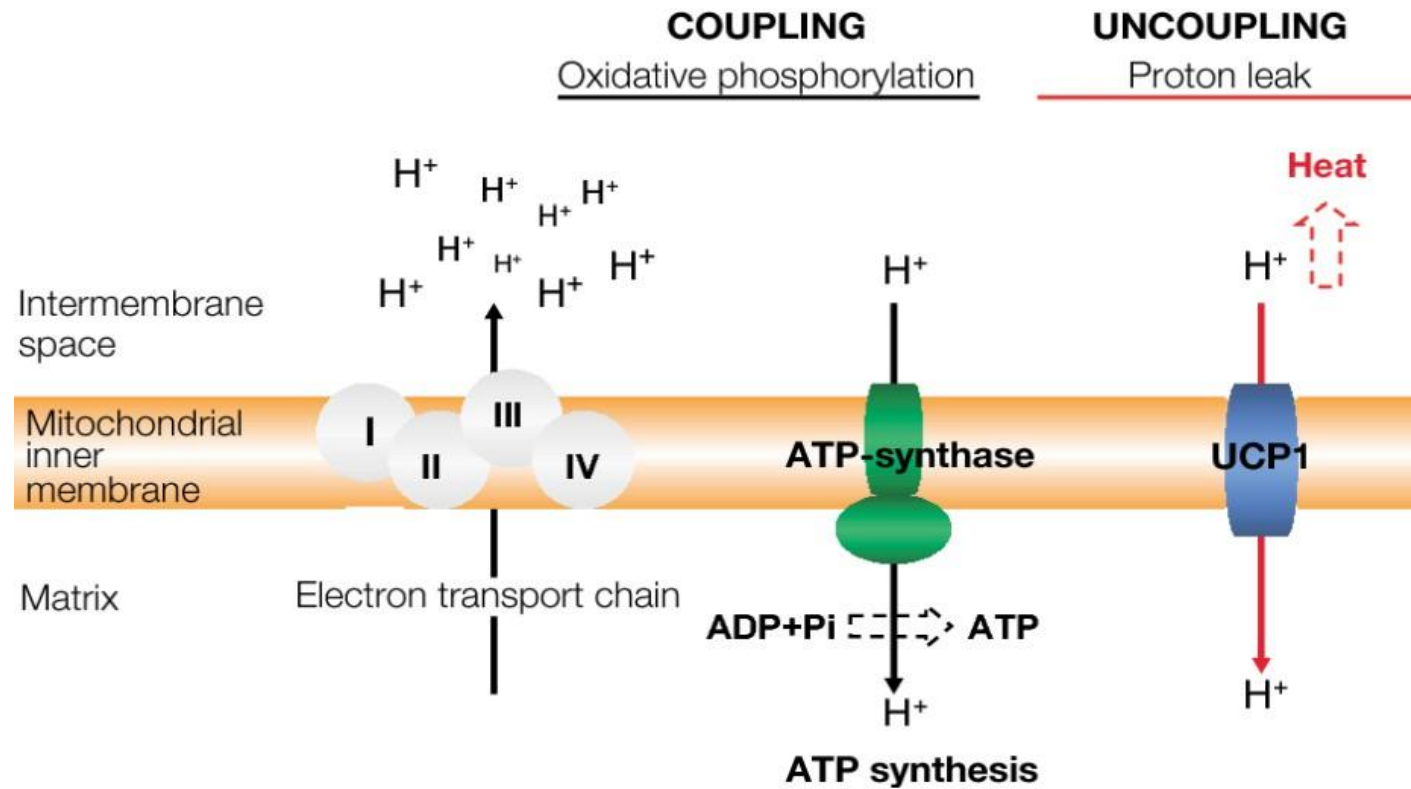
It increases metabolic rate by 3-4 times that of basal level.

Shivering is the involuntary rhythmic contraction of skeletal muscle.

Non-shivering thermogenesis



Mechanism of non shivering thermogenesis



- Quantity of brown fat determines the level of chemical thermogenesis.
- Cells of brown fat are rich in mitochondria that carry out uncoupled reaction.
- Brown fat also has rich sympathetic innervation.
- In infants and children, brown fat is present in considerably larger amount than adults.
- Therefore non shivering thermogenesis is the major mechanism of increasing body temperature in infants and young children.
- In adults, non shivering thermogenesis contributes to about only 10% of thermogenesis.

- Epinephrine and Nor epinephrine causes rapid rise in body temperature.
- Thyroxine secretion increases on exposure to extreme cold, which promotes body metabolism and heat production, slowly developing but prolonged increase in body temperature.

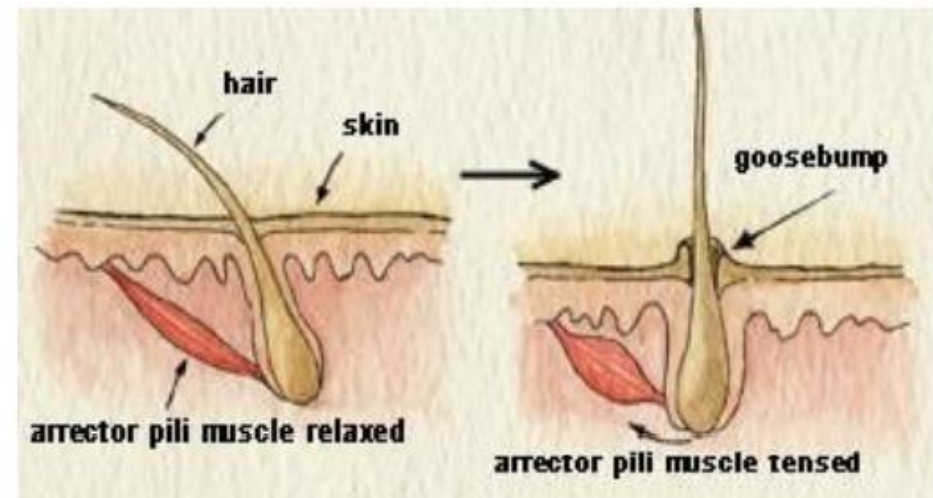
INCREASED PHYSICAL ACTIVITY AND INCREASED APPETITE

Cutaneous vasoconstriction

- Posterior hypothalamus
- ↓
- Stimulation of sympathetic discharge
- ↓
- Cutaneous vasoconstriction
- ↓
- Decreased cutaneous blood flow
- Decreased heat loss

Pilo erection

- Contraction of Pilo erector muscle at the hair root
- It entraps a layer of air in the hairs
- Act as an insulator
- Decreases transfer of heat from the body



Change in body's attitude

- Example- body flexes maximally (curling up of the body)
- It decreases surface area of the body
- Decreases heat loss

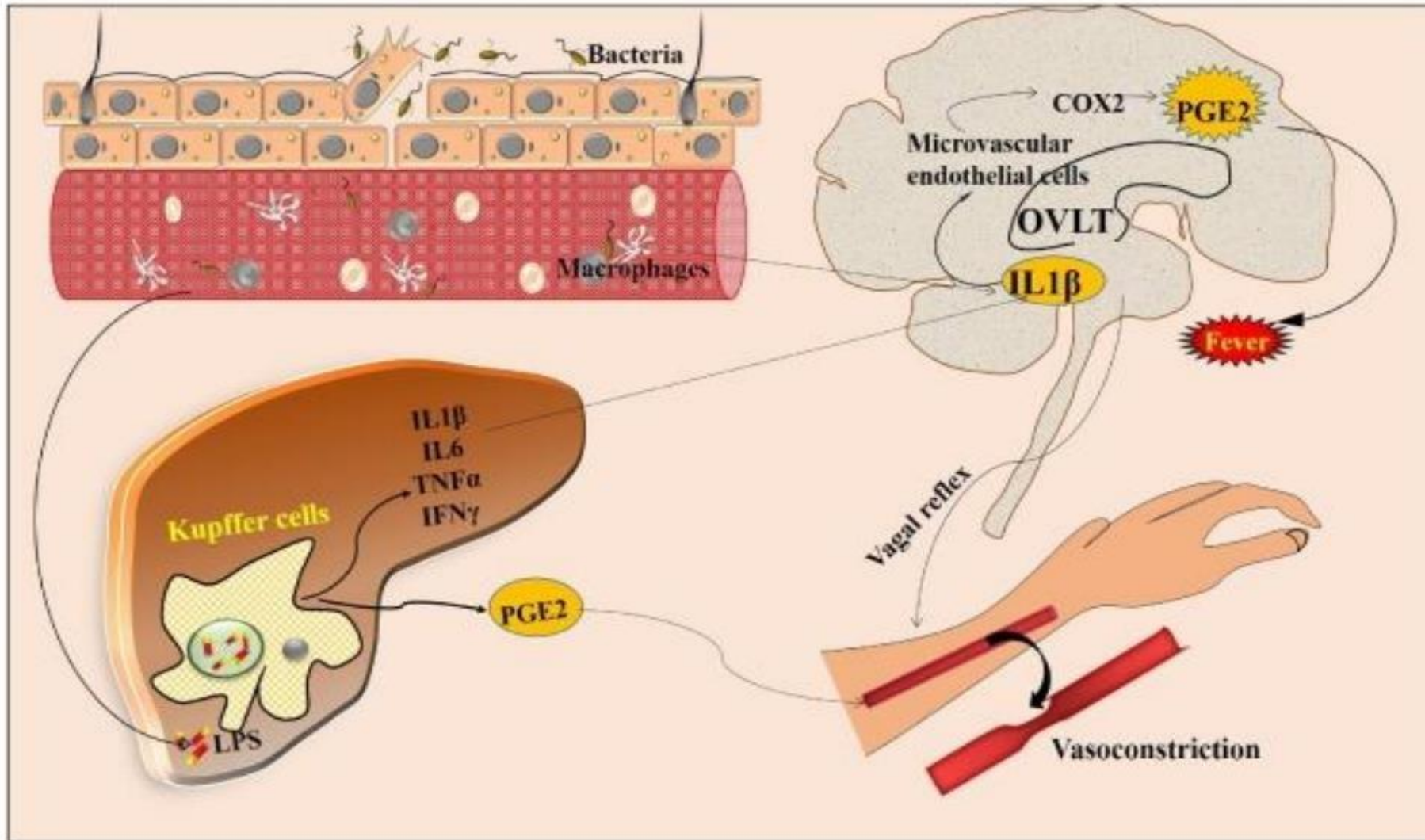


APPLIED ASPECTS

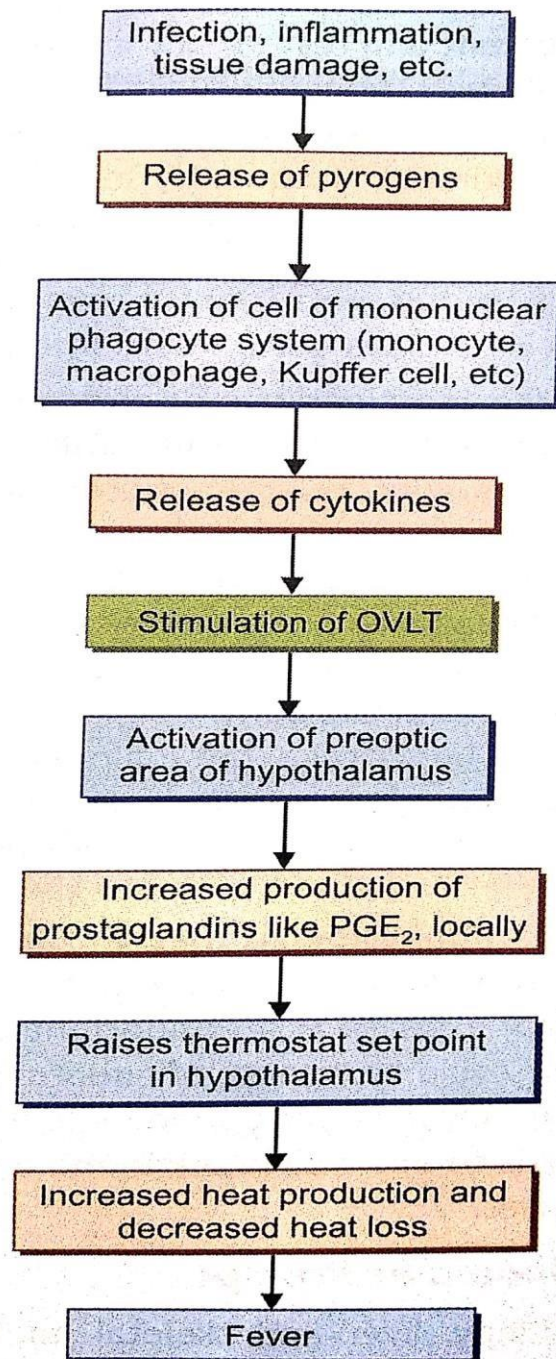
➤ FEVER

Fever or pyrexia is the increase in body temperature above normal range.





MECHANISM OF GENESIS OF FEVER



MECHANISM OF GENESIS OF FEVER

HOW fever helps?

- i. Kills pathogens by thermogenic action
 - ii. Induce enzymatic activities
 - iii. Enhances the production of antibodies
 - iv. Slows down the growth of some tumor
- Aspirin and many other non steroidal anti inflammatory drugs decrease body temperature by inhibiting hypothalamic production of prostaglandins.
 - Chills and rigor: The temperature receptors then signal that actual body temperature is below the new set point, usually produces chilly sensations due to vasoconstriction and occasionally enough shivering to produce a shaking chill.

Exposure to extreme Heat-Heat Stress

HEAT EXHAUSTION

- Sudden exposure of body to high temperature peripheral vasodilation blood pressure falls. (heat collapse)
- Features include nausea, vomiting, tachycardia, weakness, confusion headache etc.
- Patient sweats profusely
- Improves by fluid replacement, salt intake, cooling of the body and rest.

HEAT SYNCOPE

- State of circulatory failure that occurs due to excessive heat.
- Major pathophysiologic dysfunction is due to venous pooling of blood that decreases venous return.

HEAT STROKE

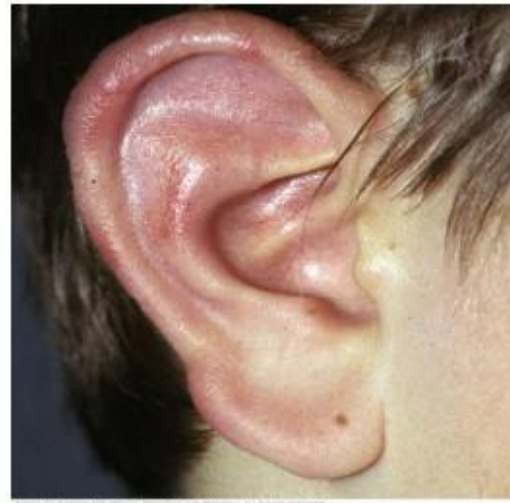
- Occurs when a person with dry skin is exposed to very high temperature in a dry atmosphere.
- High core temperature (105°F to 108°F)
- Extreme rise in temperature will damage brain tissue.
- Symptoms- dizziness, abdominal distress, neurological deficits and loss of consciousness may occur.
- Medical emergency.
- Immediate therapy include rapid reduction in body temperature . Eg- immersion of body in cold water.
- Prompt hydration should be maintained

MALIGNANT HYPERTHERMIA

- Various mutations of the gene coding for ryanodine receptor lead to excess calcium release during muscle contraction triggered by stress, especially on exposure to anaesthetics or depolarizing neuromuscular blockers.
- Leads to contractures of the muscle, increased muscle metabolism, and a great increase in heat production.
- Treatment is immediate use of **dantrolene sodium**.

Exposure to cold

- FROST BITE



- When body is exposed to extremely low temperatures, surface areas can freeze.
- Usually seen in ear lobes, digits of hands and feet.
- In extreme cases, permanent damage results due to extensive formation of ice crystals in the cell.
- Leads to impairment of circulation, local tissue damage .
- Gangrene often follows thawing, frost bitten areas must be removed surgically

HYPOTHERMIA

- Body temperature is between 28 - 31°C
- If falls below 25°C, it is known as deep hypothermia.
- Causes-
 - ✓ Accidental when exposed to extreme cold.
 - ✓ Hypothyroidism
 - ✓ lesions of hypothalamus
 - ✓ pontine haemorrhage etc.

- Features-

- Reduced metabolism, enzymatic activity.
 - Slowing of heart and respiratory rate
 - Lowering of blood pressure
 - Retardation of glucose metabolism
 - Loss of consciousness and death may occur in severe cases.
-

Induced hypothermia

- Hypothermia is induced artificially by giving sedatives, anesthetic agents or by artificial cooling.
 - Slowing of metabolic processes
 - Respiration and heart rate falls
 - Blood pressure falls
 - Loss of consciousness
 - ✓ At rectal temperature of 28°C, the ability to spontaneously return the temperature to normal is lost. But if rewarmed with external heat, return to the normal state.
-

- Hypothermia is made use of in cardiac and brain surgery.
 - The blood supply to these organs is temporarily cut off as oxygen need is greatly reduced.
 - Blood pressure is low and bleeding will be minimal during surgery.