Temperature Regulation

Relation between temperature and biological activities

Temperature fluctuation is less in aquatic ecosystem and more in terrestrial ecosystem

Ocean → -2 to + 30°C

Land → -70 to + 85°C

Life exists between 0 to 40°C

Few bacteria & algae can live at 70°C [e. g. in hot water springs]

Some blue green alga Synechococcus can survive in temp. 75°C.

Eggs of a fresh water crustacean Triops can survive temp. 80°C to 103°C

Temp. affect chemical Reaction Rate (reaction rate is higher at higher temp.)

Therefore it affects Metabolic Rate. This is indicated by increase in oxygen consumption.

Therefore Growth.

Very high temperature can cause heat death, which due to—

1. Denaturation of proteins, thermal coagulation.
2. Thermal inactivation of enzymes.
3. Inadequate oxygen supply.
4. Damage to membrane structure.

Very low temperature can cause cold death. This depends on the tolerance of the organisms.

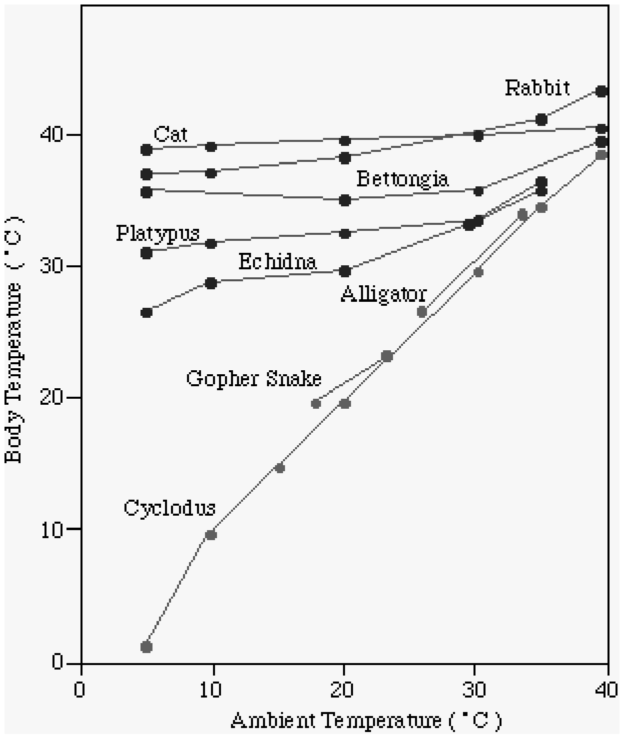
1. Guppies die at 10°C. (normally live at 23°C)
2. Some can survive freezing temperatures. Arctic fish Trematomus can swim at temp. –1.3°C. They have anti freeze substance in their blood/ body fluid.

Poikilotherms (Cold blooded animals)Poikilos means changeable. – have T_b almost similar to the environment. However due to metabolic processes T_b is slightly higher than T_a Ex. In Fish muscle temp. is 0.44oC higher than T_a. (T_a = Ambiant temp. T_b = body temp.)

Homoetherms – Maintain constant T_b. The constancy required especially for Nervous system. Due to the constancy of T_b they can occupy the environments of widely fluctuating temperatures.

Heterotherms – Regulate when they are active not when resting Ex. Armadillo, sloth, Marsupials etc.

The temperature regulating ability is better in higher mammals and birds as compared to the lower mammals and reptiles. (Phylogenetic trend) This is illustrated by the following figure.



It shows better regulation in cat, rabbit as compared to Platypus , Echidna which are better than snake and alligator

The regulation ability also shows Oncogenetic trend i.e. young Regulate less, adult regulate better. New born are usually Poikilothermic, need more care. Exception to this Caribou calf (type of deer.)

Temperature Regulation – is a Balance between heat loss and heat gain.

Heat loss
- Radiation
- Convection
- Conduction
- Evaporation

Heat Production
- Endothermy (metabolic heat)
- Ectothermy (absorption of heat)

For good Regulation Animals need
1. Sensitive Thermostat
2. Ability to use metabolic heat
3. Insulation to avoid Heat loss

Homeotherms have all these & they also can change metabolic rate according to need.
Poikilotherms – have poor insulation. They can not change basal metabolic rate. Hence they are poor regulators of temperature.

Following figure shows how the homeotherms manage in changing ambient temperatures.

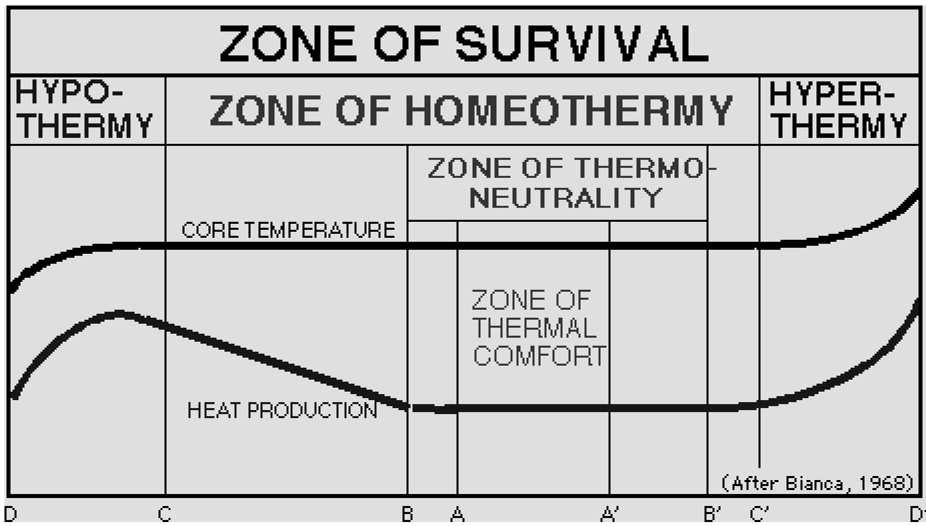


Figure - Zone of Survival (after Bianca 1968).

Within the "Zone of Homeothermy" (C to C'), a mammal can maintain a constant, or steady state, core temperature. Within the **"Zone of Thermal Comfort" (A to A'),** there is little sensation of heat or cold, and a steady state core temperature can be maintained without any efforts . **B to B' is Thermoneutral zone when Basal Metabolic Rate (BMR) is the lowest.**

At the **lower critical temperature (B)**, heat produced by increased metabolic activity maintains homeothermy. However, at **C** (**Incipient lethal temp**.**low**), heat production cannot balance heat loss, the core temperature begins to fall, and the animal becomes **hypothermic.** With more cooling, heat production peaks, and then declines, further lowering the core temperature. At the lethal body temperature (**Cold death -D**), an animal dies from the cold. For most species, the lower lethal temperature is 59-68°F (15-20°C), or about 36°F (20°C) **below the normal core temperature.**

With air temperature rising above the "Zone of Thermal Comfort" (A'), the animal makes efforts for cooling . At the **upper critical temperature (B')**, increased sweating and (or) panting may be associated with lowered metabolic heat production. At C'(**Incipient lethal temp**.**high**), further intensification of sweating and (or) panting cannot maintain homeothermy, and the animal becomes **hyperthermic.** The rise in core temperature increases the metabolic rate **via the van't Hoff effect, triggering positive feedback, which further increases the core temperature.** Thermal death of an adult occurs at **(Heat death) D**. For mammals, the van't Hoff effect is the two-to three-fold rise in heat production caused by an 18°F (10°C) rise in tissue temperature. For most mammals, the upper lethal body temperature is 108-113°F (42-45°C), or about 5.4 to 10.8°F (3 to 6°C) above the normal core temperature.

Critical Temperature & Thermo neutral zone vary from Animal to animal. Critical temperature in naked man is 25 to 27^{o}C. In Arctic fox it is -30 to -40^{o}C

Dogs, cat, rabbits, sheep can lower BMR (about 20%) in hot conditions. Homeotherms can change thickness of insulation.
BMR is the lowest in homeotherms for maintaining constancy of T_b observed in thermoneutral zone. In this zone the animal is most comfortable. The boundries of thermoneutral zone form critical temperature low & high from where the animal has to struggle for maintaining constant T_b. Critical temperature & thermoneutral zone vary from animal to animal.

Temp. regulation in homeotherms i.e. Birds & Mammals.
Elephant 36^0C, Man 37^0c, Rat, Horse, Cow – 38^0C, Cat, Pigs, Dogs, Sheep – 39^0C
Rabbit, Chicken – 41^0c, Sparrow 43^0C

In general
Monotherms }
} 30 – 36^0C
Marsupials }
Higher mammals have 36-38^0C Birds 39 to 42^0C

Heat production in homeotherms :

1] <u>Exergonic oxidative reaction</u>

Food is oxidised to produce energy. These reactions are carried through out the life. Heat production is **non-shivering type heat energy or thermogenesis.**

<u>Ingestion of food</u> – Casuses rise BMR & also lead to increase in temperature. This is known as specific dynamic action of food. Spicy food causes more rise in temperature.

2] <u>Muscular contraction</u>

High muscular activity& exercises increases body temperature (tb)from 37^o C upto 40 ^{0}C.

Shivering thermogenesis – When exposed to cold, rapid muscle contraction is shown by the animals. It produces 16000 Kcal/m2/24hrs
Ex. Man in 4^0C bath show 18 fold rise in heat production by shivering.

3] <u>Endocrine factors (are fast in action)</u>

Non-epinephrine & epinephrine rise metabolic rate, therefore temperature increases.

<u>Thyroxins</u> - (are slow in action)
Hyperthyroidism – rises metabolic rate
rises temperature by 0.5^0C
Hypothyroidism – rises temperature by 0.5^0C
decreases temperature

<u>Brown Fat</u> – B.A.T. – (Brown adipose tissue) a special tissue in mammals.
Special thermogenic tissue found in new born mammals including man. Present in all new born mammals in cold region. It helps them to fight cold. Also present in hibernating mammals & helps them in Arousal.

It produces heat by oxidizing fat and the heat production is so rapid, like a furnace.
Location – found in neck & Thorasic region.
It warms the heart & brain first.
Then heat spreads through circulation.

Difference between normal white fat and brown fat.

White Fat	B.A.T.
→ Cells round & small → Few fat droplets → Few vacuoles → Few mitochondria	→ Cells large, polygonal → Numerous fat droplets → Many vacuoles → Numerous small mitochondria → It also has high protein & phospholipids →It also has cholesterol, enzyme, myoglobins, flavin compounds, cytochrome and they give reddish brown colour.

How BAT gets stimulated and releases energy?

Stimulus through sympathetic Adrenelgic nerves

↓

Secrete N Epinephrine

↓

Binds numerous receptors on BAT cells.
1,50,000/cell ! Therefore cells are very sensitive.

↓

ATP —ATPase→ AMP (acts as 2nd messenger)

↘ **Mobilizes lipase**

↓

Free fatty acids (FFA)

↓

Oxidized in mitochondria &
& this leads to rise in O_2 consumption

Heat loss – It has to be regulated because at low temperature heat production has to be increased. Metabolic rate rises, food requirement rises. But food availability less due to winter.

Therefore heat conservation has to be done. In different environment, heat loss is by different ways :-
Aquatic life – conduction more
Teristerial life – Evaporation – 40 %

Radiation - 55 %

At low temperature, heat loss is by conduction & radiation whereas at high temperature, heat gain is by conduction & radiation.

Evaporative heat loss is always there i.e. 0.6 Kcal/gm evaporation of water.

There are different mechanism to regulate heat loss.

Mammals in hot environment increase sweating to raise evaporative heat loss. They also show panting to raise evaporative heat loss. Some mammals become nocturnal to avoid evaporative heat loss.

Birds don't have sweat gland. They tolerate hyperthermia (T_b 2^0C more warmer than mammals). They also show evaporation from respiratory surface & also from thoracic & abdominal air sacs. An experiment was done on Birds. The air sacs were inactivated which caused 50 – 60 % reduction in evaporation leading to hyperthermia.

In hot air, pigeons show rise in tidal volume (i.e. volume of air / breath) which causes more evaporation & cooling.

For this purpose, air sacs are useful for pigeons.

Temp	Resp. Rate / min	Tidal Vol. / min.	Total air flow / min.
42^0C	46	4	184 ml/min.
44^0C	51	12	612 ml/min.

Birds show panting & <u>Gullar</u> <u>fluttter</u>. (Rapid movement of floor of mouth & throat). By this they achieve cooling by evaporation.

Storks & Egrets dip legs in water. In storks they often urinate on legs (1 urination / min).

In cold environment insulation is useful to prevent heat loss.

Birds have feathers & mammals have hair.

Mammals adjust their coat thickness. the coat is thicker in winter & thinner in summer. They even change their colour. Mammals in temperate region have thicker fur.

Small animals can't have thick fur.Therefore shelter in burrows e.g. Mice.

Some mammals have naked skin like pigs, whales and walrus. But they have a thick fat layer below skin which has low melting point , so it remains in fluid condition in low temperature also. The Eskimos use this fat & apply it to their shoes to keep it soft. This fat acts as insulator & also as source of energy.

The animals living in cold environment have skin which is resistant to cold & the sensitivity of skin is lower due to fat deposition. But still the nerves are sufficiently sensitive.

Eg. Pigs remain comfortable at 8^0C but man becomes uncomfortable at 31^0C . In seal when skin is at 0^0C, 5 cm below the body is warm.

In Whales fat layer is present called as Blubber for body heat regulation.

Arctic fox has thick fur & is comfortable at -40^0C. This insulation which protects the animal during cold becomes a problem when the animal is active and warmed up because it prevents heat loss.

During metabolic activity, metabolism is fast so more heat is produced which has to be given out.

For this purpose animals have thinly insulated extremities.
In Arctic fox, legs are thinly insulated so while sleeping it curls up to cover the legs.
When active, heat is given out through the legs.
In Gulls, Arctic dogs & Reindeers have extremities thinly insulated.
- But they can tolerate cold
- Remain sensitive
- Remain flexible (low M.P. fat)

Rete Mirabile

Arterial blood gives heat to cool venous blood which is going in body therefore heat is conserved. During activity fast circulation through rete mirabile therefore useful in going out heat.
In JackRabbit, external ears are big which help in giving out heat in summer. But in cold environment circulation is reduced in the ears.
In cold environment, X-Ray of ears looks black
In hot environment, X-Ray of ears looks bright

Thermostat (Regulator)
In mammals – Hypothalamus
In Birds – Spinal cord
Anterior hypothalamus protect against heat. Post hypothalamus protect against cold.
Stimulii from different parts of the body are received.

↓

Messages to body through effector nerves. Message is also sent to Autonomous nervous system which controls sweat gland, cutaneous blood flow, pilo erection.
Even if Autonomous Nervous System is damaged, blood vessels respond to lower blood temperature. In cold, the Blood vessels contract & in hot , the Blood vessels expand.
When there is prolonged change in T_a

↓ .

It Stimulates endocrine system.
(Thyroid) – long term effect.
(adrenal) – short term effect.

↓

In cold, secretion rises
In hot, secretion decreases
Affect Metabolic rate to regulate temperature. Animals extreme cold show adaptation of body i.e. C.N.S. tolerate & functions at low Ta. Nerve Axons, heart also tolerant & functional at low T_a.

Temperature Regulation in Poikilotherms :
Poikilotherms cannot alter metabolic rate.
Low T_a → low metabolic rate
High T_a → high metabolic rate
Even then they try to maintain Tb constant by various phenomena
i) Gradient selection behaviour

Animals show movement towards a particular temperature, suitable for their survival.
Eg. 1) Free living Nematodes – When exposed to thermal gradiant, shift to middle part.
Parasitic nematodes select warmer temperature even if they suffer damage.
2)Housefly larvae – select warm (feeding) temperature 15^0C to 33^0C.

But pupating larvae selects cold temperature because warm temperature will be harmful to pupa.

This type of gradient selection can be altered by acclimation.

ii) Metabolic Warming –

This is also a behaviourial adaptation in poikilotherms.
Eg. Butterflies show warming up movement of wings.
Femame Python coils around eggs & keeps her body warm by muscle contraction.
Cold waterfishes like Tuna & Sharks swim fast to maintain high Tb (14^0C higher than T_a)
They die if prevented from swimming . Hence they are kept in circular tank.
Due to fast swimming gaseous exchange also is possible.

iii) Heat gain from environment or heat loss to environment –

Desert locust remain inactive in morning when temp.(T_a) below 17^0C & start moving at T_a 17^0C to 20^0C. Make body perpendicular to sunlight so that body is exposed to more sunlight and heat is gained to make the body warm.

During noon → Ta = 40^0C
Therefore the locusts rest in bush and keep body parallel to sun rays so that minimum surface is exposed and heat gain is minimum.
In the Evening – Again keep body perpendicular to sunrays to gain heat by absorption.
Butterflies – bask in sunlight to gain heat by ectothermy.
Lizards – Bask in sunlight for absorption of heat. To avoid heat loss to cool substratum , keep body on dry grass.
Body colour of poikilotherms also helps in losing or gaining heat.
Snout Beetle – Living in hot environment has light colour. Absorb only 26% heat.
Carrion Beetle – living in cold environment. Body is therefore dark & absorb 95% heat.
Nocturnal moths- have furry insulation to prevent heat loss. They show shivering thermogenesis of thoracic muscles.
Iguana in cold environment – has Dark colour absorb 74% heat & Reflect 6%.
Phrynosoma (horned toad) – is light colour in hot environment & dark in cold environment & absorb 65% of heat.
Earless lizard – lives in Desert & in night burries in the sand.
Takes head out in the morning. Blood filled sinuses in the head region get heated in sunlight. When warm blood spreads in the body, the lizard emerges out.
Snakes in Arctic region have longer body so that they can absorb more amount of heat by increasing surface area.
Lizard chuck walla shows panting for evaporative cooling.
Use of evaporative heat loss by Bee, for cooling—In summer bees bring water to the hive and do fannning to increase evaporative heat loss to achieve cooling
In winter bees show clustering to prevent heat loss and keep the hive warm & they keep on changing their places.
Reptiles in cold reduce cutaneous flow & in hot the cutaneous flow increases.
In insects they have waxy layer on cuticle.
$T_a > 30^0$C layer melts evaporation rises therefore cooling is achieved.
T_a less than 30^0C the wax layer prevents evaportion.

Snakes in northern region show viviparity for survival. (e.g. Vipers)

In Poikilotherms the Thermostat is C.N.S,

Peripheral Receptors send stimuli to C.N.S. & according to the signals sent the CNS modifies the insect behaviour so that heat is gained or lost. Thus through regulation of hear loss and heat gain , the poikilotherms also try to regulate the body temperature.

Acclimation & Acclimatization

When an animal is subjected to changed condition in laboratory, animal shows compensatory changnes to new environment. These changes are known as acclimation. In other words acclimation is adjustment to laboratory conditions.

In case of temperature regulation acclimation is of 2 types i) Cold Acclimation ii) Hot or warm Acclimation

Acclimatization – Compensatory adjustment of organism to change in the environment, in nature or natural condition is known as acclimatization. Adjustment to seasonal changes in temperature come under acclimatization.

Normally when an animalis is exposed to a T_a lower than normal then initially the body temperature T_b drops , thereafter the animal compensates and tries to bring the T_b to normal. When exposed to hot T_a the T_b initially increases and then the animal tries to bring it to normal through compensation.

As shown in the figure when a animal from Normal temp. t_a is subjected to cold t_a, then there is initial drop in body temp. as shown by position 4. If the animal is exposed to hot environment there is initial rise in body temp. shown by pattern 4. If the body temp (t_b) from 4 settles to 2 then the compensation is known as "perfect compensation" & acclimation as "Perfect Acclimation". If the temp. settles between 2 & 4 i.e. 3 then compensation is not full proof so known as 'partial compensation' & hence known as "partial Acclimation"

If the body temp (t_b) settles to pattern 1 i.e. in cold Ta the body becomes warmer than normal & in hot Ta it become cooler than normal then the compensation is known as "over shoot" or "excess compensation". And if the body temp. as shown from pattern 4 changes to 5 i.e. in cold it further drops & in hot environment it further rises then the compensation is not there or it indicates "no compensation."

The animals, depending upon their genetic ability show different type of compensation. However it is difficult to generalize about compensation because there are too many variation in acclimatory compensation.

Many animals show compensatory changes in particular range of temp.

So also the acclimation depends on physiological state of animal such as hormonal state, health, injuries ets.

Not only the animals show different type of acclimatory compensation. It is found that in an animal different tissue show different type of acclimatory compensations. This is of course is related to the importance of tissue in the body.

As shown in diagram below a fish trout when acclimated to 16 to 8^0C temp. following Precht's pattern was seen in which brain showed perfect acclimation, liver showed over shoot compensation, whole body showed partial compensation & gills showed no compensation.

It is generally observed that the animals which show torpidity & hibernation or are poor in compensatory acclimation. Whereas the animals that remain active in extreme environment are better in compensatory acclimation.

The animals which live in tropics & polar environment enjoy stable environment & hence are poor in compensatory acclimation as compared to those living in temperate environment which have more temperature fluctuations.

Changes that occur during Acclimation & Acclimatization

There are various changes that take place in Acclimation & Acclimatization that include physiological changes like glycolysic, electron transport cycle & Kreb's cycle.

In cold acclimation protein & enzyme secretion is more as compared to hot acclimation. All the changes during acclimation are not understood except the following -

Normally changes occur in --

i) Protein & phospholipid synthesis & turnover.

ii) Synthesis of isozymes suitable for new environment.

iii) Modification of membrane lipids.

Normally membrane lipids become unsaturated fats so that they remain fluid in cold condition.

Likwise animals show behavioural responses (refer to Gradient selection in poikilotherms)

<u>Cold Acclimation</u>

When birds or mammals are kept at low temp. in laboratory, initially their body temperature falls down but then they show rise in metabolic rate, rise in O_2 consumption. This change is proportional to change in temp. As oxidation is faster, the food intake rises. The enzymes in liver, muscles and mitochondria rise. Glucose, pentose, fatty acid pathways are mobilised. They become faster. Adrenal & thyroid secretion rises. Most important is that the peripheral circulation rises to keep skin warm & in them normally insulation by fur coat does not change.

<u>Cold Acclimatization</u>

This is a slow process & is seasonal. The change is prolonged & gradual & hence the compensatory changes are different. In nature when change occurs the animal show changes in thickness of fur coat. They reduce the peripheral circulation & both these prevent heat loss. This is because in environment with approach of winter there is scarcity of food. It is found that the thickness of fur rises in large animals. In them fat is mobilised & unsaturated fat gets deposited in joints & extremity so that the flexibility is maintained. Their CNS, tissue, nerves gradually gain resistance to stand the cold. Sparrow gain resistance at rate 6^0 drop / month. For sensitivity of tissues is increased . There is higher sensitivity of the tissues to neurotransmitter or the transmittor subs. Along with these the animal show behavioural changes in them.

Ex. Dog, rats, bees show aggregation phenomenon in cold season.

Acclimation & Acclimatization for heat & hot environment show similar changes & hence considered together. When skin heat receptors feel heat they lead to reflex responses which include

1) Dilatation of cutaneous blood vessels to rise blood flow in the skin so that heat is given away.
2) Sweating rises.
3) If Sweat glands are absent (birds) then evaporation from respiratory surface rises.

All these processes cause evaporation of water & hence cooling. In man in cool air 1 litre water/day is evaporated from body surface. Rise by 1^0C rises water evaporation at a rate 20 ml/hr.
Donkeys & camels live in desert environment where ta is high. In them to save water sweating start late or at higher temp. It starts between 31-35^0C temp. The organism have to tolerate hyperthermia.
The stimulus for sweating is different in different animals. In some exposure to sun causes sweating. In female sheep sweating is stimulated when mammary glands are heated, in male sheep sweating is stimulated when scrotal sac skin is heated. In general sweating causes evaporative heat loss. However birds don't have sweat gland & hence they show evaporation from respiratory surface.
Ex. : Gullar flutter – Pigeon, Storks
Panting – hawk, pigeon etc.
Fluffing of feathers – Ostrich, Pigeon, sparrows.
Dusting of feathers or dust bath – sparrow, ostrich. This is how they try to achieve cooling.
Desert birds soar high in the air & enjoy cool air currents.
A bird 'Bobby' spreads the wings & keeps legs under shadow so that cooling is achieved.
Stork urinates on the leg or shows panting & this stops when it enters water.
In mammals respiratory surface evaporation is raised. In cows pulmonary evaporation rises 3 fold when temp. rises to 68^0F to 111^0F.
Dogs & cats show panting.
In goats horns play important role in cooling. If horns are covered by woollen cap the goat dies because of rised brain temp.
In human beings, also when a person is heat acclimated certain physiological modifications are seen.

a) capacity of sweating is doubled.
b) sweating starts earlier.
c) sweat contains less salt.
d) efficiency of cardio vascular system rises.

<u>Hibernation, Aestivation & Torpidity</u>

<u>Hibernation</u> :
It is a seasonal dormancy shown by the animal which may be shallow or deep for a short period or a longer period. It is shown in winter season hence winter sleep or winter dormancy.
In hibernation there is extreme drop in temp. of body due to which physiological processes become extremely slow & hence energy is conserved. For this purpose the animals need lot of preparation.
In hibernating animal the thermo regulator is set to a low temp. (normally 2^0C). Heat conservation mechanism is turned off & animal enters into a deep sleep. Hibernation is shown by certain animals like monotremes, insectivorous, rodents, bats i.e. mainly mammals. It occurs in form of annual cycle & is governed by hormones because if serum of a hibernating around squirrel is injected in an active ground squirrel it shows hibernation.

<u>Preparation of hibernation</u> :

Various physiological changes occur during hiberation. In favourable season usually the animals show fat accumulation. The carbohydrates are converted to fat & stored. Hampster store food material in their nest & they show deposition of low m.p. fat.
Hegdehog show rise in insulin & rise in thyroxin. In them if thyroxine is injected hibernation is retarted.
Pituitory & adrenal glands play important role in hibernation.
Pituatarin causes hibernation in hampster whereas adrenalactomy leads to failure of hibernation. Thus endocrine factors play important role in hibernation but their mechanism is complex.
In hamster if adrenal gland is removed hibernation is prevented but in a hibernating hamster adrenal activity is low. So also if nor-adrenaline is injected then also no thermogenic response is seen.
The t_b of hibernating animals drops slowly normally at a rate 2-4 0C/hr & drop is associated with peripheral vasodilatation & reduced muscle tone.

During hibernation
T_b falls down
↓
Heat rate reduces significantly

In ground squirrel it is 200-400 / min whereas in hibernating ground squirrel it is 7-10 beats / min. Beats become irregular. Heart remains functional at low temp. & it is not sensitive to vagus inhibition.

Respiratory rate of animal drops. Thre is a drop in cardiac output. In ground squirrel it reduce to 1/65 as compared to normal.

In some species the blood is collected in spleen which rises in size so also erythrocyte count & haemoglobin level rises & clotting time is prolonged.
Nervous system remains active even at 9^0C the brain shows response to peripheral stimuli.

Magnesium content of serum becomes high in hibernating hedgehog & Marmo bat.
Hypothalamus plays an important role in hibernation. Posterior hypothalamus is important for hibernation & anterior is important for arousal. In a hibernating ground squirrel if posterior hypothalamus is damaged, it fails to hibernate & if anterior hypothalamus is damaged it fails to arouse.
Hibernating animals has a unique ability to prevent drop in the temp. which can be serious. If the body temp. becomes very low the animal shows arousal, they feed & again hibernate. In some animals for this purpose there is cyclica arousing. Ground squirrel wokes up after every 11 days where as hampsters also wake up every few days, feed & hibernate.
During hibernation the overall metabolic rate is 20-1000 times slower. Inspite of this there is a weight loss in the animal which can be from 10-30%.
The hibernating animals show resistance to adverse condition (other than temp.)
Ex. When hibernating ground squirrel is exposed to ionising radiations there are no ill effect seen during hibernation. However when they arouse the in effects are apparent.

<u>Arousal or Waking up</u> :

Waking up is very fast in the animal. A bat is kept for 144 days in refrigerator become active when taken out. In ground squirrel the temp. rises from 4^0C – 35^0C in 4 hrs. In Birch mouse the temp. rises from 1^0C /min. In this arousal process the animals are helped by specialised tissue known as brown adipose tissue. It produces heat like a furnace in very high amount. Usually the stimulus for arousal is changed season & warming of ta. All the are stimulator or super cooling also acts as stimulator for arousal.

When the stimuli is reached a series of process takes place. Due to stimuli peripheral blood vessel contract called as vasoconstriction. So blood flow towards thoracic muscle causing warming. So also autonomous stimuli are send to BAT (Brown adipose tissue) & it is activated by nor-epinephrine. Due to which BAT is activated & starts oxidation of triglycerides or unsaturated fats. In arousal autonomous nervous system is activated, then BAT is activated, Heat is produced, heart rate become faster than respiratory rate rises leading to arousal.

Thus mammals living in living environment. Their winter is long & severe so this unique phenomenon of hibernation by which the animals bring down their metabolic & rate & conserve their energy during adverse condition.

Torpidity (Torpor)

Daily sleep (Torpor) is seen in bats, Birds & mammals. This phenomenon is daily dormancy.In this the T_b rapidly drops down to reduce metabolic rate due to which the animal conserves energy.

Torpidity many a times is related to environmental condition & food availability. In some animals when food is scarce they can raise torpidity from few hrs to few days. Whereas some animals can show continuation of torpidity into hibernation & aestivation.

Bat (especially microchiropteron) – show Diurnal torpidity which is during day time, is seen in summer to avoid ill effects of intense heat.

Myotis (bat) shows Torpidity in hot summer days, where the T_b drops to 5^0C so that metabolic rate is reduced. This bat when is cooled below 5^0C don’t wake up & dies because of super cooling. However the same bat during winter hibernates if a hibernating bat is supercooled it wakes up & become active or it regulates the temp. to maintain it to 5^0C. Thus torporing bat cannot resist supercooling whereas hibernating bat can resist supercooling.

2) Humming bird – smallest 1.7 g
largest 19 g

They have very high energy requirement as they are very active and the metabolism is high. At around 27^0C temp., in the blue throated humming bird the heart beat is 7 to 21 beats /sec. The O_2 consumption of the bird is 1.18 ml/g/hr. The energy requirement of the bird is so high that if the body temp. remain normal at night time (when the bird is not feeding) , the bird will die due to energy shortage. To overcomes this the animals shows torpidity. Due to drop in temp. Heart rate became less & the O_2 requirement becomes $1/10^{th}$ of normal.

If this torporing bird is cooled to 8^0C then many a times the bird dies due to super cooling , it cannot wake up.

3) Desert Rodents show torpor mainly to overcome the food scarcity. In pigmy mouse the T_b is dropped to 23^0C during day time for a period of 12 hrs & they become active at night. In Kangaroo Rats we find that the duration of torpidity is adjusted according to food. It can be from few hours to few days.

Thus torpidity is a diurnal phenomenon in which the animal allows to drop in T_b to conserve energy.

Aestivation (Summer sleep or summer dormancy)
Some animals have ability to remain dormant during unfavourable summer months when there is water scarcity or intense heat.
Aestivation is shown by desert animals And variety of them like snails, ground squirrel etc. some show aestivation & hibernation. e.g. Snails show hibernation / aestivation according to availability of water. Ground squirrel aestivate in summer and hibernate in winter. Normally in insects, during summer the adults die but the eggs & pupae survive by remaining dormant.
In case of snails, sawbugs, shrimps adults remain dormant in unfavourable condition.
Desert Amphibians. show aestivation / dormancy
Ex. Spade foot toad – has spur like projection on hind leg for digging. In drought period it starts digging & burrows in the soil. It encloses itself in gelatinously material, mud ,sand & remain their for 8-9 months. It wake up with 1^{st} showers of rain & life cycle is completed in 3 months.

In the same manner ticks & mites show dormant condition. They remain dormant during winter & summer & remain active only during spring.
e.g. Dermacentre (Rocky mountain wood tick)
Mammals like kangaroo rat, pocket mouse aestivate when there is scarcity of food whereas in white footed mouse aestivation occurs when there is shortage of water.
Some birds like swift aestivation is due to scarcity of food.

A very unique phenomenon is shown by lung fishes like Protopterus, Lepidosiren, Neoceratodus which show aestivation. They remain alive in earthen cocoon for many years & for this purpose they store urea in their tissues to absorb water. The metabolic rate falls to 1/100 due to which they can aestivate for a long period.
Thus torpidity, aestivation hibernation are the phenomena in which the animals allows the T_b to drop down & thus conserves energy. By conserving energy they can overcome adverse conditions. The phenomena are similar to each other & the purpose is conservation of energy only. The only difference in them is length of dormancy & the season of dormancy.