COURSE CODE:	**ANP 503**
COURSE TITLE:	**Environmental Physiology**
NUMBER OF UNITS:	2 Units
COURSE DURATION:	**Four hours per week (1-Lecture, 3-Practical)**

COURSE DETAILS:

Course Coordinator:	**Dr. M. O. Abioja** *B.Agric., M.Agric., Ph.D*
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Office Location:	**ANP Staff Office, COLANIM**
Other Lecturers:	**Dr. J. O. Daramola, Dr. J. A. Abiona**

COURSE CONTENT:

Effects of climate on livestock production, Acclimatization and adaptation, Physiological basis of adaptation, Heat stress, Physiology of thermoregulation: Heat balance, Heat gain, Heat loss (Sensible heat loss, Insensible heat loss- Panting and Sweating), Physiological, behavioural and hormonal responses to heat stress, Modification of the microclimate to enhance animal productivity, Management of exotic breeds in tropical environment.

COURSE REQUIREMENTS:

This is a compulsory course for ANP 500 Level Students in the University. In view of this, students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

1. Pat Willmer, Graham Stone, Ian Johnston. *Environmental Physiology of Animal* 2nd edition. Wiley-Blackwell. 2004

2. Richard W. Hill. *Comparative physiology of animals.* Harper and Row 1976.

3. Knut Schmidt-Nielsen. *Animal Physiology: adaptation and environment.* Cambridge University Press. 1990.

LECTURE NOTE:

EFFECTS OF CLIMATE ON LIVESTOCK PRODUCTION

The variation in phenotype of livestock is an outcome of both variation in genotype and the environment where the animal is found.

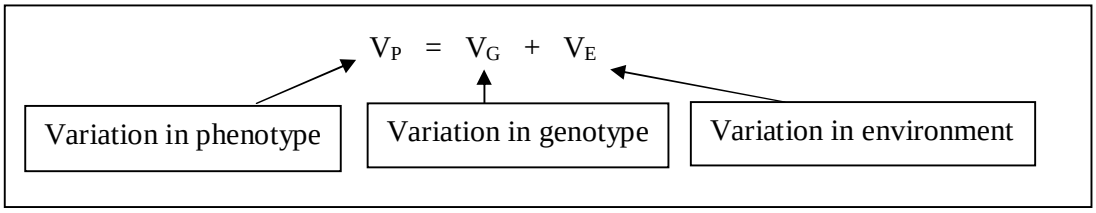

Figure 1: Showing the schematic representation of the effect of environment on the phenotype of an animal

Environment

Environment is the living and non-living components surrounding an organism. This includes both internal and external environment

Internal environment: This consists essentially of the fluids that surround the cells. The composition and condition of these can be regulated within narrow limits by the animal.

External environment: this includes all factors external to the animal that influence its functions over which the animal has little control.

Internal environment	External environment
• Blood • Lymph • Tissue fluid • Haemolymph • Coelomic fluid • Pleural fluid • Peritoneal fluid • Cerebrospinal fluid • Synovial fluid • Aqueous humour • Vitreous humour	**Climatic factors:** • Temperature • Humidity • Rainfall • Solar radiation • Photoperiod • Wind **Others:** • Management system • Nutrition • Parasite/pathogen interaction • Air and water pollution • Social environment • Litter size • Parity of dam, *etc.*

Table 1: Showing the various components of internal and external environment of animal

All these factors do affect productivity of livestock and at extremes can be lethal

Weather and climate

Weather is the short-term day-to-day fluctuation of the meteorological variables.

Climate is the long-term average condition of over 30 years of meterological variables in a given region.

Macro-climate is the general large scale climatic condition of the open atmosphere in a large area or country.

Micro-climate is the climatic condition closely surrounding an animal e.g. the condition under a tree, in the pen, *etc.*

Climatic variables: Temperature (ambient, minimum, maximum, mean temperatures), Humidity, Rainfall (amount and distribution), Sunshine (day-length and intensity), Wind (direction and speed)

Relationship between various climatic variables

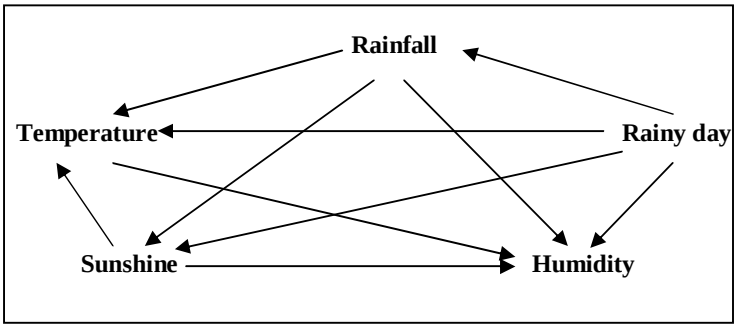

Figure 2: Diagrammatic illustration of relationships between various climatic variables

Climatic zone:

- **Temperate region (close to the poles)**
- **Tropical region (close to the equator)**

The term 'tropical' is used geographically to designate the area between the *Tropics of Cancer and Capricorn* (between latitude 23^{o}N and 23^{o}S).

The climate is not uniform throughout the tropics.

Variability exists in diurnal, daily and seasonal temperatures and other climatic variables, being least at the equator.

Of these, temperature, rain fall (humidity) and photoperiod are the most important on the livestock production.

The climate is relatively hotter in the tropics than in the temperate region with high humidity reinforcing the effect of the livestock.

Effects of climate on productivity of livestock

- The effect of climate varies on account of interactions between the climatic variables and diurnal, daily and seasonal changes
- Animals have different levels of adaptation to different climatic stress, e. g. temperate-type Holstein cattle have a thermal comfort zone for milk production within the range -5 to 20^{o}C, with optimal production at around 10^{o}C and with a critical temperature range after which milk production declines steeply, of 21-27^{o}C. the critical temperature is however in other temperate breeds (Jersey and Brown Swiss) and higher still in tropical breeds
- Seasonal fluctuation in availability and quality of roughages for livestock during dry season also affect productivity in the tropics
- Other factors affecting animal productivity includes diseases and parasites, low genetic potential and poor management system

Some effects can be seen in:

- Reduced growth rate and prolonged time to reach puberty

- Low milk yield per lactation
- Reduced fertility and *libido* in male
- Reduced length and intensity of oestrus
- Slow return to oestrus and conception after weaning
- Embryonic mortality
- Reduced feed utilization
- Increased morbidity and mortality

ACCLIMATIZATION AND ADAPTATION

Most livestock are homeotherms (animals that maintain the body temperature constant). They have a range of environmental temperatures that they can withstand without changes in basal metabolism and this is termed *zone of thermal neutrality* or *thermal comfort*. The temperature boundaries are the upper and lower critical temperatures.

Stress: Any condition that imposes a deviation on the internal variables from the controlled levels.

Homeostasis: This is the regulation of the internal environment. It is the tendency for internal variables such as water content, solute concentration, pH, body temperature, respiratory rate, *etc*. to remain at controlled levels.

Acclimatization: Long-term adaptive physiological adjustment which results in an increased tolerance to continuous repeated exposure to complex climatic stress.

Acclimation: Adaptive changes in response to a single climatic variable, the type found in simulation experiments in the laboratory.

Adaptation (physiological): Is the capacity and process of adjustment of the animal to itself, to other living things and to its external physical environment

Adaptation (genetic): The heritable animal characteristics which favour survival of a population in a particular environment

Adaptation (biologic): Refers to the morphological, anatomic, physiological, biochemical and behavioural characteristics of the animal which promote welfare and favour survival in a specific environment

Examples of some adaptive features in livestock in hot environment

- Short sleek coat of the N'Dama cattle is an adaptation to a hot environment
- Prominent dewlap and hump in zebu cattle
- Possession of higher number of sweat glands in zebu
- Wallowing in pigs
- Skin and coat pigment in Yankasa sheep

Animals need to be well adapted to the environment else they will not thrive well in such an environment. Well adapted animals are characterized by:

- Good growth rate
- High milk yield
- High reproduction rate
- High resistance to disease
- Low mortality rate and longevity
- Ability to withstand stress

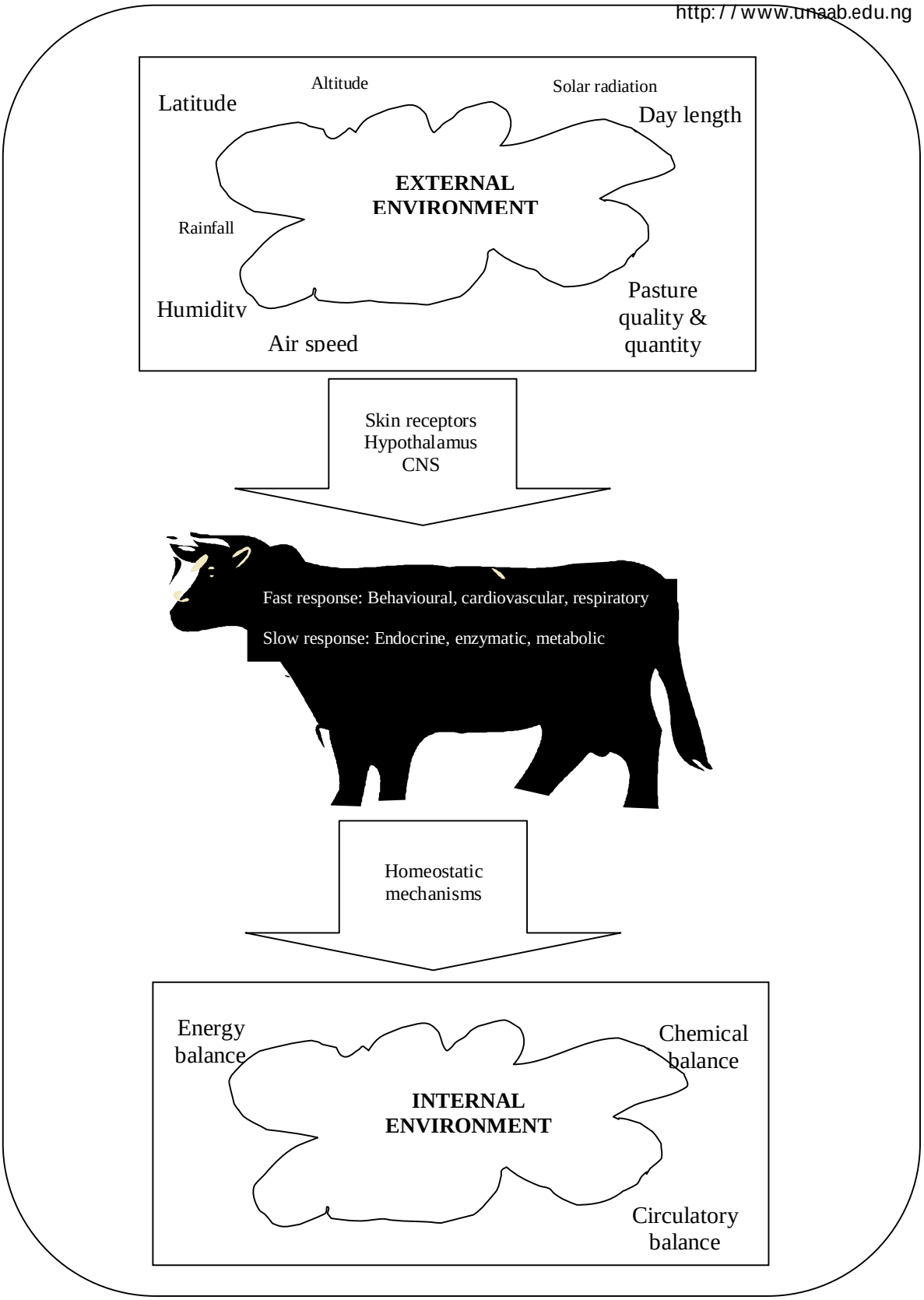

Figure 3. Diagrammatical illustration of the concepts of acclimatization and homeostasis

PHYSIOLOGICAL BASIS OF ADAPTATION

Mechanisms of homeostasis

Mechanisms by which an animal maintains a constant internal environment are behavioural responses, chemical balance, feed consumption, body water balance, thermoregulation, pH control, osmotic and electrolyte regulation, circulatory balance of cardiovascular activities, metabolic process and blood pressure. Maintenance of homeostasis is mainly under the control of the central nervous system (CNS) and endocrine system.

Neural and endocrine control mechanisms

- **Central Nervous System:** Neural mechanism in animal adaptation is therefore the mental processes and bodily actions of animals, caused by the functioning of nerves which enhance the animals' survival and reproductive success in its environment. CNS comprises the **brain** and the **spinal cord**.
- **Peripheral Nervous System:** The peripheral part is the pairs of nerves that leave the cerebrospinal axis and pass to the various organs of the body. It contains fibres of two kinds: *afferent* and *efferent* nerve fibres. Afferent or sensory nerve fibres carry impulses from the periphery to the CNS while efferent or motor fibres carry impulses from the CNS to muscles and other organs.

Hypothalamus

- This is a relatively small area of the brain situated at the base o f the brain. It is an important integrative organ for homeostasis
- It contains temperature sensitive cells (thermoreceptors)
- It serves as an important link between the nervous and endocrine systems
- It exerts control on the endocrine activity of the body by influencing the pituitary function
- It is significant in the regulation of autonomic activities
- It is the control centre for thermoregulation, feed intake, water intake, osmoregulation and cardiovascular activities, control of sweating, sleep regulation, control of hibernation
- Stimulation of the anterior hypothalamus has an excitatory sympathetic role

Autonomic nervous system (ANS): This is the totality of visceral motor pathways controlling the involuntary system.

ANS regulates:

- Motor and sensory functions of the gut
- The contraction of heart
- The tone of blood vessels and blood flow
- Blood pressure
- Contraction of bronchioles
- Contraction of urinary bladder
- Thermoregulation
- The diameter of pupil and visual accommodation

Activities of the ANS:

- Controlled by hypothalamus, the brain and the spinal cord
- Not under conscious control, but are influenced by the cerebral cortex and the limbic system
- Control of autonomic function is mediated by visceral reflexes (barorecptor reflex, cephalic phase gastric secretion, micturation and defaecation reflexes)
- Can be divided into two

ANS

Sympathetic: The fight or flight system. When stimulated, it slows digestion, peristalsis and in secretion of digestive juices, dilation of pupils, erection of hair; increases blood pressure and flow to the limbs

Parasympathetic: This promotes the even regulation of daily activities, e.g. digestion, blood flow, *etc.*

Synapse

The point at which the nerve cell connects with another is the synapse. Nerve endings have synaptic knobs which contain transmitter substance. These substances can be either acetylcholine (from cholinergic nerves) or nor-adrenaline (from adrenergic nerves). Transmitter substance through diffusion are passed from pre-synaptic membrane (of knob) through synaptic clef to the post-synaptic membrane (of adjoining nerve), to effect depolarization and consequently the potential action.

- Both sympathetic and parasympathetic systems contain afferent and efferent nerves
- Efferent nerves of both systems contain two types of neurons- the preganglionic neurone which connect the CNS with the cell body of postgangloninc neurone
- All preganglionic nerves are termed cholinergic because they release acetylcholine from their endings which interact with receptors on the postganglionic membrane
- Most postganglionic parasympathetic fibres also secrete acetylcholine; some secete other transmitter notably vasoactive intestinal polypeptide (VIP)
- Most postganglionic sympathetic fibres release nor-adrenaline (nor-epinephrine) and are termed adrenergic, but sympathetic fibres supplying sweat glands and the vasodilator fibres to striated muscle release acetylcholine
- Recent evidence suggests that depolarization of all postganglionic nerve endings release acetylcholine, which then liberates nor-adrenaline
- Acetylcholine and nor-adrenaline are synthesized at the nerve endings but are very rapidly inactivated

The ANS and the endocrine system coordinate the functions of different organs for homeostasis and for specific function such as reproduction or response to injury.

THERMOREGULATION

Thermoregulation: 1st demonstrated by Blagden in 1775 who described how a man in a small room heated by a red-hot stove remained well while a piece of steak beside him cooked.

Poikilotherms: 'Temperature conformers' (cold-blooded animals). Their internal temperature depends on the environment. Include fishes, amphibians, reptiles and invertebrates. Activities of poikilotherms depend on environmental temperature, which s independent on weather, season, and time of day. Poikilothermic species defend body temperature mainly through behavioural responses.

Homeotherms: 'Temperature regulators' (warm-blooded animals) maintain stable body temperatures over a range of environment. Include birds and mammals. Though homeotherms vary widely in size and belong to diverse families, they all maintain internal temperatures within or close to the narrow range 37-39^{o}C.

Body temperature: Healthy body temperature measured under standard condition varies little among individuals. The temperature of the body is however not constant in space or time.

Body can be considered to consist of:

- **Core:** Produces heat, stirring and control mechanism, maintain uniform temperature
- **Shell:** Surrounds the core, insulating, with temperature gradient

Note: The Core and the Shell idea is a simplification, though useful. No sharp or fixed boundary between the two. The tissues of the shell are not inert. The temperature of the core is not uniform.

HEAT STRESS

- Some of the common factors that can lead to stress (stressors) in livestock production include transportation, noise, fasting, water deprivation, hotness, coldness, *etc*.
- Most livestock (mammals and avians) are homeothermic animals
- They maintain the core body temperature constant or within a narrow range
- They employ various means to regulate the body temperature which include both sensible and insensible heat loss methods
- They have a thermoneutral zone in environmental temperature in which body temperature maintenance is possible
- When ambient temperature increases beyond the thermoneutral zone, animals exhibit varying physiological responses depicting that they are stressed
- This form of stress is termed heat stress or distress
- Heat stress is a multi-faceted adaptive response that occurs when an animal's capacity for heat dissipation is exceeded by the heat load acquired through excessive exposure to high environmental temperature. It results from the interactions of air temperature, humidity, radiant heat and air speed, where the air temperature plays the major role

PHYSIOLOGY OF THERMOREGULATION

- Reaction of livestock to stress can be divided into three phases: alarm, resistance and exhaustion phases.
- During initial *alarm* phase, the stressor stimulates postganglionic neurons and the medullary tissue of the adrenal gland which release catecholamines including adrenalin and/or noradrenalin. These catecholamines cause a rapid release of glucose.
- A second adaptive or *resistance* phase follows and stimulates the hypothalamus, which in turn commands the adrenal cortex to release a glucocorticoid hormone called corticosterone. This hormone is responsible for the formation of glucose from the body's reserves of carbohydrates, lipids and proteins through gluconeogenesis
- Finally if the bird does not recover from the stressor and the availability of body reserves and hormones from the adrenal gland are inadequate, a third or *exhaustion phase* leads to fatigue of the homeostatic mechanisms and death.

Figure 4. Broiler chickens showing panting behaviour (Abioja, 2010)

- Homeothermy in animals is controlled by a centre located in the hypothalamus. It was discovered that behavioural response to high environmental temperature is prevented by destruction of the hypothalamus. The pre-optic anterior hypothalamus (PO/AH) has been identified as a region of the brain which is rich in both warm- and cold-sensitive neurons that are sensitive to changes in its local tissue temperature. The entire panting responses to heat can be abolished by bilateral vagoctomy in chickens.
- Homeothermic animals appear well provided with peripheral thermoreceptors in the skin. Peripheral and deep body thermoreceptors situated outside the central nervous system provide afferent thermal information to the hypothalamus

Thermobalance

Animal's thermobalance is a composite of heat production and its dissipation. The hyperthermic birds, in the bid to survive, lower heat production and increase heat loss.

Heat gain

- Body heat gain results from three sources: chemical, mechanical and thermal sources
- Chemical source of body heat involves metabolism of feed
- Mechanical source is related to physical activity
- Body heat gain is derived from a thermal source if ambient temperature is greater than the body temperature
- Thermal heat gain may be through conduction, convention or radiation

Heat loss

Body heat can be dissipated by either sensible (non-evaporative) or insensible (evaporative) heat loss means

Sensible (non-evaporative) heat loss

- Heat loss from body surface by conduction, convection and radiation is termed sensible or non-evaporative heat loss (NEHL)
- Animals manipulate NEHL by increasing surface area and blood flow (peripheral vasodilation) to the body surface
- The degree of cooling is influenced by differences between body and ambient temperatures
- However, as this is exceeded, NEHL becomes insufficient and insensible or evaporative heat loss (EHL) mechanism resumes

Insensible (evaporative) heat loss

- Panting.
- Sweating

Predisposing factors to heat stress

- Season
- Location
- Ambient temperature and humidity
- Housing system
- Stocking density and ventilation
- Age, strain and adaptive response of birds

Indicators of heat stress in livestock

- Increase water intake
- Increased rectal temperature and respiratory rate
- Changes in haematological parameters
- Increased blood pH
- Changes in electrolytes and metabolites
- Reduced tri-iodothyronine, thyroxine and immune function
- Reduced feed intake and growth performance
- Increased mortality and morbidity
- Reduced egg size, production and shell quality in layers
- Reduced fertility and egg hatchability in breeders