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# Ecophysiology: Environment and Adaptation in Animals

by

William Ose Odiete



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# Ecophysiology: Environment and Adaptation in Animals

by

**Professor William Ose Odiete**

B.Sc. (UNN), M.Sc; Ph.D (Lond.)



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## I. INTRODUCTION

Of the many aspects of the study of animals, one of the most fascinating and challenging is the study of their physiology. This broad field of study called Animal Physiology deals with the way in which an animal carries out its work and functions. Physiologists look at animals in many ways:

1. As biochemical machines which acquire chemicals from the environment and arrange these in a series of electron transfer to provide the energy necessary for the operation of their machinery. Animals must acquire fuel, distribute it, burn it and remove the waste. This aspect of physiology includes nutrition, respiration, and transformation of energy, circulation and excretion;
2. Animals move about and behave, see, smell, feel, hear and react to other animals or to objects or conditions in their environment. These activities depend on a battery of sensitive receptors, on a group of specialised effector organs and elaborate integrating nervous and hormonal systems. The physiology includes irritability, receptor or sensory mechanisms, muscular activity, glands, behaviour, hormones and the nervous systems;
3. Life is constant renewal; the old must be replaced by the new. It is only through this replacement by a somewhat variable progeny that an evolutionary change is made possible and the formation of increasingly more complex and specialised animals become a reality. This aspect of physiology deals with reproduction, development and growth in animals; and
4. An animal rarely lives under constant environmental conditions. The physical, chemical and biological environments constantly change or fluctuate. Most animals face not only nutritional uncertainties but also marked daily and seasonal alterations in their environment. An animal must adjust, regulate, tolerate and resist these changes. This aspect of physiology is referred to as Environmental or Ecological Physiology or Ecophysiology.



My interest is Ecophysiology. Ecophysiology requires a good knowledge of anatomy of animals, animal behaviour, biochemistry, biophysics, chemistry, cytology and histology, ecology, ecotoxicology, electrophysiology, physical geography, zoogeography, mathematics, molecular biology and the other areas of animal physiology. It is quite a vast area of study.

Environmental alterations or oscillations can be fatal to animals. In order to survive, the animal must make adjustment or compensation, an active attempt to come to terms with its external environment. This is one of the basic properties of all living organisms. They have a wonderful capacity for maintaining the stability of their external form and internal functions in the face of disturbances from the external environment. Living organisms possess a high degree of internal order or orderliness which is all the time being actively maintained in the face of an external state of disorder. This capacity of animals was first observed by the great French physician and physiologist Claude Bernard, around the middle of the last century. He observed that the internal conditions or internal environment of the human body are maintained at an astonishingly constant level *vis-à-vis* the changing conditions of the external environment by a system of ingenious devices. In 1929 Walter B. Cannon, the American physiologist coined the term 'Homeostasis' to describe this state of affairs.

## II. PERIODICITY IN THE ENVIRONMENT

Life on this planet Earth is and always has been exposed to strong rhythmic environmental changes caused by planetary movements.

- (1) The Earth spins or rotates on its polar axis giving rise to day and night and the sun appears to rise in the east and sink in the West. The periodicity of this rotation or day night cycle is approximately 24 hours, called solar day. An organism living on the surface of this planet is exposed to and influenced by the 24 hour natural day-night cycle. Light intensity increases during the daytime. Correlated with this are the daily rhythms of temperature and humidity.

- (2) The earth revolves around the sun in about  $365\frac{1}{4}$  days giving rise to an annual cycle. The earth, as it performs its voyage around the sun is inclined at an angle and the face of it presented to the sun varies. The consequences of this progression are the unfailing seasons and the number of hours per day (day length or photoperiod) on it which varies with the seasons and latitude.
- (3) (a) The combined revolutions of the Moon and the Earth, and of both of them around the sun, give rise to the more complicated periodicity of moonlight and tide both of which are important variables in the lives of animals and plants - particularly those which live in the sea. The most important effect of the Moon's revolution around the Earth is the control of the complex tidal cycles. The gravitational pull of the Moon causes the waters of the Earth to "pile up" underneath it and as the Earth spins on its axis the heap sweeps around the world giving rise to two high tides in every lunar day (i.e once every 12.4 hours) and two low tides. The time intervals between the two tides vary.
- (b) The Sun also exerts a gravitational pull on the waters of the Earth although of a smaller magnitude. When the Sun and the Moon are pulling in the same direction the tidal range is particularly high (spring tides), whereas when the two are at  $90^\circ$  to each other the tides are less high (neap tides).

### III. SIGNIFICANCE OF THE MAJOR ENVIRONMENTAL FACTORS TO ANIMAL LIFE.

#### (1) Temperature:

The rates of biochemical reactions and metabolic processes are temperature dependent, increasing or decreasing at rates dictated by van't Hoff's  $Q_{10}$  law, which states that rates are approximately doubled for every  $10^\circ\text{C}$  rise in temperature. For each biochemical phenomenon there is a Temperature Optimum. At excessive temperatures (too hot or too cold) death results due to denaturation of proteins and enzymes, depolymerization of nucleic acids, thermal inactivation, different  $Q_{10}$  rates and inadequate oxygen supply all of which lead to destruction of living cells.

## (2) Light

Solar radiation is the ultimate source of energy for all life. Life exists in and operates on a relatively narrow band of the electromagnetic spectrum - called the visible spectrum or light.. In photosynthesis solar energy is channelled into the pyrophosphate bonds of adenosine triphosphate (ATP) and the reduced pyridine nucleotides. In turn, these are used to synthesize the complex organic molecules that form the food of animals. Plant life cannot exist without light and if there is no plant life there will be no animal life.

## (3) Humidity

Humidity is the invisible water vapour content of the air. It controls the rate at which water evaporates from the surfaces of terrestrial organisms.

## (4) Tides

Tides affect the littoral or intertidal zone i.e. that part of the continental shelf near the shoreline. It is submerged by sea water at high tide and exposed at low tide. The zone experiences tides and the impacts of waves twice daily. The physico-chemical characteristics of the zone fluctuate such that intertidal animals are faced with the risk of desiccation or dehydration, gaseous exchange (breathing), feeding and reproduction.

## (5) Oxygen

Oxygen is required for the production of energy. The common source of energy for all living organisms is adenosine triphosphate, ATP. Large amounts of the compound are formed in the oxidation of foodstuffs and smaller amounts during anaerobiosis. Energy is required in all that we do. In aquatic habitats, there is less oxygen than in air as oxygen is only sparingly soluble in water. Its solubility decreases with rising temperature, increasing salinity and depth of water in rivers and oceans. Its rate of diffusion in water is only 0.000034 cm per minute. Very low oxygen concentrations occur in muddy creeks and rivers and at great depths of the sea. Organic pollutants and aerobic organisms quickly deplete oxygen. In warm surface waters oxygen photosynthesizing phytoplankton may increase concentration.



In air the oxygen content varies only with altitude, the partial pressure of oxygen is greatest at sea level decreasing exponentially with altitude. Animal life ceases in conditions of no or very low oxygen.

#### (6) **Water**

Water forms 70% to 97% of the protoplasm of animals. Digestion of food and subsequent absorption of the end products, all biochemical reactions in the body, gaseous exchange, circulation and transport of materials all take place in the aqueous state. Water is essential in the maintenance of body form and shape and proper health, in elimination of wastes, the release of energy, secretions, in reproduction and embryonic development. Too little or too much water kills an animal. Too little causes shrinkage in cells, and an excessive rate of metabolism. Too much results in swelling and too low metabolic rates.

For aquatic animals the amount of body water is controlled by osmosis, diffusion of water and salt between the animal and the sea water, freshwater or brackish water and the formation of urine. The average salt content of sea water is 35 parts per thousand or 3.5%. Freshwater is 1% of sea water i.e. 0.035% salt. In estuaries and mangroves fluctuation in salt content is the characteristic.

The greatest physiological threat to life on land is the danger of dehydration or desiccation. Water is lost from the bodies of terrestrial animals

- (1) by evaporation from the general body surface,
- (2) by evaporation from the respiratory surfaces,
- (3) in the urine, and (4) in the faeces.

#### IV. **PERIODICITY IN ANIMALS**

The periodicity occurring in nature is also exhibited by animals. Animals possess unseen internal clocks or chronometers or oscillators which drive overt or observable cyclic movements, metabolic and physiological processes, behaviour, etc., called rhythms. The oscillators and rhythms measure out time, marking it out in units of periods or cycles.



The cycle or rhythm or oscillation is a sequence of an event that repeats itself through time in the same order and at the same interval. All metabolic and physiological processes in animals require a certain length of time and are repeated hence they are called physiological or biological clocks. Rhythmicity occurs at all levels of biological organisation, from cell, tissues and organs to organisms and communities.

## 1. **PHYSIOLOGICAL CHRONOMETERS NOT ADJUSTED TO EXTERNAL CHRONOMETERS**

Some physiological clocks are independent of the periodicity in the environment. Examples,

### a. **High Frequency Oscillators**

(i) Our heart beat measures out time at a high frequency. From the time of our conception in the womb or test tube to this minute the heart has been undergoing a cycle of contraction or activity alternating with relaxation or quiescence at 70 -90/min. The oscillator is the S-A node in the heart.

(ii) Breathing in and out is rhythmic and controlled by oscillators located in the medulla oblongata in the brain of vertebrates. The oscillators are neurons which undergo spontaneous phases or activity alternating with inactivity or quiescence at 12 - 15 min. in man.

### b. **Monthly Chronometers: Oestrous Cycle in Women.**

In women an oestrous cycle occurs once in every 28 days during which an egg is released by the ovary. Ovulation measures out time in lunar months. Associated with this cycle is a menstrual cycle of similar period.

These three examples of physiological chronometers are not adjusted to external time - cues such as sunset or sunrise or seasons or day length and the speed at which they run is not regulated against the passage of time but by temperature, oxygen demand, emotions, exercise, hormones, etc.

## **2. PHYSIOLOGICAL CHRONOMETERS ADJUSTED OR SYNCHRONIZED TO ENVIRONMENTAL CYCLES**

The majority of biological oscillators (i) measure time, (ii) do so in relation to environmental time - cues (sunrise, day, sunset, night, high tide, daylength, etc.) and (iii) use this temporal information to control the timing of the organism's chemistry, physiology or behaviour.

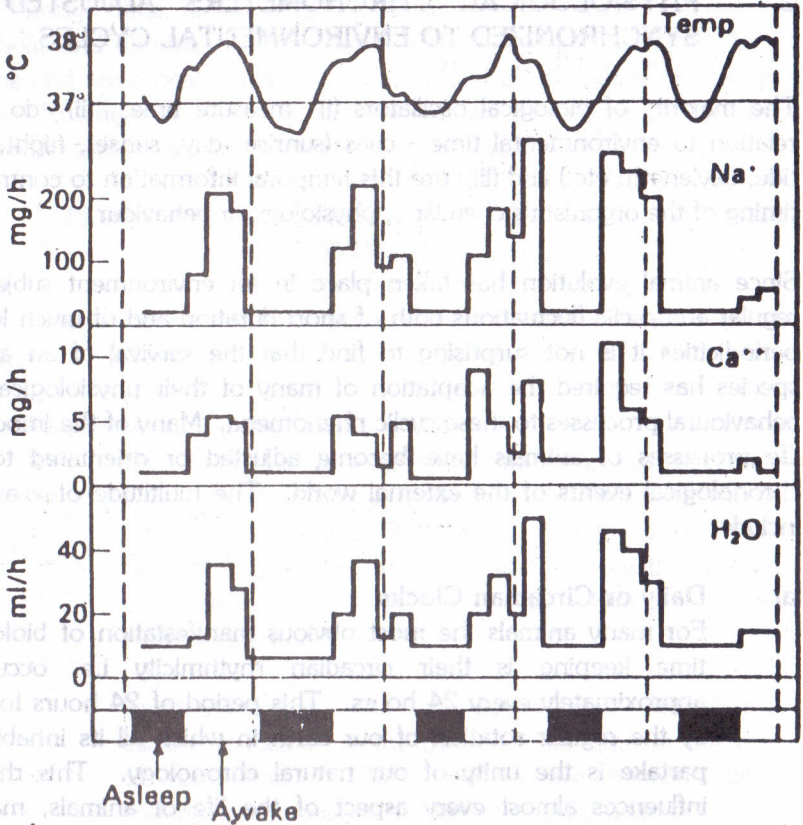
Since animal evolution has taken place in an environment subject to regular and cyclic fluctuations both of short duration and of much longer periodicities it is not surprising to find that the survival of an animal species has required the adaptation of many of their physiological and behavioural processes to these cyclic phenomena. Many of the important life processes of animals have become adjusted or orientated to the chronological events of the external world. The multitude of examples include:

### **(a) Daily or Circadian Clocks**

For many animals the most obvious manifestation of biological time keeping is their circadian rhythmicity i.e. occurring approximately every 24 hours. This period of 24 hours formed by the regular rotation of our earth in which all its inhabitants partake is the unity of our natural chronology. This rhythm influences almost every aspect of the life of animals, making them hatch, grow, move, respire, feed, digest, mate, sleep, etc., more at specific times of a day and less at others.

### **Examples:**

- (i) Human body temperature gradually rises to a peak by mid-day declining gradually to the lowest level at night and rising again about the same time the next day. Figure 1, see p. 8.



**Fig 1.**

Daily variation in human body temperature and urinary Na, Ca and volume (From Brady, 1979)

- (ii) The majority of animals are active at daytime (diurnal) and sleep at night time, others are active at night time (nocturnal) and sleep during the day, and still other animals are dusk and dawn active only (crepuscular).
- (iii) In man the sodium, chloride and hydrogen ions all remain at fairly constant levels in the blood stream throughout the day but appear rhythmically in the urine because of the kidney's rhythmic treatment of them (Figure 1).



(iv) In vertebrates the level of many hormones circulating in the bloodstream varies markedly round the day. The root of this lies in the hypothalamus which controls:

- i. feeding
- ii. thirst and drinking
- iii. sexual desire and drive
- iv. body water and ionic content
- v. body temperature
- vi. metabolic rate
- vii. pituitary gland.

The hormones associated with these activities such as antidiuretic hormone, testosterone, interstitial cell stimulating hormone, adrenocorticotrophic hormone, several corticosteroid hormones, thyroxine, etc. fluctuate in their levels in the bloodstream. The hypothalamus is thus an important driving component in the vertebrate's overall circadian rhythmicity.

(v) Many insects emerge from their pupae at a certain time of day e.g. Drosophila emerge at daybreak, an adjustment to a change of humidity.

(vi) It has been known that some people are able to estimate, with a high degree of accuracy, a particular time of the day even if all external time indicators are absent. They are able to wake up from normal sleep just a few minutes or so before a pre-set time. This 'head-clock' allows one to do everything to a fixed schedule with remarkable punctuality.

## b. Tidal and Lunar Rhythms

### (i) Tidal

Intertidal species have evolved strong tidal and semi-lunar rhythms by which they anticipate the hazards of intense solar radiation, desiccation, freshwater irrigation, freezing and predation by birds and take the necessary behavioural or physiological avoiding actions.



(ii) **Lunar**

Marine invertebrate animals have bi-monthly or monthly lunar breeding cycles in which all members of the species within a particular region become sexually active and spawn at

- (i) full moon or Neap Tides and/or
- (ii) new moon spring tides.

Examples include sea-urchins, crabs, oysters, mussels, periwinkles and polychaete worms most notable are the Palolo worms in the Pacific coral reefs. This synchronisation is essential to the maintenance of the species since it ensures that reproductive cells are discharged in sufficiently high concentrations to provide a reasonable chance of fertilisation taking place.

c. **Annual And Seasonal**

The best known aspect of biological timing is the fact that animals breed only at specific times of the year:

- (I) In temperate fishes, birds and mammals variation in size of ovaries and testes, gamete formation, ovulation, spawning, development of nuptial colours, level of gonadotrophic and gonadal hormones and the development of behavioural patterns such as migration, taking up of territory, courtship display and copulation all take place once a year and are related to longer or shorter day lengths or photoperiods.
- (II) Also related to photoperiods are diapause and emergence of adults from pupae in insects, reproduction, polymorphism (in aphids), moulting and the production of parthenogenic generations.

3. **USE OF PHYSIOLOGICAL CLOCK IN DIRECTION FINDING / NAVIGATION**

Birds of many species migrate between continents and go and return, often to the exact same nest sites. The best long distance flights are those of the Arctic terns which nest in the Arctic and fly non-stop to the

Antarctic, to escape harsh winter months of the Northern hemisphere. These birds make an annual round trip back to their nesting site of over 35,000 km.

Birds, bees and ants have the ability to consult or 'read' the time of day from an internal clock and use this information to ascertain where the sun ought to be at a particular time of the day. By observing for a short time, the position of the sun, the sky pattern, sky polarised light, stars or even the moon bees and birds determine the sun's arc or movement across the sky or its complete trajectory to the zenith or azimuth. The bird or bee then compares the sun's position with home sun position for that particular time of day (e.g. "It is 3 O'clock, the sun ought to be there in the sky but it is not there but here") and so establish that it is displaced to the west or east, north or south of home. It then orientates its flight in that direction. The clocks are continuously consulted.

During their evolutionary including ourselves have developed various endogenous or innate physiological rhythmicities whose periods match those of the cycle of:

1. Day and night (circadian, period approx. 24 hours)
2. Lunation (circalunar, period approx. 29 days)
3. Tide (circatidal, period approx. 12.4 or 24.8 hours)
4. The seasons (circannual, period a year)
5. The time between successive spring low waters (semilunar, period 14.7 days).

## V. ADDUCTOR RHYTHM IN AN INTERTIDAL BIVALVE MOLLUSC

I started my career in Ecophysiology by investigating the adductor rhythm in an intertidal bivalve mollusc, *Scrobicularia plana* Da Costa, (Fig. 2)



Fig. 2. *Scrobicularia plana* Da Costa

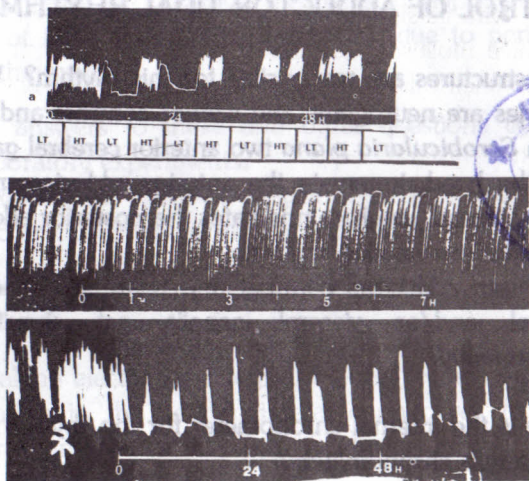
in the early 1970s at the University of London. The animal lives buried in soft mudflats with its siphons protruding through the mud to the water above. A bivalve mollusc is a laterally compressed or flattened animal enclosed by two shell valves. There is a spring-like ligament at one edge which forces the valves apart resulting in gaping. Two muscles, one anterior the other posterior, attach the left to the right valves and when they contract fully the shell valves enclose the whole animal. The gape is varied by the degree of contraction of the adductor muscles. In some bivalve molluscs 2 posteriorly located siphons can protrude between the gape into the surrounding water and be retracted into a mantle cavity.

Adductor muscle activity can be recorded by attaching a thread to a shell valve, a Starling heart lever and a revolving barograph drum for long period of time. Tide was simulated in my experiments by means of a tide machine. The periodic slow raising and lowering of a weight displaces varying amounts of sea water in a tank and this results in the variation of the level of water so that the sediment in the tank is alternately submerged for 6 hours and exposed to the air also for 6 hours as in high tide and low tide respectively.

Figure 3.a. shows the tidal rhythm:

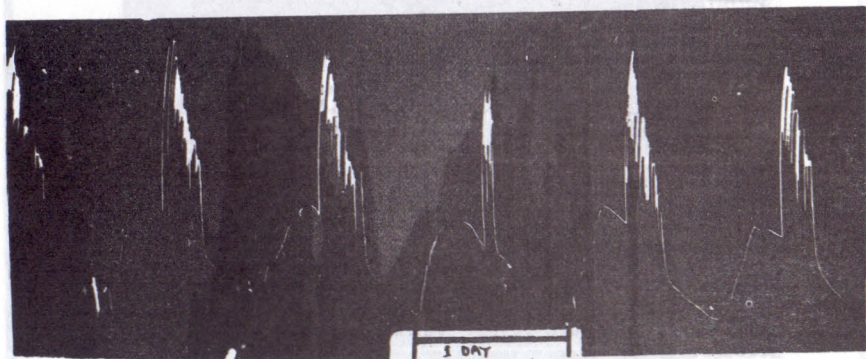
- (a) Periods of activity occur at high tide alternate with quiescence at low tide.
- (b) The rhythm diverges from 12.4h by 2 to 3 hours and it commonly falls within the range 11 - 14 hours.
- (c) The bivalve has an endogenous adductor rhythm as can be seen in Figures 3.b and 4 when the animal is permanently immersed first in sea water and next subjected to aerial exposure. The endogenous rhythm is adjusted to approximately coincide with the tides.
- (d) Freshwater and estuarine bivalve molluscs though not under the influence of tides, still exhibit an innate bimodal activity pattern of adductor activity and quiescence with a period close to 12.4h as in *Egeria radiata* L., *Anodonta cygnea* L. and *Dreissena polymorpha*.





**Fig 3 (a)** Adductor tidal rhythm. HT, high tide, LT, low tide. Effect of (b) permanent immersion in sea water and (c) aerial exposure on the adductor rhythm of *Scrobicularia*

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**Fig 4:** The adductor rhythm of *Egeria radiata*. Part of 1 week of activity. Adduction downward in the traces. Scale = 24h.



## VI. CONTROL OF ADDUCTOR TIDAL RHYTHM

What internal structures are responsible for this rhythm? We know that adductor muscles are neurogenic and cannot contract and relax without innervation. In *Scrobicularia plana* two anterior cerebral ganglia, one on each side of the head, innervate the anterior adductor muscle while a larger complex visceral ganglion innervates the posterior adductor muscle. A number of questions needed answers:

1. Since both adductors contract and relax simultaneously do the cerebral and/or visceral ganglia act simultaneously or independently?
2. Where is the internal chronometer for the rhythm located? Are both ganglia chronometers?
3. An adductor muscle is usually divided into a portion that can contract and relax rapidly, called phasic fibres and another part of it that can maintain contraction for very long time called tonic or slow fibres. According to 'catch mechanism' hypothesis first proposed by Von Uexkull (1929) tonic muscles are responsible for the prolonged contraction at quiescence during which paramyosin myofibrils set or lock and remain so without the expenditure of energy. Nerve impulses are not required to maintain the contraction once the 'catch' or locking has taken place

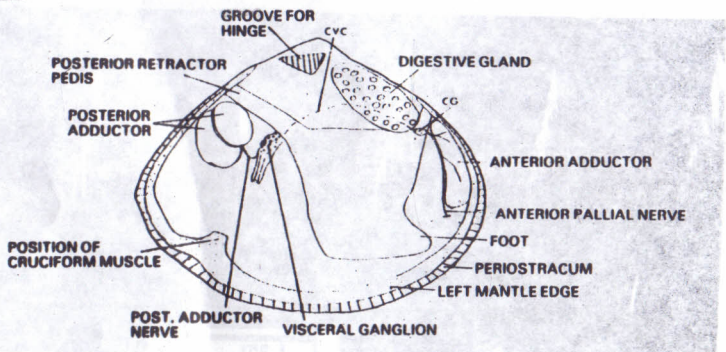


Fig. 5. *Scrobicularia plana*, with right shell valve, mantle and siphons removed, showing the anatomical relationship between the adductor muscles and their respective local ganglia and nerves. X 1.5. CG = Cerebral ganglion; CVC = Cerebrovisceral connective.

An opposing view, the 'tetanus mechanism' hypothesis, is that the maintenance of the prolonged contraction is due to periodic neural re-excitation of the muscle.

I sought the answers to these and other questions by performing a number of laboratory experiments:

- a. by excising the cerebral ganglia and cutting across the anterior adductor muscle in mechanical recording.
- b. by excising the visceral ganglion and the posterior adductor muscles also in mechanical recording.
- c. by making electrophysiological bipolar recording of nerve action potentials in the cerebrovisceral connectives from cerebral to visceral ganglia and the posterior adductor nerve.
- d. by making faradic and chemical stimulation of the ganglia and the cerebrovisceral connectives.
- e. by making simultaneous mechanical recording of adductor activity with the aid of an electrical transducer and an electrophysiological recording of cerebrovisceral connectives and posterior adductor nerve action potentials.
- f. by making light and election microscopic studies of the ganglia and adductor muscle fibres, both phasic and slow type.

ODIETE: ADDUCTOR RHYTHM OF SCROBICULARIA

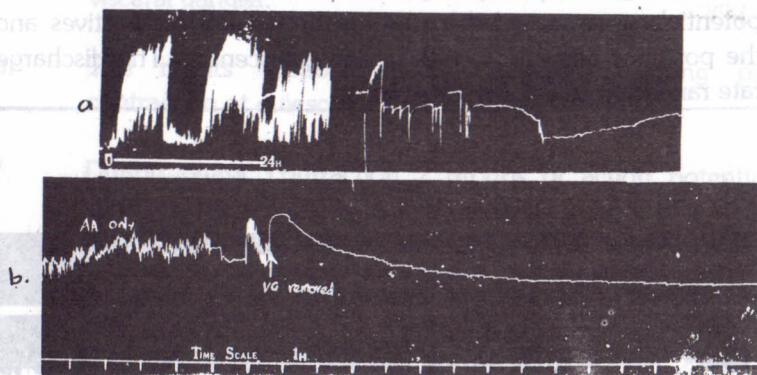


Fig. 6 The effect of the excision of the visceral ganglia on anterior adductor rhythm. a, first part, normal behaviour under the influence of tide; second part, activity after the posterior adductor was cut and the visceral ganglia were removed. b, anterior adductor activities only (the posterior adductors were cut) in permanently immersed animals. At arrow in each record, the visceral ganglia were removed.



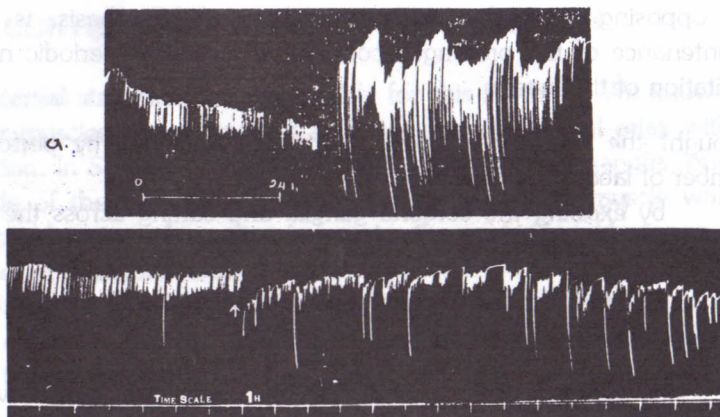


Fig. 7. The effect of decerebration on posterior adductor activity. a, first part, normal tidal rhythm; second part, the rhythm after the removal of the two cerebral ganglia and after cutting the anterior adductor across. b, posterior adductor activity only (the anterior adductor was cut) in a permanently immersed animal. At arrow, the two cerebral ganglia were removed.

## RESULTS

The results of the investigations were published by Odiete 1976. a, 1976, b. 1979.a and 1979.b.

1. It was the first time that anyone could record nerve action potentials distinctly without 'noise' from nerves of a bivalve mollusc.
2. Distinct high frequency rhythmic discharges of nerve action potentials were recorded in the cerebrovisceral connectives and the posterior adductor nerves during quiescence. The discharge rate ranged from 2 - 3 in 8 seconds.



Fig. 8. The effect of decerebration on CVC potentials. A, record of spontaneous activity in CVC; at S in B, the nerve was cut at X2. Horizontal scale, 1 in = 8s; vertical scale, 2cm = 1mV.

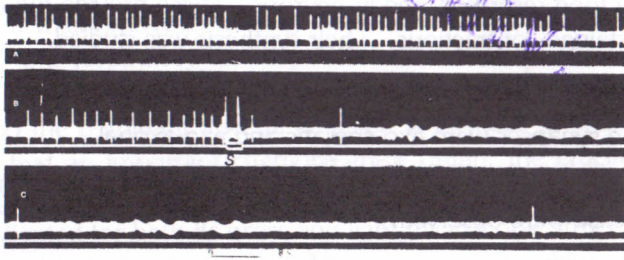


Fig. 9 The effect of excision of the visceral ganglia on CVC potentials. A, record of spontaneous activity in CVC; at S in B, the nerve was cut at X3 C, continuation of B. Vertical scale, 2 cm 1mV. Same time scale.

3. The rhythmic discharges originate in the visceral ganglia ONLY for they are abolished upon removal of the visceral ganglia. The tidal chronometer must therefore reside here.
4. The cerebral ganglia do not exhibit any rhythmic activity as decerebration did not affect tidal rhythm nor rhythmic action potentials.
5. From time to time the cerebral ganglia were found to inhibit the visceral ganglia.
6. The results support tetanic mechanism during prolonged contraction at quiescence.
7. During phasic contraction 2 groups of action potentials were recorded namely group A and group C. There is an increase in the frequency of the action potentials at the onset of phasic contractions which then declines, that of group A rapidly, that of group C gradually.
8. Nerve fibre pathways in the bivalve were ascertained with some accuracy.



9. Fast fibres are spirally striated and slow fibres had paramyosin myofibrils.
10. Yellow pigmented lipid globules in visceral ganglia neurons are the food reserve stored in neurons. These provide the energy for sustained contractions. Their synthesis was studied.
11. There were myelinated axons in the visceral ganglia.
12. The synapses were axo-somatic and axo-axonal.
13. many neurosecretory granules were described and transmitter release were observed.

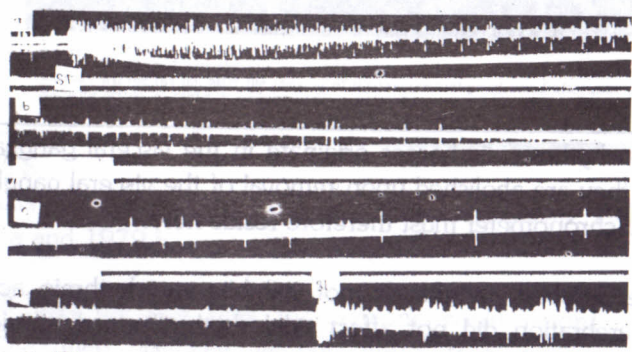


Fig 10 Posterior phasic activity. Lower trace, posterior adductor muscle activity; phasic adduction, downward at S in a and d. Upper trace, the corresponding posterior adductor nerve action potentials. At S in the recordings, the left mantle edge was stimulated with a camel hair brush. Horizontal scale: 1" = 2.5 cm. Vertical scale: 2.5 mV.

ODIFTE: ADDUCTOR NERVE RECORDINGS IN SCORICULARIA

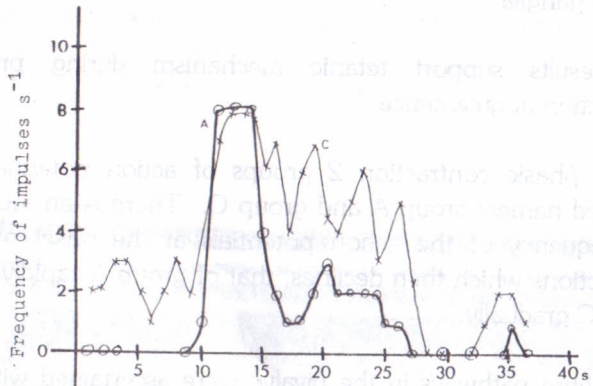


Fig. 14. The frequencies of spontaneous group A and group C potentials recorded from the posterior

## VII. CRUCIFORM MUSCLE SENSE ORGAN

*Scrobicularia plana*, as in most bivalve molluscs take in water into its mantle cavity via an incurrent siphon for the purpose of gaseous exchanges, microphagous feeding and reproduction. Water containing excretory and respiratory waste products are expelled via an excurrent siphon. The siphons are located at the posterior end of the animal where also the dominant visceral ganglion is located. It is therefore not suprising that an important chemoreceptor organ, the cruciform muscle sense organ is also located at the bases of the siphons. This receptor was investigated for both its gross and light microscopic structure, sensory modalities and electrophysiology. My findings were published by Odiete (1978 a. and 1981. b.), some of the results are shown in Figures 12:

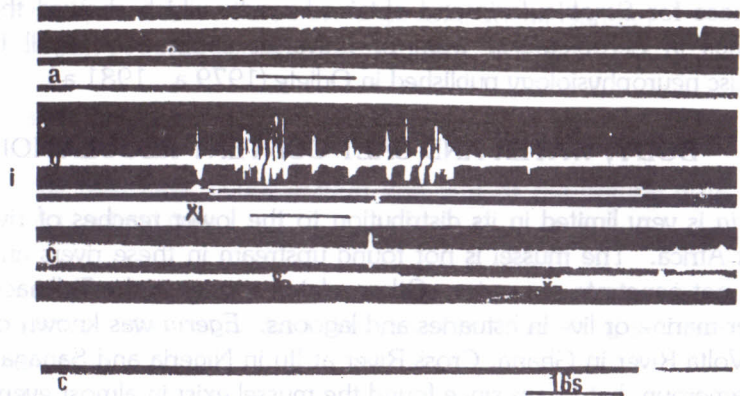


Fig. 12 Electrophysiological recording of sense organ activity. a, record nerve activity in a closed animal; b, the effect on the sense organ of the addition of liquid from dead and rotting *Scrobicularia* to the sense organ papilla (X1, in b); a burst of nerve impulses is evoked; c, the effect of pulling the ends of the cruciform muscle (X2 & X3, in c).

- a. Long dendritic processes from neurones of the sense organ ganglion penetrate the epithelial lining of the narrow and short duct situated between the intramuscular slit and a large posterior cavity which opens to the siphonal space through a narrow canal in the sense organ papilla.
- b. I also found that motor nerve fibres innervate the anterior ends of the cruciform muscle strands. The latter become stretched during rapid rhythmic activity and contracted during closure and quiescence.

The slit is widened during activity and narrowed at quiescence.

- c. The sense organ responds to foul water suggesting it is a chemoreceptor for this condition.

## VIII. UNIVERSAL APPLICATION OF FINDINGS

Upon my return to the University of Lagos from my study leave in 1975, I continued in this area of research for a while. In my search for suitable specimens I came across the freshwater mussels *Egeria radiata* L. and *Mutela dubia* Gmelin. *Egeria* is in the same superfamily as *Scrobicularia*. It has a cruciform muscle sense organ and two long siphons as in *Scrobicularia*. I performed experiments on *Egeria* similar to those for *Scrobicularia* and obtained results which showed that my findings in *Scrobicularia* were of universal application in all bivalve mollusc neurophysiology published in Odietę (1979 a., 1981.a.)

## IX. BODY, WATER AND SALT CONTENT REGULATION

*Egeria* is very limited in its distribution to the lower reaches of rivers in West Africa. The mussel is not found upstream in these rivers and also does not penetrate sea water. Other related species in the Tellinacea are either marine or live in estuaries and lagoons. *Egeria* was known only in the Volta River in Ghana, Cross River at Itu in Nigeria and Sanaga River in Cameroun, but I have since found the mussel exist in almost every river and creek in the Niger Delta. *Egeria* is of economic importance in thriving local fishery industries in West Africa and its rearing or aquaculture was desirable.

In the 1970s a number of other shellfish and finfish species were also being considered for possible aquaculture in brackishwater areas of the Niger Delta by the NIOMR & ARAC. The species included:

1. periwinkles: *Tympanotonus fuscatus*, *Pachymelania aurita*.
2. oyster: *Crassostrea gasar*
3. catfish: *Clarias gariepinus*, *Heterobranchus* spp., *Chrysichtys nigrodigitatus*.



The salinity of brackishwater fluctuates with wet and dry seasons which can exert serious osmotic stress on the fries, fingerlings and adults. Before they can be cultured in brackishwater their salinity tolerance and osmoregulatory powers need to be ascertained. Between 1978 and 1988 investigations were carried out, three at M.Phil Level, on the osmotic regulation in *Egeria*, *Tympanotonus*, *Elops*, *Clarias* and *Chrysichthys*.

The others include:

- iv. ten pounder : *Elops lacerta* Val.
- v. hermit crab : *Clibabarius africana* Aurivillius, extensively used in toxicological studies, hence the need for a study.
- vi. snakehead : *Ophiocephalus*
- vii. African reed fish : *Calamoichthys calabaricus* Gunther
- viii. lungfish : *Prototerus annectens* Owen.

Studies carried out in each species included:

1. Body fluid ionic concentration and that of the natural water in which animal lives.
2. Changes in body water and ionic content, tolerance, survival and mortality when a species is immersed in diluted and full strength sea water.
3. Permeability of catfish skin to  $\text{Na}^+$
4. Structure of kidney, size and density of renal corpuscles.
5. Rate and volume of urine formation.
6. Nature of nitrogenous waste substances.
7. Salt secreting glands in gills of finfish.
8. *Tympanotonus* and *Protopterus* were further subjected to continuous aerial exposure. The periwinkle is normally collected in mudflats at low tide and kept in jute bags or cane baskets, out of water, for weeks before they are sold or eaten. They are

frequently transported in these containers from the Niger Delta to markets in Lagos. In addition, the mudflats dry up from mid-December to early March.

## FINDINGS

The results of these investigations have been published in Odiete (1979). b.) Egonmwan (1980), Odiete and Jacob (1985), Ezenwa *et al.* (1986) and Chukwu & Odiete (1990). Figure 13 shows a typical result.

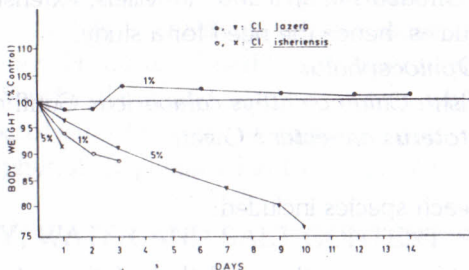


Fig.13A. Body weight changes in *Clarias* spp. in 1% and 5% diluted sea water.

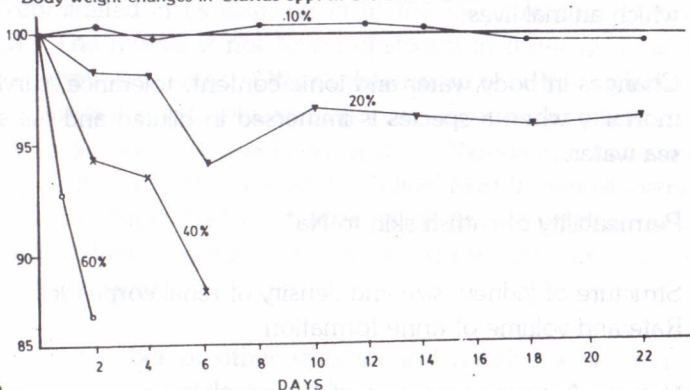


Fig.13 B. Body water loss of *Ch. nigrodigitatus* in diluted medium (10%, 20%, 40% and 60% sea water).

- a. *Egeria*, *Tympanotonus*, *Elops* and *Chrysichthys* are good examples of hyper-hyposmotic regulators. They can survive in low and in higher salinities up to 18‰.

They are hyperosmotic in media of 0 to 7‰ salinity and hyposmotic in higher salinities. They are therefore suitable species for aquaculture in brackishwater. The mechanisms of regulation include:

- i. impermeable body covering in *Chrysichthys* and *Tympanotonus*
- ii. active absorption of salt and volume regulation in freshwater and in media of low salinities.
- iii. tolerance to dehydration and to limited increase in plasma or haemolymph ionic concentration in hyperosmotic media.
- iv. *Tympanotonus* is very tolerant of prolonged aerial exposure up to 3 months without food. During this period the periwinkle reduces evaporative water loss by withdrawing into its shell and covering the aperture with its operculum. Yet it loses water, on the average of 1.05% of body weight per week. At the end of 3 months the cumulative evaporative water loss may be up to 20% of body weight. Any further water loss kills the animal.

- (b) The other species are strictly stenohaline. *Clibanarius* cannot tolerate low salinities nor more than 18‰ salinities. It is an isosmotic form. When used for toxicological studies it is therefore necessary that dilutions of toxicants and bioassays must be made from brackishwater, *Clarias*, *Ophiocephalus* and *Calamichthys* are also stenohaline freshwater forms unable to survive in brackishwater.



They are hyperosmotic forms and have very high densities of renal corpuscles necessary for pumping out water from the body as fast as it enters. *Clarias* skin is permeable to water and salt.

- (c) I took the opportunity of working on these fishes and my association with NIOMR to do collaborative research on the pituitary glands of *Clarias* and *Chrysichthys* and successfully including spawning after injecting a pituitary gland extract prepared from the fish. (Ezenwa *et al.*, 1986).

### Marine Vertebrates

Marine bony fishes have blood in which the salt content is 3 to 4 times less than the sea water in which they live. They face a constant problem of dehydration as do desert animals and hence the term "physiological drought" describes their condition. To be able to survive in the sea these fishes drink sea water, pass out excess salt through special salt glands and excrete a non-toxic trimethylamine oxide substance.

The fascinating ones are the marine birds and reptiles which accumulate salt in their blood as a result of feeding. The excess salt is removed through glands located near the eyes which, in the case of crocodiles, the salt solution was mistakenly called 'crocodile tears'.

## X. THE GIANT WEST AFRICAN LAND SNAIL

I became interested in the study of the common giant West African land snail in 1977. I had decided on this snail while I was doing my Ph.D thesis in London. Fortunately for me, in 1978 the National Science and Technology Development Agency (NSTDA) announced its intention to support researches on the domestication of some Nigerian wildlife especially:

- the 'grass cutter' or cane rat, *Thryonomys swinderianus*
- the giant rat or pouched rat *Cricetomys gambianus*.
- the giant land snail : *Archachatina* and *Achatina* sp.

Prof. C. I. Olaniyan, the head of my Department was then chairman of the Board of the Agency and so I had no difficulty getting a Federal Government grant for the research done in collaboration with others from the University of Ibadan.

For a period of 12 years (1977 - 1988) researches were conducted here at the University of Lagos on the giant snail in the following areas:

- i. Water relations
- ii. Nutritive value
- iii. Economic potential
- iv. Reproductive biology
- v. Growth
- vi. species and their distribution in South Western Nigeria.
- vii. Circulatory, respiratory and excretory physiology.
- viii. Feeding, digestion and digestive enzymes
- ix. Snail farming
- x. Behaviour.

The amount of research work we have covered on the giant land snail in this University constitutes a topic for a separate inaugural lecture. I earned the alias "Mr. Igbin" on this campus and in far away places on account of my FREE snail farming consultations from interested people and organisations. Many publications, (Odiete 1981.b; 1982; Odiete & Akpata, 1983.a; Oke & Odiete, 1997), M.Sc. dissertations and 3 Ph.D theses were among the outcome of the researches. The three Ph.Ds are:

1. A Ph.D thesis on the digestive enzymes, in 1992.  
The digestive gland of the snail is a major source of several carbohydrases, lipase and peptidases. In this **extensive** biochemical investigation  $\alpha$  - amylase, maltase, lactase, **sucrase** and cellulase were purified from crude digestive gland **extracts**.
2. A Ph.D thesis on land snails and slugs in the south western states in Nigeria also in 1992.  
The study revealed the distribution of 30 species of land gastropod molluscs in 9 families of which 15 were new species. One of them was named by my student, Mr. Chris Oke, as *Subulina odieti*, another *Ptychotrema shagamuensis*, another *Pseudopeas ugbowoensis*, *Trochozonites kwali* and *Trochozonities iguobazi*, suggesting the places where first collected.

3. A third Ph.D thesis on the reproductive biology of the giant land and garden snails was begun here at the University of Lagos and completed at Oxford University in England and completed at Oxford University in England.  
There is still room for more Ph.Ds on the snail.

## HIGHLIGHTS

1. The major environmental factors affecting snails are:

Temperature  
Humidity  
Water  
Space/Intraspecific competition  
Soil  
Shelter  
Food

- a. **Thermal stress:** Snails die rapidly in high temperature and intense sunlight. Continuous exposure to air temperatures of more than  $33^{\circ}\text{C}$  result in death in a few days. High temperatures depress fecundity and cause atrophy of the genital system. In very low temperatures e.g.  $10-15^{\circ}\text{C}$  and in very high temperatures they aestivate. The snail withdraws its body into the shell and the opening or aperture is sealed with a whitish epiphragm made with mucus and crystalline calcium carbonate which is secreted by the mantle or collar. They remain in a state of suspended life. They switch off living for the time-being. There is no activity, movement, feeding and growth.

- b. **Desiccation Stress:** Snails lose water from the exposed body (head, foot, collar and lungs). The snail keeps the entire body surface moistened with mucus secreted by a pedal gland whose duct opens on the ventral surface just behind the mouth. Not only does this mucus protect the delicate sole of the foot from drying during locomotion, it also serves to fix the expanded parts of the foot whilst the contracted portions are moving forward. The mucus



forms a whitish dry trail left in the wake of the animal. The collar also secretes a watery fluid which pours into minute longitudinal channels on the dorsal surface of the foot and head.

The water used in these ways come from the haemolymph or blood and must be replaced in time. The body water content of a deshelled snail ranges between 42 and 51% of body weight.

In very low relative humidities and generally dry conditions without shade and water snails die in a few days. A cumulative evaporative water loss of more than 14% of body weight results in aestivation. The eggs cannot hatch in dry conditions. They require a moist environment to hatch. Juveniles also aestivate, but may die without aestivating. Snails die in prolonged aestivation.

2. To reduce these effects snails are active at night and wet mornings, seek shaded humid places and hide in under-growth in bushes and forests. For snail farmers constant watering and keeping them in shaded places or with abundant wetted dry grass or leaves are a must.
3. In the dry season months from mid-November to mid-or late March every year snails go into aestivation. Dry season is characterised by very low humidity, no rains, every where is dry, vegetation is scanty and annual plants are die. Aestivation is thus an annual cycle synchronized with dry and hot conditions when food is also scarce. When it rains again or the snail is wetted, it breaks out through the epiphragm.
4. Aestivation in the snail is similar to hibernation shown by small temperate birds and mammals such as hamsters, pocket mice, dormice, ground squirrels, bats, hummingbirds, marsupials, etc., in winter months. There is no food anywhere and almost everywhere is covered by snow.

Being small in size and having inadequate external insulation heat loss rate is so high the animals cannot maintain constant body temperature. Faced with these problems many birds and mammals migrate to warmer climates but others burrow into the ground and temporarily suspend living, called hibernation and remain so, with one or two awakenings in order to urinate, until the spring (from October until May). In this hibernating state the animals are poikilothermic. Metabolic rate, circulation, respiration and all other physiological functions drop to absolute minimal rates. Hibernators and aestivators do not respond to external stimulation such as touch and noise.

5. In the natural environment soil with a high moisture content into which the snail can burrow for egg laying or oviposition is preferred, Eggs are laid under litter. However, snails in captivity lay eggs on surface of hard soil. Eggs will not hatch if dry, continuously exposed or in clayey soil.

Incubation period is 19-22 days in loamy soil or among moist leaves.

6. Overcrowding or high density (e.g. 25 per m<sup>2</sup>) results in slow growth rate even when snails are supplied with sufficient food, water and Calcium. High densities result in accumulation of high amounts of faeces and nitrogenous wastes deposited on food. Snails are reluctant to eat food contaminated by faeces and nitrogenous wastes. High density reduces sexual maturity. overcrowding limits mobility and mortality rate is high.

7. The type of food eaten has tremendous effect on growth of snails. Succulent leaves and fruits especially ripe pawpaw fruit, banana and oranges and leaves such as those of water leaf and cocoyam give the most rapid growth rates.

8. Snails ingest soil showing preference for alkaline soil due to its high Calcium content. They ingest chalk and egg shell for Calcium. Shell growth is rapid when there is sufficient calcium.

9. The natural enemies are tailor and soldier ants which kill snails. A number of snakes eat snail eggs especially the egg-eating *Dasyteltis* sp.
10. Snails do not harbour any known dangerous ecto- and endo-parasites.

All terrestrial animals suffer evaporative water losses, some very high as in the snail, amphibians and birds others low as in insects and mammals. Their responses to thermal and dessication stress vary widely. Frogs and toads have a relatively high surface permeability. Reptiles reduce surface evaporation by having an impermeable skin.

Except the birds and mammals, all other animals are poikilothermic and ectothermic. Their body temperature, metabolic rate, activity and evaporative water loss vary with external temperatures. They rely on behavioural mechanisms such as coming out to absorb the sun's radiant energy in cold mornings and hiding in crevices when it is very cold and under humid shaded places when it is very hot. Birds and mammals maintain fairly constant body temperatures and do not rely on external heat source to do so (homeothermic and endothermic). Some of the mechanisms employed include:

- a. producing heat internally to offset heat loss in a cold environment by physical and chemical methods.
- b. adjusting their metabolic rates
- c. external and internal heat insulation.
- d. redistribution of blood to peripheral organs and countercurrent arrangement of peripheral blood vessels.
- e. hormonal and hypothalamic control.

The most fascinating cases of the ability to withstand thermal and dessication stress are desert mammals particularly the camel which capacity to do without water is legendary. It was Schmidt- Nielsen in 1963-64 who had to show that the camel does not store water in the hump.

The camel is exposed to intense heat during the day and very cold temperatures at night. Its body temperature rises to about  $41^{\circ}\text{C}$  by the evening and during the night cooled to as low as  $34^{\circ}\text{C}$ , thus the camel



exhibits a body-temperature fluctuation of 6 to 7°C an adaptation in the interest of water conservation. Instead of wasting a large volume of water by sweating during the intense heat of the day the camel tolerates a considerable degree of hyperthermia. The camel can go on working without drinking water for 6 - 8 days in desert conditions. It tolerates dehydration of up to 1/3 of its 500 kg body weight. When water is available it continues drinking until up to one-third of its body weight.

Small desert hemotherms reduce evaporative water loss and heat stress by being nocturnal and living in burrows. Animals in extreme temperatures show

- (a) tolerance and (b) acclimatization to cold and freezing condition and to high temperatures.

## XI. THE ROLE OF THE ECOPHYSIOLOGIST IN POLLUTION CONTROL

The environmental factors that I have been highlighting are those imposed on animals and other living organisms by nature - the result of planetary movements. The changes are gradual, rhythmic and predictable and the earth's inhabitants adapt in time. There is a natural ecosystem stability and very high biodiversity maintained by biogeochemical cycles of water, C, N, S, P and others, and by food webs.

In contrast changes in the environment imposed on the earth's inhabitants by man are:

- a. Continuous, non-stop
- b. Steadily increasing as populations increase and as industry expands.
- c. Concentrated in urban areas.
- d. Distrupt ecosystem stability and
- e. Destroy biodiversity.

Biodiversity is very important to man:

- 1. As food. About 103 plant and very many animal species feed the world.

2. In Biotechnology. Genetic materials in plants, animals and micro-organisms contribute to better health care, enhanced food production and efficient methods of afforestation, reforestation and detoxication of hazardous wastes.
3. Drugs or Pharmaceuticals are derived mainly from natural sources (plants and some marine animal species). About 120 chemicals are extracted from 90 species as pharmaceuticals.
4. Over 20000 natural compounds obtained from plants such as starch, ink, gum, timber, rubber, beverages, fibres, polishes, etc., are used in industry.
5. Nature has provided man with a cornucopia of materials for research.
6. In aesthetics and enjoyment of nature.  
Loss in biodiversity, destabilization of biogeochemical cycles and ecosystems threaten the continued existence of man on the planet.

Most of the anthropogenic changes are due to emissions into the environment. The emissions are described as contaminants when their

- i. concentrations
- ii. characteristics and
- iii. duration

are not such as to cause injury or harm to man, animals, plants and property or cause irreversible changes in the physical, chemical and biological environment or unreasonably interfere with comfortable enjoyment of life. When they are injurious or cause harm, they are ~~pollutants~~.

In collaboration with chemists and pharmacologists, the ecophysiological tries to:

1. Identify the sources and anthropogenic processes capable of disrupting ecosystems and causing loss in biodiversity. The sources and effects of the following in the aquatic environment are well - documented:

Acids and alkalis

Anions

Acid deposition

Detergents

Domestic sewage and farm manures

Food processing, beverages, and brewery wastes

Gases

Greenhouse gases

Heavy metals

Heat

Nutrients

Petroleum, Dispersants and PAHs

Organic toxic wastes

Pathogens

PCBs, Dioxins and Dibenzofurans



## Radionuclides

## Solids and Particulate matter.

In 1995 - 1997 the World Bank supported a study by the Lagos State Ministry of Environment and Physical Planning, MEPP, on providing an industrial database for Lagos State. I was involved in this project through World Environmental Systems, WES. It was a multidisciplinary study. We have provided data on:

- distribution of existing industries, the names, types, and locations on a map of the state.
- updated knowledge of the raw materials required in each industry.
- discharges of each industry in quantity and quality (i.e. chemical analysis) including water intake and use.
- discharge points into the environment.
- receptor bodies of water : streams, creeks, rivers, and the lagoon.
- assessment of the chemical and biological quality of the receiving water bodies

In all there were about 2000 medium and large-scale industries distributed as in Table below.

Industrial Sector	Total	% Total
Pharmaceuticals, Hospitals, Medical Labs.	398	20.0
Chemicals, Paints & Allied Chemicals	115	5.7
Cosmetics, Soaps, Detergents, Dry Cleaning	73	3.6
Food processing, Beverages, Hotels & Farms	275	13.7
Textile, Weaving Apparel & Leather	96	4.8
Plastics & Rubber	131	6.5
Oil Marketers	258	13.0
Metals & Metal Products	144	7.2
Printing, Paper, Publishing and Photographic	201	10.0
<b>Others:</b> (Electrical & Electronics, wood and wood products, non - metallic mineral products, warehouses, construction).	311	15.5
<b>TOTAL</b>	<b>2002</b>	<b>100.0</b>

(After WES, 1997)

## 2. Quantitifying and Measuring Ecotoxicological Effects.

Ecotoxicology is the science of assessing the effects of toxic substances on ecosystems with the aim of protecting entire ecosystems.

In aquatic toxicology toxicity tests or bioassays are conducted to measure the effect of one or more pollutants on one or more species of organisms. Mortality is generally used as the end point of tests. The type of bioassays include:

Acute toxicity tests

Chronic Toxicity tests

Static and Flow - Through Toxicity tests

Sediment Toxicity Testing

Bioconcentration studies.

Toxicity to aquatic life generally is expressed in terms of acute (short term) or chronic (long-term) effects. In acute toxicity death or damage to an organism occurs in a brief exposure period normally 96 hours or less time. In chronic toxicity death or damage to an organism occurs during prolonged exposure which may range from several days to weeks, months or years. Test organisms are exposed to increasing concentrations of a toxicant in order to determine some change (mortality) in the organism under controlled laboratory conditions.

Commonly determined is the 96hLC<sub>50</sub> (96 hour median lethal concentration) and LT<sub>50</sub> (median lethal times) of chemicals to standard aquatic organisms. The median lethal concentration is that at which 50% of the test animals survive exposure to a given chemical substance.

The data generated in the form of 96-hour LC<sub>50</sub> are used to evaluate the effect of a toxicant being discharged into the aquatic environment, and subsequently in the development and application of water quality criteria for the protection of the aquatic environment receiving pollutant. A criterion is a designated concentration of a constituent that when not exceeded, will protect an organism, community or a prescribed water use or quality with an adequate degree of safety. A standard is a legal entity for regulation or enforcement and may differ from a criterion because of prevailing local natural conditions or the importance of a particular waterway.

If enough acceptable data on acute toxicity to aquatic animals are available, they are used to estimate the highest 1 - hour average concentration that should not result in unacceptable effects on aquatic organisms and their uses. Similarly, data on the chronic toxicity of the substance to aquatic animals are used to estimate the highest 4 - day average concentration that should not cause unacceptable toxicity during a long-term exposure.

This concentration, as with that of the acute toxicity, is made a function of water quality characteristic such as ammonia, CN-, pH, salinity, hardness, BOD, particular heavy metals (Cu, Cd, Hg, Ni, Pb, Zn), particular pesticides (Chloridane, DDT, Lindane), detergent, etc.

Data on bioaccumulation by aquatic organisms are used to determine if residues might harm some wildlife consumers of aquatic life.

The acceptable toxicity and bioaccumulation data are those obtained using the methods recommended by the U.S. EPA, the American Society for Testing and Materials (ASTM) and United Nations agencies e.g. FAO, UNEP, UNESCO. In 1976 the EPA published formal guidelines for establishing Water Quality Criteria based on toxicity tests for 114 substances on a wide range of aquatic animals and conditions in the United States. These were subsequently revised in 1985.

The present FEPA (1991) guidelines and standards for environmental pollution control in Nigeria and Regulation S. 1. 8 (1991) on the National Environmental Protection (Effluent Limitation) Regulation are based almost verbatim on U.S. EPA Water Quality Criteria. Obviously there were no or not much data on toxicity tests on Nigerian aquatic species. We have taken the challenge up here at the University of Lagos. We are beginning to generate data on 96hLC<sub>50</sub> toxicity tests on a number of Nigerian species mainly fingerlings of *Tilapia* and *Clarias*, the periwinkle *Tympanotonus*, the hermit crab *Clibanarius*, shrimps *Penaeus notialis*, *Macrobrachium vollenhoevenii*, the giant bug *Bellostoma* and others at undergraduate and postgraduate levels.



The Environmental Physiology Unit in Zoology produced its first Ph.D under my supervision in 1991 on heavy metal concentration in the shrimp, *Macrobrachium*, sediment and water in Sasa stream at the Akowonjo area in Lagos State. The Environmental Physiology Unit has many promising young academics. The other areas of ecotoxicology which have not received much attention in Nigeria are:

Terrestrial toxicology

Wildlife Toxicology

Sediment Toxicology

Soil Ecotoxicology

Aquatic Microcosms and Mesocosms

Algal and Plant Toxicity and

Landscape Ecotoxicology.

### 3. BIOMONITORING

The ecophysiologist has a vital role to play in environmental monitoring programmes. Environmental monitoring is a process of repetitive observation, measurement and evaluation, of indicators of environmental degradation according to pre-arranged schedules in space and time for the purpose of management of the environment (Munn, 1973) Monitoring could be done daily, monthly, annually or periodically (e.g. 5 - to 10 years interval). It provides us with information on trends and changes in the environmental behaviour due to anthropogenic sources, thus providing an early warning in order that protective measures may be taken.

Regulatory agencies such as the Department of Petroleum Resources DPR, the Federal Environmental Protection Agency FEPA and Departments of Water Resources and Boards in Nigeria demand only chemical monitoring as a statutory requirement. Certain indicators such as pH, BOD, COD, heavy metals, oil and grease, etc., are among the chemicals that are monitored in water quality pollution control of water courses that receive industrial and domestic effluents.

Chemical substances, no doubt, are the major pollutants but the chemical method of monitoring has a major disadvantage. Sampling is intermittent. For example, a watercourse may be sampled at a station say every Wednesday and analysed for chemical indicators of pollution. But every week or two on Friday a factory upstream of the station

discharges toxic substances into the watercourse thereby killing aquatic organisms. By the following Wednesday when the chemist makes another sampling the toxic chemical has disappeared downstream and so detection is missed.

Secondly, analysis of samples may not be regular and hence the trends in environmental changes needed for pollution control will not be known in time.

Biological approach to monitoring should not occupy a minor role. After all, animals and plants are primarily the living organisms being eliminated. Environmental protection is largely about protection of living organisms and hence biologists should be involved. A biological monitoring of a water course record unexpected depression in the diversity of the biological community, as some species may be eliminated and many individuals killed by the chemical pollutants. Some of the missing species may be known to be especially sensitive to specific chemicals and other species to be tolerant of such chemicals. Such biological organisms are the biological INDICATORS of pollution.

## INDICATORS

For aquatic biomonitoring the most suitable species are benthic macroinvertebrates. Fishes are sensitive but are too mobile to be used as indicators although their continued absence is an indication of environmental damage to a water body.

Biological assessment of the quality of fresh watercourses using bottom dwelling invertebrates is the practice in Europe, Asia and North America but not here in Nigeria. These organisms offer many advantages. They are ubiquitous, inhabit different microhabitats within a water body and are affected by all forms of environmental perturbations. A large number of species are involved and hence they offer a wide spectrum of responses to environmental stresses. They are sessile or basically sedentary or have very low mobility and are hence affected by intermittent discharges, are easily caught and the same community can be quantitatively resampled in space and time. Further, the responses of many common species to different types of pollution have been established.



## APPLICATION OF BIOMONITORING

1. Biomonitoring is used in surveillance:
  - (a) Animals (and plants) are sampled (i) before and after a project is completed or (ii) before and after a toxicant is spilled to see if the original observations are repeated.
  - (b) Surveillance is also used to determine if water resource management techniques are working or whether conservation measures are successful.
  - (c) Benthic invertebrates are used to predict environmental impacts prior to the start of a development.
  - (d) Biological surveillance can reveal new or unsuspected pollutants in the environment. If a sudden change in biological community is detected and gives cause for concern then a detailed screening for pollutants and chemicals not hitherto considered as pollutants can be made.
2. Biomonitoring is used to ensure compliance either to meet statutory requirement (e.g. DPR, FEPA) or to control long-term water quality. Benthic macroinvertebrates can be used to test effluents and to ensure receiving water standards or they can be used to ensure that standards are maintained during and after construction of a project.

## WHAT IS MONITORED

- a. Changes in genetic composition
- b. Bioaccumulation of toxicants
- c. Toxicological testing in the laboratory and field
- d. Measurements of changes in population numbers, community composition, or ecosystem functioning.

Mr. Vice Chancellor, Sir, in the past 3 years, I have carried out the biological and chemical assessments of a number of streams in Lagos State that receive significant quantities of industrial and domestic waste waters particularly Sasa and Odo Iya Alaro streams. The results of the



investigations show the advantages of a combined chemical and biological methods.

## U. L. ARCHIVE

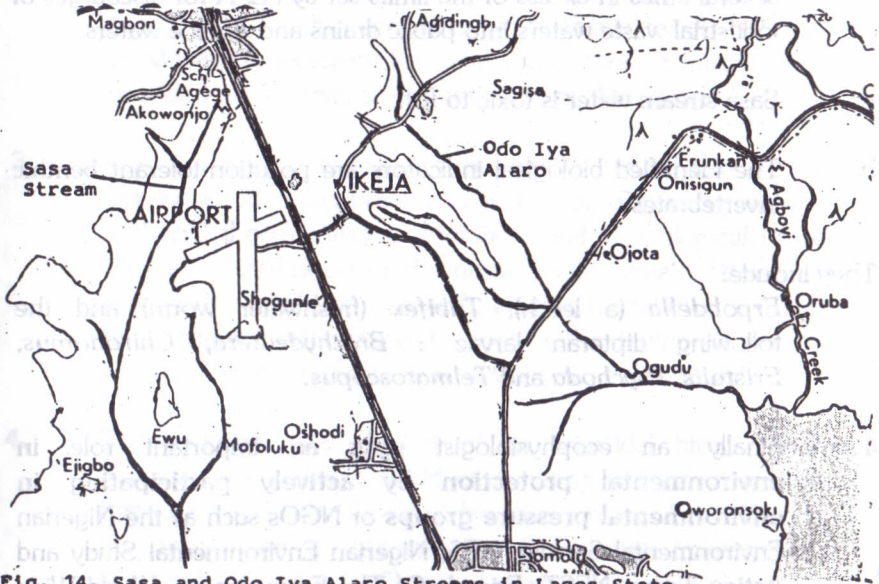


Fig. 14. Sasa and Odo Iya Alaro Streams in Lagos State.

## FINDINGS

- a. The streams are very heavily polluted throughout the year.
- b. The concentrations of chemical indicators in the water were several times in excess of the limits set by FEPA for discharges of industrial waste waters into public drains and surface waters.
- c. Sasa stream water is toxic to fish
- d. The identified biological indicators are pollution-tolerant benthic invertebrates:

They include:

*Erpobdella* (a leech), *Tubifex* (freshwater worm) and the following dipteran larvae : *Brachydeutera*, *Chironomus*, *Eristalis*, *Psychoda* and *Telmatoscopus*.

4. Finally, an ecophysiologist plays an important role in environmental protection by actively participating in environmental pressure groups or NGOs such as the Nigerian Environmental Society, NES, Nigerian Environmental Study and Action Team, NEST, Friends Of The Environment, World Wide Fund, WWF, Clean Nigeria Associates, CNA and the Nigerian Conservation Foundation, NCF, by mobilising public opinion to oppose practices or proposed practices likely to threaten the integrity of the environment.

## XII. CONCLUSIONS

1. The rotation of the Earth, combined revolutions of the Moon and the Earth and the gravitational pulls on Earth by Moon and the Sun impose on the inhabitants of the Earth marked daily, monthly and seasonal fluctuations in temperature, light intensity, day length (photoperiod), moonlight, humidity, rainfall, tide and air characteristics which alter the rate of their metabolic and physiological processes. Animal species have evolved adaptations and adjustments to these fluctuations to avoid extinction. Numerous examples were cited.

2. The ecophysiological investigates, describes and explains the varied mechanisms by which animals compensate for environmental alterations and stresses. The compensatory mechanisms in the osmotic regulation of several Nigerian economically important finfish and shellfish were described during the lecture. The ecological and physiological informations provided are necessary for their aquaculture. Similarly, the data provided on the snail are essential for snail farming.
3. The rhythmicity occurring in the environment is also a common phenomenon-taking place in cells, tissues, organs, whole animals and animal communities. Metabolic and physiological processes are the internal clocks or chronometers in animals. They measure time, do so in relation to specific environmental rhythms, and use this temporal information to control the timing of behaviour, activity, feeding, reproduction, development and growth.
4. The adductor tidal rhythm of an intertidal bivalve mollusc, *Scrobicularia plana*, the adductor rhythm in freshwater bivalves, *Egeria radiata* and *Mutela dubia*, the control of and location of the chronometer for the adductor rhythm were investigated and the results described. Excellent electrophysiological recordings were obtained.
5. Behavioural patterns are generally initiated by chemoreception. The structure and function of the cruciform muscle sense organ in *Scrobicularia* and *Egeria* were described.
6. In natural environmental fluctuations there is a balance in biogeochemical cycles, stability in global ecosystems and a high global biodiversity which are necessary for the continued existence of life forms on earth. On the other hand, human activities are transforming the global environment through emission of toxicants into the land, air and water, acid deposition, ozone layer depletion and increased atmospheric concentrations of gases that trap heat and warm the climate. Animals have not evolved adaptations and adjustments to these



changes hence biodiversity extinction and ecosystem instability result which threaten the very existence of man.

7. I have made contributions in (i) identification and location of sources of pollution in Lagos State, (ii) the discharge outfalls into receptor bodies of water, (iii) the ecotoxicological effects of a number of industrial effluents and (iv) chemical and biological assessment of the water quality of Sasa and Odo Iya Alaro streams in the state.
8. Environmental physiologists are actively involved in planning and management of resources use, the conservation of biological diversity, protection of freshwater, mangroves, the seas, land and atmosphere, and education, public awareness and training in environmental issues.

### **XIII. RECOMMENDATIONS**

1. I use this opportunity to express our gratitude to our very capable and energetic action Vice Chancellor for the creation of two departments from the former Department of Biological Sciences. However, I plead with the Vice Chancellor to complete the exercise by creating separate departments of Zoology and Marine Biology and Fisheries. The University of Lagos is the only University in Nigeria to be sited on the edge of an ocean. In the Marine Biology programme, the Atlantic Ocean off the Nigerian coast is the major focus of our study. The fisheries degree programme focuses on freshwater, brackish water and marine fisheries. The Zoology degree programme focuses on Animal Biodiversity, Crop and Stored Products Protection, Insect products, Pest Control and Management, Parasitic diseases, Hydrobiology, Pollution and Wildlife Conservation and Management. There are four-degree programmes including a Biology degree programme. A further split will enhance development of the different specialisations mentioned.
2. The Marine Biology and Fisheries Unit especially and the Hydrobiology sub-unit in the Zoology Unit need a boat for the expected regular undergraduate and postgraduate practical and

research field trips into the various freshwater streams and rivers, the Lagos Lagoon and Harbour, Badagry and Port Novo Creeks and the Atlantic Ocean. We have no boat to carry out this vital aspect of our degree programmes. We shall be very grateful if we will get us a boat.

3. FEPA should support researches in the University of Lagos on toxicity and bioconcentration tests on local test organisms and industrial effluents to enable the Agency have data for determination of Nigerian water quality criteria.
4. FEPA, DPR, state EPAs, Water Resources Boards and other large corporations and regulatory agencies should include biomonitoring in their monitoring programmes in pollution control. Such biomonitoring should not be limited to microbes but should include the use of benthic macroinvertebrates. These agencies and corporations need of ecological zoologists.

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