Everyday SCIENCE For Schools

Volume 13, Number 1, 2024

"Understanding what molluscs and crustaceans are and their description helps to understand their interrelationship with themselves and their environment" - Akita *et al*

Understanding what molluscs and crustaceans are and their description helps to understand their interrelationship with themselves and their environment - Akita et al

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Editorial Disclaimer:

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Ghana Science Association

Introduction

The Ghana Science Association (GSA), a voluntary, non-profit making and multidisciplinary organisation of scientists, technologists and mathematicians was formed in 1959. The Association traces its origin to the West African Science Association (WASA) which was formed in 1953 at the University College of the Gold Coast. WASA was formed to provide West African scientists the forum to advocate the importance of Science and Technology as a necessity and bedrock for national development. The formation of GSA broadened the scope of activities from reading of scientific papers to involvement in national and international affairs. The Association was placed on government subvention under the Ministry of Education as far back as 1961 by a Presidential Fiat. Hence the Association is supported through a budgetary allocation from the Ghana Government. Other sources of income include membership dues and proceeds from workshops and conferences. The GSA was mandated to promote, popularize and demystify science and create a scientific culture in the country. The Association has made tremendous contributions to National Development, Health and Economic Growth through scientific interventions. The Secretariat is a point where scientific and technological information and research findings are obtained by individuals and corporate bodies.

Membership of the Association is drawn from the Universities, Research Institutes, Industry, Government and Persons interested in the promotion of Science and Technology.

Vision and Mission

Vision

To become a dominant voice in Science and Technology advocacy by promoting and popularizing Science and Technology to meet national developmental needs.

Mission

Advancing Science, Technology, Engineering and Mathematics (STEM) through interaction and cross-fertilization of ideas of all interested people to: -

1. Popularize, promote and disseminate scientific information and technology transfer for national development.
2. Contribute to the development of National Science and Technology policy.
3. Collaborate with industry to set national research agenda.
4. Establish linkages with industry to promote the transfer and application of Science.
5. Seek affiliation and foster cooperative links with other national and international organizations.

Activities

1. Organization and participation in scientific conferences, workshops, seminars, symposia, public lectures, quizzes and science fairs.
2. Promotion of carrier development of scientists in Universities and Research Institutes in Ghana and elsewhere.
3. Publication of the scientific journal, magazines and books (e.g. Journal of the Ghana Science Association and Everyday Science for Schools magazine).
4. Training programmes for mathematics and science teachers to improve the teaching and learning of these subjects in Schools and Colleges of Education.

Contribution to National Development

Issues of national importance have been regularly and consistently highlighted at biennial workshops, conferences etc. Communiqués had been submitted to Government and other stakeholders on very topical themes to help shape national policies.

THE ARTICLES

COMPARISON BETWEEN MOLLUSCS AND CRUSTACEANS' ECOLOGY AND HABITATS

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Kingdom Animalia constitutes major groups of animals. All the animals in the kingdom Animalia are either eukaryotes (any cell or organism that possesses a clearly defined nucleus) or multicellular organisms (an organism that consists of more than one cell). Moreover, the kingdom Animalia also has several different phyla. Among them are the **phylum Mollusca** members are known as **Molluscs** (Fig. 1-3) and the **subphylum Crustacea** (Crustaceans are a taxon of phylum Arthropoda) (Fig. 4-6). These Phylum are the largest diversified groups with a great number of species in Animalia kingdom molluscs (Fig. 1-3).

Molluscs

***Fig.1** - Types of mollusc*
https://owlcation.com/stem/types-of-mollusc-with-pictures
https://kids.gwnews.com/articles/bivalve-facts-2

Classification

- **Kingdom**: Animalia
- **Phylum**: Mollusca; Linnaeus, 1758
- **Scientific name**: Mollusca
- **Domain**: Eukaryota

Characteristics of molluscs

- Soft-bodied
- The body comprises three parts (Fig. 2):
  - Head.
  - Muscular Foot – for movement and escape from predators or catching prey.
  - Visceral mass (holds organs) with a Mantle (secretes cuticle forming shell).
- Bilaterally Symmetrical (When the body plan of an animal can be divided along a line that separates the animal's body into right and left halves).

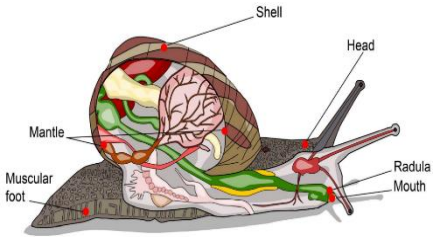

***Fig.2** - General parts of a mollusc*
https://www.chegg.com/homework-help/questions-and-answers/question-2-question-relates-observations-table-part-1-b-modifications-body-plan-lifestyle--q83345350

Mollusc Can Be Grouped Into Various Classes, Which Includes;

***Fig.3** - Classes of Molluscs*

General Terminologies

- Phora – bearing
- Mono – one
- Placo – plate
- Poda – foot
- Cephalo – head
- Scapho – sword
- Pelecy – hatchet

Crustaceans

***Fig.4** – Types of Crustaceans (https://www.iasgyan.in/daily-current-affairs/crustaceans)*

Classification

- **Kingdom:** Animalia
- **Phylum**: Arthropoda
- **Subphylum:** Crustacea
- **Domain:** Eukaryota

Characteristics of crustaceans

- A hard exoskeleton
- No internal skeleton
- Segmented
- The body comprises three parts.
  - the head
  - the thorax / Cephalothorax (head and thorax fused)
  - the abdomen.

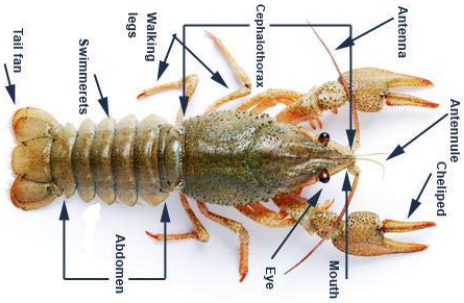

***Fig.5** - Parts of a Crustacean*
http://www.mesa.edu.au/crustaceans/crustaceans05b.asp

Classes include;

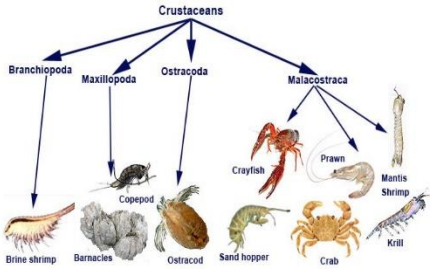

***Fig.6** – Classes of Crustaceans*
https://www.iasgyan.in/daily-current-affairs/crustaceans

Comparisons Between Molluscs and Crustaceans (Ecology and Habitat)

Similarities between Molluscs and Crustaceans

- Belong to the kingdom Animalia.
- Both members possess a type of similar covering ie. Exoskeleton or Shell.
- Both function as food and nutrient sources.
- Both are faced with similar threats.
- Both groups have both aquatic and terrestrial members.
- Both groups have both members inhabiting fresh and marine water.
- They are invertebrates.

Difference Between Molluscs and Crustaceans (Ecology and Habitat)

Body structure

Molluscs	Crustaceans
Members possess soft bodies, often encased in a hard shell	Members are characterized by segmented bodies and hard exoskeletons
Comprise of a head and a foot(muscle) and a visceral mass	Comprise of a head, thorax, abdomen and appendages
Possess the Radula for feeding (lost in bivalves) (Fig. 7)	Possess mandibles for feeding
Do not shed their shells, the shell is typically a permanent part of its body.	Shed their shells/ exoskeletons (Fig. 8)
Modified gills known as ctenidia are used in respiration	Modified Gills/ lungs are used for respiration
The excretory organ is metanephridia	Excretory organ - pair of green glands to excrete wastes
Sensory organs: tentacles, eyes, osphradium, and statocysts	Some sensory organs include two pairs of sensory antennae etc

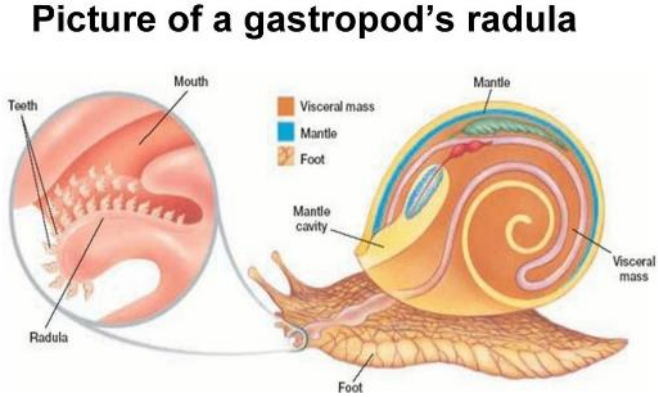

***Fig. 7* - Radula**
https://en.wikipedia.org/wiki/Radula

***Fig. 8** - shedding of the exoskeleton*
https://math.scholastic.com/issues/2017-18/101617/the-magic-of-molting.html

Feeding Modes

Molluscs	Crustaceans
Filter Feeders: Bivalve molluscs such as clams, mussels, and oysters are filter feeders. They use their gills to filter tiny food particles, such as plankton and detritus, from the water. They draw in water and filter out food particles, expelling excess water (Fig. 9). **Grazers/Herbivores:** eg snails (such as garden snails), feed on plant matter. They use a rasping tongue-like organ called a radula to scrape algae or plant material from surfaces. **Predators:** Cephalopods like octopuses, squid, and some species of snails are predators. They actively hunt for prey, using their tentacles equipped with suckers to capture and subdue their food. **Scavengers:** Some molluscs, such as certain snails and slugs, are scavengers. They feed on decaying organic matter, including dead plants and animals.	**Filter Feeding**: Some crustaceans, like certain species of shrimp and barnacles, are filter feeders. They use specialized appendages or structures (e.g., cirri) to filter food particles from the water (Fig.10). **Herbivory**: some species of shrimp and crabs, primarily feed on plant matter. They might consume algae, seaweed, or plant detritus **Predation**: Crabs, lobsters, and certain shrimp species are also known to be predators, preying on smaller organisms they can capture. **Detritivory**: Many crustaceans are detritivores, feeding on decomposing organic matter, including dead plants, animals, and faecal material. They play an important ecological role in breaking down and recycling nutrients in aquatic ecosystems. **Scavenging:/opportunistic feeders:** They feed on dead or decaying organic matter, detritus, and other organic debris found on the ocean floor. E.g. Crabs.

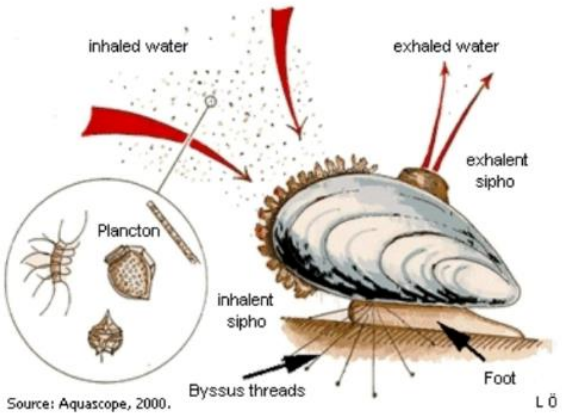

***Fig. 9** - Filter feeding in some mollusc https://www.semanticscholar.org/paper/Case-Study-Mussels-Modeling-the-effect-of-dredging-Wijsman-Dedert/7627deca7a6502a7aeb27a2e5bd714fb90ff88f4*

***Fig.10** - Feeding in some Crustacean https://www.americanoceans.org/facts/what-do-crabs-eat/*

Reproduction

Molluscs	Crustaceans
Life Cycle: starts from egg to two larval **stages—trochophore and veliger**—and **post-larval stage** (Spat) before becoming a young adult.	Starts from the egg to **nauplius stage**, followed by the **zoea larval stage** and **post-larval stage**, and finally ends with the adult growth stage.
Mode of Fertilization: ***External fertilization***: males release sperm into the water, and females release eggs or egg masses. E.g. snails, clams, mussels, and some cephalopods ***Internal fertilization***: During mating, males transfer sperm directly into the female's reproductive structures. Eg. clams, and various cephalopods like squids and octopuses.	**External fertilization**: males release sperm into the water, and females release eggs into the surrounding environment where sperm and eggs meet. E.g. shrimp, crabs, lobsters, and some planktonic crustaceans. **Internal fertilization**: Some crustaceans have evolved internal fertilization. During mating, males transfer sperm directly into the female's reproductive structures through specialized appendages called gonopods.

Habitat Preference

Molluscs	Crustaceans
Marine environments: Can be found in marine habitats, ranging from shallow coastal waters to the deep sea. They inhabit various zones within the ocean, such as rocky shores, sandy bottoms, coral reefs, and open water. Eg. Snails, clams, mussels, octopuses, and squid.	**Marine environments**: Many crustaceans are found in marine habitats, living in oceans, seas, and estuaries. They can inhabit various zones within these environments, from the intertidal zone to the deep sea. Crustaceans such as crabs, lobsters, shrimp, krill, barnacles, and many others.
Freshwater habitats: Molluscs also inhabit freshwater environments like rivers, lakes, ponds, and streams. E.g. Certain types of snails, mussels, and freshwater clams. They can be found attached to rocks, submerged vegetation, or burrowed in sediments.	**Freshwater habitats**: some crustaceans also thrive in freshwater ecosystems, including rivers, lakes, ponds, and streams. Creatures like crayfish, freshwater shrimp, and certain types of crabs.
Terrestrial environments: some have adapted to terrestrial habitats, environments such as forests, grasslands, and gardens. Land snails and slugs are examples of molluscs that have successfully colonized terrestrial ecosystems. They require moist environments to prevent desiccation since their soft bodies are prone to drying out.	**Terrestrial environments**: While most crustaceans are aquatic, some species have adapted to terrestrial environments. Land-dwelling crabs, such as coconut crabs, can be found in coastal areas and even venture further inland. Additionally, terrestrial hermit crabs reside in coastal areas and spend much of their time on land, utilizing empty shells for protection.

Intertidal zones: Molluscs are often found in intertidal zones. Creatures like limpets, certain types of snails, and mussels are well adapted to these dynamic and sometimes harsh environments (Fig. 11)

Specialized habitats: Some molluscs have specific habitat requirements. For instance, hydrothermal vent communities in the deep sea (Fig. 12) harbour unique species like giant tube worms, clams, and snails that are adapted to extreme conditions like high pressure, darkness, and high temperatures.

Intertidal zones: Crustaceans are also found in intertidal zones (Fig. 11).

Specialized habitats: Crustaceans can also be found in specialized or extreme habitats. Some inhabit the depths of the ocean, including the deep sea and hydrothermal vent ecosystems (Fig. 12). These environments pose unique challenges, such as extreme pressure, darkness, and varying temperatures.

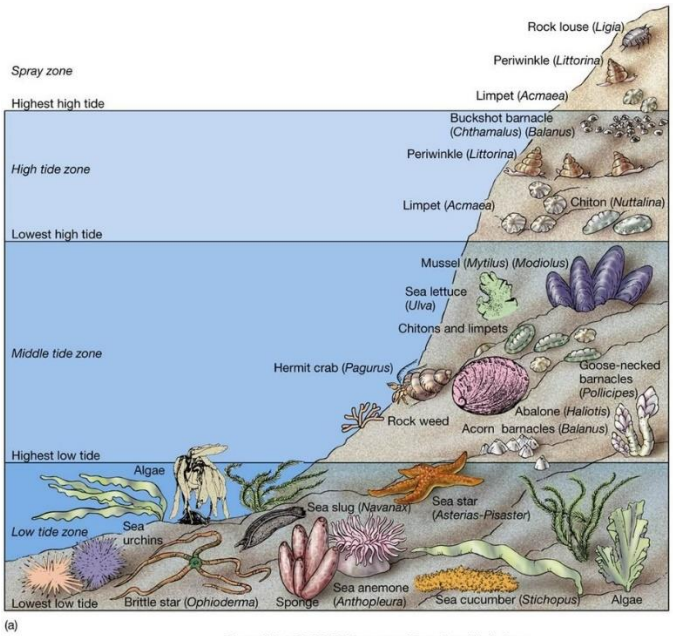

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Fig.11 *- Molluscs & crustaceans in the intertidal zone https://biol326.wordpress.com/2018/03/11/lifes-a-beach-challenges-of-living-life-in-the-rocky-intertidal-zone/*

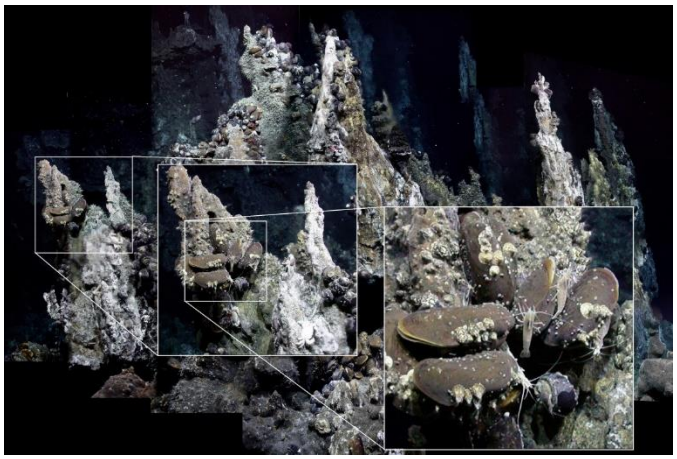

Fig.12 - *Hydrothermal Vent communities with Molluscs and crustaceans https://schmidtocean.org/wp-content/uploads/FK160407-VentLife_HighRes-FisherWHOI-1140x764.jpeg*

Adaptive Features

Molluscs	Crustaceans
Shells - protect the soft body and internal organs.	Exoskeleton
Foot and Muscular System - for crawling, gliding, and burrowing	Segmented Body
Radula - for scraping and rasping food.	Gills and Respiratory Structures – exchange of gases
Sensory organs - detect environmental cues, locate food sources, and avoid predators.	Specialized Appendages: Crustaceans have diverse and specialized appendages for various functions, including walking, feeding, etc.
Gills - exchange of gases in water and on land	Sensory organs - detect environmental cues, locate food sources, and avoid predators.
Mantle- produces the material necessary for shell growth and repair.	

Economic Importance of Molluscs and Crustaceans

- **Employment and livelihood:** These organisms, therefore, provide employment (Fig. 13-14) opportunities and recreational interests through stocking, picking, feeding, sorting, and other activities related to crustacean/mollusk gathering or cultivation. This, in turn, is a source of income supporting their livelihood. E.g.,

Shellfish Industry and pearl industries. E.g., include clams, oysters, crabs, mussels, and scallops harvested from the wild and through aquaculture. Pearls have been highly prized for centuries and are used in jewelry, providing significant economic value in regions where pearl farming is practiced.

Fig.13 *– Oyster harvesting https://thefishsite.com/articles/fulfilling-the-potential-of-senegals-oyster-farming-sector-fao-fish4acp*

Fig.14 *- Mud crab harvesting https://www.asiafarming.com/mud-crab-farming-in-the-philippines-evergreen-profitable-business*

- **Bioindicators** usually serve as bioindicators or biomonitors (Fig. 15) in various aquatic environments. Since they are found in numerous environments, including terrestrial, brackish, marine, and freshwater habitats. The creatures are, therefore, the perfect subjects for comparative analyses. Biomonitoring helps demonstrate the ability of some species of crustaceans and molluscs to point out sites with lower environmental quality. This helps to identify environmental problems, including the decay in the water quality mainly due to sewage and wastewater discharges, but also to levels of metals (Ag, Al, B, Hg, and Pb) surpassing environmental guidelines in abiotic matrices.

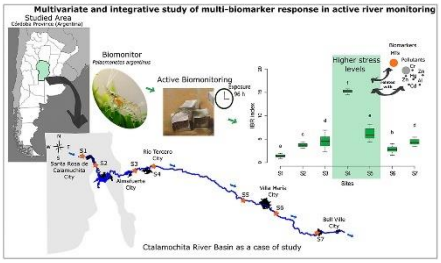

Fig.15 *- The use of active biomonitoring and the integration of biological responses through an IBR confirm that native biota could be a useful monitoring tool for bioavailable pollutants in aquatic ecosystems constituting a highly valuable approach. https://www.sciencedirect.com/science/article/abs/pii/S004565351830844*

- **Food** - A large number of crustaceans/ molluscs are consumed by man, especially lobsters, shrimps, prawns, squillae, crabs clams, oysters, mussels, and crayfishes, etc. (Fig. 16).

Fig.16 *– Varieties Of Molluscs and Crustaceans https://Www.Alamy.Com/Stock-Image-Seafood-Plate-Different-Molluscs-And-Crustaceans-Lay-Over-Ice-166098807.Html*

- **Nutrient** – both groups of organisms are known to be rich in protein, and possibly help to meet the food requirements for mankind's ever-increasing population.
- **Export revenue** - countries involved in the production and trade of crustaceans and molluscs turn to earn some percentage of revenue.
- **Biomedical value** - The shells of crabs and other crustaceans are used in medicine to treat and prevent inflammatory diseases. Some researchers at Florida Atlantic University have developed an orally administered crustacean microparticle dietary supplement to prevent and treat IBD and other inflammatory diseases using the shells of crabs and other crustaceans. These chitin or chitosan (Fig. 17) microparticles undergo anti-inflammatory mechanisms applicable in developing novel preventive and therapeutic substances for treating inflammatory bowel disease (IBD). a gel-like pad could be formed by mixing different substances, which could be placed directly on the wound," Tuvikene explains. The preparation developed from chitosan could be very useful in treating burns, where infections occur more easily, and healing takes a long time. Chitosan was used in treating the wounded from the Iraq and Afghanistan wars.

Fig.17 *- Chitosan powder https://phys.org/news/2020-05-crustaceans-woundsthe-future-medicine.html*

In the 1960s, scientists discovered that the sky-blue blood inside horseshoe crabs (Fig. 18) would clot when it detected bacterial toxins. Vaccines, drugs, and medical devices have to be sterile before they're put inside people. A better toxin-detection system meant less contamination risk for patients, so fishermen soon started collecting and selling the prehistoric animals to be bled.

***Fig.18** - Horseshoe crabs are bled at a facility https://www.npr.org/2023/06/10/1180761446/coastal-biomedical-labs-are-bleeding-more-horseshoe-crabs-with-little-accountabi*

- **Geological value -** The most common arthropods in fossil records are Ostracods (seed shrimp). These fossils were first discovered around the Cambrian era and continue to be found by archaeologists, even today. M. B. Hart compiled a microfaunal zone layout based on Ostracoda and Foraminifera arthropods. Freshwater ostracods from the Baltic amber of the Eocene era, assumed to have been washed onto trees during surges, have also been discovered. These organisms are, therefore, of geological significance, particularly for local or regional marine strata biozonation. The arthropods are also useful paleo-habitat indicators due to their prevalence, minute size, and the easily preserved generally moulted and calcified bivalve carapaces, a commonly discovered microfossil.

Threats Faced by Molluscs and Crustaceans

Both face similar threats, such as:

- **Coastal Development** - The number of people living on the coasts has rapidly increased in recent decades (Urbanization), causing significant development of coastal areas. Coastal development can negatively impact the ocean by destroying coastal habitats, run-off of sediments and pollution (Fig.19). Coastal development involves activities such as the creation of harbours, stabilization of shorelines, and aquaculture that involves the destruction of sensitive marine habitats. Coastal structures can modify natural coastal processes like wave energy, sediment transport, and shoreline dynamics. This eventually results in Pollution.

***Fig.19** - Pollution from coastal development https://www.envpk.com/marine-pollution-its-risky-effects-on-marine-life-humans/*

- **Dredging and mining** – This disrupts the sea floor and its habitat. Dredging or underwater mining can be a crude, inefficient, non-selective, and hugely destructive means of collecting fish and minerals. This leaves a trail of destruction; plant species will be uprooted, countless small invertebrates (benthic organisms) will be broken and killed, and many decades of slowly maturing habitat will be destroyed. At the end of this activity, a wasteland will remain. But this is only part of the damage. Most organisms, the actual target species to be collected, will also be destroyed; many more will be collected but unusable due to damage as they are rolled and tumbled along with all the other debris. E.g., scallop dredging (Fig. 20-21).

***Fig.20** - Empty and broken scallop shells swept into a pile, possibly due to the raking action of dredges, on a heavily worked area. https://www.marine-bio-images.com/blog/lyme-bay-marine-ecology/scallop-dredging-how-we-approach-marine-habitat-protection-from-entirely-the-wrong-direction/*

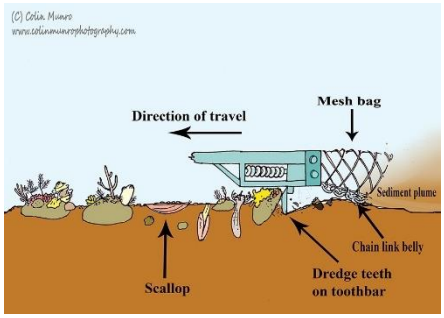

***Fig.21** - Illustration showing the key parts of a spring-loaded scallop dredge and how it works on the seabed*

Ocean Acidification - As oceans gradually acidify due to rising carbon dioxide (CO_2) emissions, some of these marine organisms will find it harder to build their shells or skeletons. Ocean acidification acts a lot like osteoporosis, which causes bones to become brittle in humans. For oysters, scallops, and other shellfish, lower pH means less carbonate, which they rely on to build their essential shells. As acidity increases, shells become thinner (Fig. 22), growth slows down and death rates rise.

***Fig.22** - Oyster shells are bleached rather than destroyed by changes in pH levels: pH 8.1 is ambient conditions; pH 7.8 is estimated value in year 2001; pH 7.5 is estimated value in year 2003. Photo: N. Sezer/Istanbul University https://www.iaea.org/newscenter/news/jeopardy-at-sea-what-atoms-in-clams-tell-us-about-ocean-acidification*

***Illegal, unreported and unregulated (IUU)* fishing** - Ocean food production is threatened by overfishing and habitat destruction often caused by IUU fishing and exacerbated by climate change, which in turn leaves coastal communities more vulnerable to the impacts of this loss (Fig. 23). Continued IUU fishing will deplete fish stocks and destroy habitats, decrease the value of many fisheries, threaten species extinction, disrupt marine food webs, increase food security risks and disrupt coastal communities' social cohesion. Many of these effects are already being felt.

Fig.23 *Coastal communities and fishing activities in Ghana. Mining impacts have changed the colour of the Pra Estuary; the chemicals within the water may bioaccumulate in the biota (such as Molluscs and Crustaceans) and possibly transfer the toxins into the food chain and the food web.*

Lack of effective regulations - weak governance that fails to enact or live up to fisheries management regulations; and barriers to enforcement of fishing regulations caused by lack of political will, lack of enforcement capacity, and sometimes corruption.

Conclusion

Molluscs, which include bivalves, gastropods and cephalopods, belong to the large and diverse phylum Mollusca, forming the second largest species-rich phylum in the world after Arthropoda. Molluscan diversity concerns all aspects of biology (morphology, physiology, behaviour, genetics and ecology) and additionally includes a long extremely rich and informative fossil record. (Haszprunar, 2020).

Crustacea is a diverse group of arthropods that includes over 67,000 species, making it one of the largest groups of animals on the planet (Scholtz, & Richter. 1995). They are found in a wide variety of habitats, ranging from deep-sea trenches to freshwater streams, and are characterized by a hard exoskeleton, jointed limbs, and two pairs of antennae (Martin& Davis, 2001). Crustaceans play important ecological roles as primary consumers, predators, and decomposers in aquatic ecosystems, and many species are also commercially important as seafood (Lotze *et al*., 2006). Some examples of economically important crustaceans include crabs, lobsters, and shrimp. Both groups are marked as important ecosystem components, contributing significantly to the biodiversity from the coastal and terrestrial regions to the abyssal depths of the ocean.

Molluscs and crustaceans inhabit various aquatic ecosystems (Fig. 24a) varying from freshwater, and estuarine to marine environments (e.g., rivers, lakes, wetlands, ponds, estuarine, lagoons, intertidal sandy beaches, rocky shores, deep seas and among many), as well as on aquatic plants (e.g., ***sargassum***, a genus of brown macroalgae in the order Fucales of the Phaeophyceae class) (Fig. 24b). The shells of some molluscs are beautiful, valuable and can be used for ornamentals (Fig. 24c). Some species are more sensitive to pollution and eutrophication than other species. The number of distinct species (Fig. 24d) and their relative abundance effectively measure the state of the aquatic ecosystems. Nonetheless, molluscs and crustaceans are threatened by human impacts such as plastic pollution, mining, fishing activities, ocean acidification, etc. Understanding what molluscs and crustaceans are and their description helps to understand their interrelationship with themselves and their environment. They are useful biological indicators that can be used to describe the state of an aquatic ecosystem. There is a need for the conservation and protection of aquatic ecosystems and their animals through environmental stewardship, reform policies, and increasing educational awareness.

Fig.24a *Aquatic ecosystems in Ghana. Some Gastropods are found in a lagoon in Ghana.*

Fig.23b *Sargassum on an intertidal sandy beach in Ghana.*

Fig.23c *Shells of Molluscs from sandy beaches in Ghana.*

Fig.23d *Molluscs and Crustaceans from intertidal Sandy shore in Ghana.*

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THE EFFECT OF COOKING METHODS ON THE QUALITY AND SAFETY OF MEAT

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Abstract

Meat, a rich source of protein, vitamins and minerals is a staple food globally. While cooking methods enhance meat's safety, palatability and shelf life, they can also impact its nutritional value. This review explores how various cooking techniques, including frying, grilling, roasting, and boiling, affect meat's nutritional quality. Additionally, this review discusses the formation of potentially harmful compounds such as heterocyclic aromatic amines (HAA) and polycyclic aromatic hydrocarbons (PAH) during several cooking methods. To reduce HAA in meat before it is cooked, garlic and organosulfur compounds can be used since they can potentially reduce HAA formation in cooked beef. Also, marinating meat in dissolved suspension solutions can reduce HAA formation during high-temperature cooking; for instance, honey-containing marinades have also been found to inhibit HAA formation in fried beef steak and chicken breast. The level of PAHs can be reduced by pretreating meat (reducing the pH); thus, marinating meat in acidic mixtures such as lemon juice and vinegar can help block PAH formation on meat surfaces. Reducing processing temperature, time, and fat content of meat can also help reduce the PAH levels in meat. The fat content can be reduced by trimming excess fat from meat before cooking to minimize flare-ups, increasing PAH formation.

Awareness among consumers about the risks associated with different cooking methods should be advocated to ensure safety practices in meat preparation in order to ensure continued enjoyment of meat while protecting the health of consumers.

Introduction

Meat is one of the most important sources of human nutrients, and it is widely consumed by people across the world as it is a well-known protein and energy source for daily diets (Aderonke and Ifeanyi, 2019). Meat is a nutrient-dense food and provides major nutritive contributions to the diet of its consumers. Meat has an exceptionally rich nutritional value and is an excellent source of essential amino acids and nutrients such as vitamins B3 and B12, iron, zinc, magnesium, and selenium (Khalid *et al.*, 2021). Meat processing is inevitable in meat and meat product preparation for human consumption. To improve meat's tenderness, nutritional content, digestibility, and microbial safety, raw meat is subjected to cooking methods (Suleman *et al.*, 2020).

Cooking is a heating operation usually applied to meat before consumption (Oz *et al.,* 2016). This helps improve the quality and safety of meat and extend its shelf life (Suleman *et al.,* 2020; Talab, 2014). Cooking meat improves its palatability, destroys many microorganisms, improves the storage life of meat products, inactivates indigenous proteolytic enzymes, prevents the development of off-flavors, and modifies the texture or tenderness of meat and meat products. During the cooking process, there is an increase in temperature, which leads to the production of a desirable flavor or aroma (Suleman *et al.,* 2020). Some undesired and unintentional consequences, such as loss of amino acids and the synthesis of toxic compounds, often occur during cooking (Pearson and Tauber, 1984; Meade *et al.,* 2005). Applications of cooking methods include ohmic cooking, ultra-high temperature treatment, grilling, frying, boiling, and roasting.

Cooking meat at high temperatures Has been reported to generate mutagens or carcinogens such as heterocyclic aromatic amines and polycyclic aromatic hydrocarbons (Sugimura *et al.,* 2004). Carcinogenic heterocyclic amines are formed in protein-rich foodstuffs when exposed to high cooking temperatures. This review discussed the effect of the various cooking methods (frying, grilling, roasting, and boiling) on beef's nutritional quality.

Frying

Frying is an ancient method of cooking that Has been widely patronized because of the uniqueness of its color and taste characteristics and, as a result, one of the most used cooking techniques for meat (Ananey-Obiri *et al.,* 2018). Frying enhances food's sensory quality by creating aroma compounds, attractive color, and a desirable texture. Additionally, frying can render potential microorganisms inactive and increase the availability of nutrients in the fried meat (Hosseini *et al.,* 2016). However, undesirable changes such as degradation of heat-susceptible vitamins, development of carcinogens (heterocyclic aromatic amines and polycyclic aromatic hydrocarbons) and potential loss of protein content are some disadvantages (limitations) of frying meat (Zhang *et al.,* 2014). The process of frying significantly alters the chemical composition of meat. Frying induces changes in the fatty acid composition of meat due to oil absorption, leading to an increase in oleic and linoleic acids (Bosco *et al.,* 2019).

Meat frying involves complex chemical reactions that significantly impact its characteristics and quality. Maillard reaction, lipid oxidation, protein denaturation, and moisture loss are key processes that occur during the high temperature frying of meat (Shiping *et al.,* 2022). These processes contribute to fried meat's unique flavor, aroma, and palatability (Khalid *et al.,* 2023). It is also important to note that the frying process can lead to the formation of heterocyclic aromatic amines (HAAs) and polycyclic aromatic hydrocarbons (PAHs), which are known to be potential carcinogens and have raised concerns regarding their impact on human health (Zhang *et al.,* 2022). These carcinogens are regarded as 2A carcinogens. Fried meat carcinogenicity is closely related to the content of heterocyclic aromatic amines.

HAAs are formed in muscle foods when the temperature exceeds 150°C, through the Maillard reaction with creatinine, amino acids, and sugars as precursors (Jamali *et al.,* 2016). According to a study conducted by Li *et al.* (2012), frying can lead to an increase in the content of N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA) and N-nitrosopyrrolidine (NPYR), while decreasing the contents of histamine and cadaverine. N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA), and N-nitrosopyrrolidine (NPYR) are nitrosamines, which are known to be potentially carcinogenic compounds. These substances are formed through the nitrosation of secondary amines and can have detrimental effects on human health, particularly in relation to cancer development. Histamine, on the other hand, is a biogenic amine involved in various physiological processes, including immune response and neurotransmission. Still, its excessive accumulation can lead to histamine intolerance and allergic reactions.

Cadaverine is a polyamine that is naturally present in living organisms and is involved in various cellular functions, but its excessive presence can be associated with food spoilage and has been implicated in certain diseases. The formation of HAAs in fried meat can be influenced by several factors. One such factor is the quality of the cooking medium, specifically the frying oil. During frying, the oil is absorbed and accumulates on the surface of the meat, participating in the formation of HAAs (Mehta *et al.,* 2022). Different types of oils can vary in their ability to produce HAAs. For example, a study found that rapeseed oil and peanut oil produced higher levels of harman and norharman (types of HAAs) in fried meat compared to lard, sunflower oil, soybean oil, and palm liquid oil. This is because tryptophan degradation during the roasting of seeds to produce these oils can easily produce HAAs (Chen *et al.,* 2022).
Another important factor in forming HAAs is the frying temperature and time. Higher temperatures and

longer frying times can lead to increased levels of HAA in the meat. A study found that at high temperatures of 200°C and 220°C, two types of HAAs (IQ and MelQ) were detected in chicken meat fried for 6 minutes (Chen *et al.,* 2022).

Fig. 1.0 *Frying meat*
Adopted from oceanproperty.com

Fig. 2.0 *Fried meat*
Adopted from enistoresonline.com

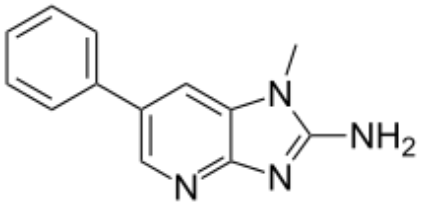

Fig. 3.0 *PhIP*
Adopted from wikipedia.org

Grilling

Grilling is a popular and common cooking method where food products, especially meats and fish, are exposed to high temperatures. It allows consumers to prepare a quick meal, increases the palatability of aromas, and enhances flavor characteristics due to Maillard's reaction. Grilling meat is mostly done via the combustion of charcoal or an electric grilling machine. Grilling is usually done at 260 °C or a higher temperature for 5–10 min, depending on the size and cut used (Suleman *et al.,* 2022). Raw meat becomes easier to digest, almost sterile, and affects the color, flavor, taste, and textural properties of meat when grilled (Oz, 2014; Nuray and Oz., 2019; Cordeiro *et al.,* 2020).

During grilling or any other cooking method, physical and biochemical changes such as color changes, formation of odors and flavors, protein denaturation, lipid oxidation and texture modifications occur as a result of the application of heat during cooking (Boles, 2010) Color is one of the important qualities of raw and processed meat. When beef and other meat products are subjected to high heat temperatures between 55 °C and 65 °C, denaturation of myoglobin and other protein begins in meat. (Ascioglu and Sevik, 2019; King and Whyte, 2006) The change in color after beef is grilled is a result of the maillard molecules that begin to form along with melanoid pigments, which are associated with grilled-meat color above the 85 °C threshold (Kondjoyan *et al.,* 2014).

Despite the positive effect of grilling on beef, grilled beef may serve as a source of carcinogenic compounds that may contribute to the formation of lung tumors (Martin *et al.,* 2015). Food safety issues are most commonly concerned with PAHs and HCAs, which are endogenous dietary carcinogens formed simultaneously during high-temperature cooking of red meat (Nor Hasyimaha *et al.,* 2020; Nor Hasyimah., 2018; Trafialek and Kolanowski, 2014; Alaejos and Afonso, 2011; Sinha and Norat, 2002). A number of epidemiological studies have linked frequent consumption of grilled meat with increased risks of malignancies (colorectal, gastrointestinal, pancreatic, prostate, and breast cancers), since dietary carcinogens are among the leading causes of human carcinogenesis (Heinen *et al.,* 2009; Trafialek and Kolanowski, 2014; Hasyimaha *et al.,* 2020)

Fig. 4.0 *Grilling meat*
Adopted from wineenthusiast.com

Fig. 5.0 *Grilled marinated meat*
Adopted from epicurios.com

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are potentially carcinogenic and mutagenic compounds which are a complex group of compounds with two or more aromatic rings cyclopentadiene rings composed of 5–6 carbon and hydrogen atoms which are formed through the pyrolysis of organic matter (protein, fat or carbohydrate) of foods at high temperatures above 150 °C, the incomplete combustion of coal, fossil fuel, wood or other fuels under reduced oxygen levels, chemical modification of oil used as cooking medium and when fat and juices from the meat drip onto the hot grill and produce smoke (Zhang *et al.,* 2022; Singh *et al.,* 2020; Sampaio *et al.,* 2021; Babu *et al.,* 2019; Hasyimah *et al.,* 2020; Chung *et al.,* 2011).

PAHs are classified into two groups based on the aromatic fused benzene rings in their structural configurations. A light PAH has 2 to 3 rings and is highly volatile and has relatively low toxicity, while a heavy PAH Has four rings or more rings and

is more stable and toxic (Baszczyk and Mielzynska-Svach, 2017). Examples of light PAHs are naphthalene, acenaphthene, fluorene, anthracene, phenanthrene, acenaphthylene whiles examples of heavy PAHs are pyrene, chrysene, benzo[a]pyrene, dibenz[a,h]anthracene, benzo[b]fluoranthene, indeno[1,2,3-cd]pyrene, benzo[k]fluoranthene, dibenzo[a,h]anthracene, benzo[g,h,i]perylene. Additionally, PAHs can be divided into groups based on their molecular mass (Hamidi *et al.*, 2016). Charcoal grilling is a traditional cooking method that increases the production of polycyclic aromatic hydrocarbons.

In grilling, the formation of PAHs depends on the type of meat, fat content, cooking conditions (method, temperature, time, equipment used, etc.), the type of fuel used, proximity to the heat source, and direct contact of food with fire (Onopiuk *et al.*, 2022; Farhadian *et al.*, 2012; Oz, 2021; Koszucka and Nowak., 2019).

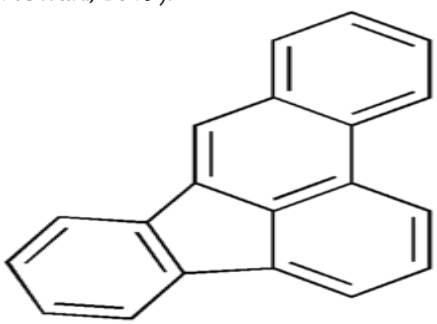

Fig 6.0 Benzo[b]fluoranthene
Adopted from Wikipedia.org

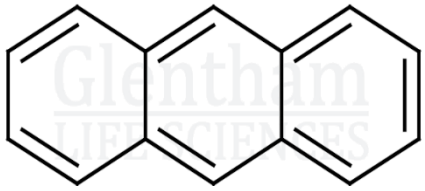

Fig. 7.0 *Anthracene*
Adopted from glentham.com

Heterocyclic Aromatic Amines

Heterocyclic aromatic amines (HAAs) are formed mostly in meat products such as beef, mutton, pork, chicken, etc., since they are rich in protein during thermal processes such as grilling, frying, boiling, and roasting. HAAs are initiated with the Maillard reaction, which reduces sugars such as glucose, free amino acids, and creatine, the precursors. HAAs are grouped into two major types: thermic Has (amino-imidazo-azaarenes (AIAs)) and pyrolytic HAAs (amino carbolines). Thermic HAAs (such as 8-MeIQx (2-amino-3,8-dimethylimidazo [4,5-*f*]quinoxaline), 4,8- DiMeIQX (2-amino-3,4,8-trimethylimidazo[4,5-f]quinoxaline), and PhIP (2-amino-1-methyl- 6-phenyl- imidazo[4,5-b]pyridine)) are formed as a result of the complex reactions that involve creatine, creatinine, free amino acids and sugars through the Maillard reaction at temperatures between 150 °C and 250 °C (Jägerstad *et al.*, 1998; Nagao *et al.*, 1977; Barzegar, 2019; Wang *et al.*, 2021), while pyrolytic HAAs (such as Norharman (9 H-pyrido[4,3-b]indole) and Harman (1-methyl-9 H-pyrido[4,3-b]indole)) are produced by the pyrolysis of proteins (Barzegar, 2019).

The formation of HAAs in food is not only influenced by the precursors in meat but also by physical factors of heat treatment, such as temperature and time, and preparation method particularly boost the formation and have a strong influence on the formation reaction of HAAs type, temperature, and duration of the thermal processes. A study by Polak *et al.* (2020) showed that, grilling carried out on a double hot plate grill with grilling temperatures of 120 °C to 280 °C and stopped when the internal temperature of 72 °C was reached had higher HAA levels observed at 260 °C compared to 240 °C, at 13.97 ng g−1, as a 68.7% increase with the highest total HAA levels found at 280 °C (29.64 ng g−1 grilled pork steak), as a 258.0% increase compared to 240 °C whiles a study also by Utyanov *et al.* (2020) found that every 5 minutes of heat treatment led to an increase of about 50% of HAAs concentration with the highest amount of HAAs formed in beef, in the same time with the lowest concentration detected in poultry.

Several health risks are associated with PAHs and HAAs and have been linked to an increased risk of cancer when consumed in large amounts (Cross and Sinha, 2004), which makes it essential to explore effective mitigation strategies. Public health and ensuring the continued enjoyment of these delicious dishes depends on identifying and implementing methods to reduce the formation of these harmful compounds in grilled beef and meat products.

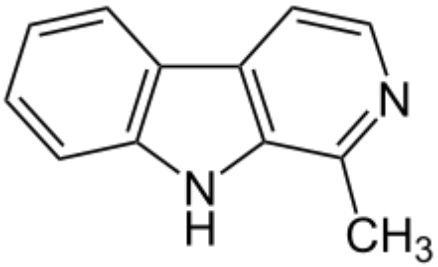

Fig. 8.0 *Harman*
Adopted from Wikipedia.org

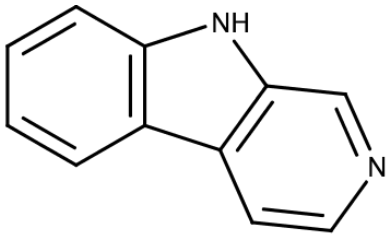

Fig. 9.0 *Norharman*
Adopted from eppigraph.genouest.org

To mitigate the formation of PAHs and HAAs in meat, several studies regarding the marination of meat have been conducted. Marinating is a traditional cooking technique mostly used to improve the flavor and tenderness of meat to satisfy consumer demand (Lemose *et al.*, 1999). Marinating is mostly done before the meat is grilled and is done by either using simple preparation of marinades or ready-to-use forms (Hasnol *et al.*, 2014; Hashim *et al.*, 1999).

Studies conducted have shown that marinating can reduce the formation of PAHs and HAAs formed during the

cooking process (Gibis, 2007). A study by Shabnam *et al*. (2017) showed that all spices/herbs in single or mixture forms used in the study were found to reduce total HCA concentrations in marinated grilled beef, ranging from 21.2% for beef marinated with curry leaf to 94.7% for the combination of turmeric and lemon grass (50:50 w/w).

Also, at the optimum marinade formula (turmeric: lemon grass 52.4%:47.6%), the concentration of 2-amino-3-methylimidazo [4, 5-f] quinolone (IQ), 2-amino-1-methyl- 6-phenylimidazo [4,5-b] pyridine (PhIP), Harman, Norharman and AαC were 2.2, 1.4, 0.5, 2.8 and 1.2 ng/g, respectively. This inhibitory activity of the herbs and spices used are rich in various phytochemicals and have been reported to inhibit HCAs formation due to their antioxidant properties. They act as a radical scavenger to trap free radicals created in different pathways of HCAs formation (Gibis and Weiss, 2012).

There is a need to focus on preventing and controlling HAAs and PAH formation in grilled meat by utilizing various strategies to avoid public health concerns and safety issues.

Boiling

It is widely believed that there is no single right temperature for cooking meat. Meat with a high collagen content (large amounts of connective tissue) will have to be cooked at above 60 °C to break down the collagen (below this temperature, collagen hardly breaks down at all). In comparison, meat with little connective tissue would be better cooked at 50 °C or less to prevent hardening. In cooking meats, Maillard reactions do not take place below 140 °C, which would be far too high a temperature for cooking.

Heat can cause proteins to lose their native conformation (denaturation) by supplying kinetic energy to the polypeptides, increasing their "thermal motion," and thus rupturing the weak intramolecular forces (such as nonpolar interaction, various types of electrostatic interaction, and disulfide bonds) that hold the proteins together. A protein begins to unfold as the temperature rises. When practically all of the tertiary and secondary structures are gone, the unfolded protein may cluster, have its disulfide bonds scrambled, suffer side-chain changes, and cross-link with other polypeptides (Yu *et al*., 2017).

According to Wasserman (1968), the exposure of meat to water when cooking results in the leaching of the water-soluble flavor precursors. The surface of the meat undergoes drastic physical and chemical changes. Initially, as the moisture on the surface is boiled away, the flavor developed would be similar to the moist heat-treated meat. However, the liquid moves from the interior to replace the surface moisture, carrying with its soluble components of the tissues. As the concentration of these compounds increases, they become involved in chemical reactions, resulting in the development of changing flavor and color spectra. With increasing temperatures, the fat melts and covers the entire surface. The decomposition products formed react with the other meat components or contribute their flavors to the overall flavor. Free sugars, sugar phosphates, nucleotide-bound sugars, free amino acids, peptides, nucleotides, and other nitrogenous components, such as thiamine, have been proposed as the principal water-soluble flavor precursors. During heating, carbohydrates and amino acids are reduced, with cysteine and ribose losing the most (Jayasena *et al*., 2013).

According to Wasserman (1968), the protein chain unfolds when meat is heated to around 70 °C, revealing buried -SH groups. Further heating to roughly 110 °C causes oxidation of the -SH groups to -S-S- connections, which results in a loss in meat softness. The formation of H_2S from the -SH groups begin at about 80 °C and increases exponentially with increasing the temperature and heating time. These -SH groups are part of the structural protein and do not arise from water-soluble exponents.

The amount of H_2S evolved is a function of the pH of the meat and consequently indicates the animal's nutritional and emotional status. It is now widely known that the flavor precursors are water soluble (Batzer *et al*., 1960) and that the aroma components will be located among these extractives. This means that when meat is overcooked, flavor precursors are leached into the water, diminishing the flavor of the meat. When the sugars in the flesh are heated, they caramelize, altering the color from colorless to hues of amber and brown to a black carbonized mass. The odor transforms from sweet to bitter and caustic as the bitterness and acidity increase (Wasserman,1968). During cooking, a complex series of thermally induced interactions between non-volatile components of lean and fatty tissues occur, resulting in many reaction products. Although taste components influence the flavor of cooked meat, the volatile compounds produced during cooking determine olfactory attributes and contribute the most to the distinctive flavors of meat (Hwang *et al*., 2012). According to Mottram (1998), a comparison of boiled and roast beef shows that many more aliphatic thiols, sulfides, and disulfides have been reported in boiled meat.

Fig 10.0 *Cooking meat Adopted from yourcookingbuddy.com*

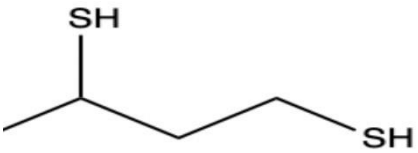

Fig 11.0 *Thiol group Adopted from ChemTalk*

Fig 12.0 *Cooked meat Adopted from RecipeVibes*

Roasting

Roasting meat is one of the most popular cooking methods globally. This cooking method is a typical high-temperature cooking method that enhances the color and flavor of meat through caramelization and Maillard reaction (Chao *et al.,* 2021). The Maillard reaction is sometimes referred to as non-enzymatic browning, and causes the distinctive brown color of roasted meat, as well as the flavor and taste (Shahidi *et al.,* 2014). Roasting depends on the type of meat and the roasting time and temperature (Suleman *et al.,* 2022). During roasting, the temperature can reach 200 °C–220 °C, but the temperature usually employed for slow roasting is 160 °C while at 170–180 °C (Roldan *et al.,* 2013). In the roasting process, several flavor precursors degrade and react with one another to generate various volatiles (Dashdorj *et al.,* 2015). In general, the reactions involved in this process are lipid oxidation, the Maillard reaction, and their interactions (Wang *et al.,* 2022a).

Compared to other processing techniques, roasting increases lipid oxidation because it employs high temperatures for longer periods. Grilling, however, seems to have less impact on lipid oxidation than other cooking techniques (Dominguez *et al.,* 2014). Lipid is an important precursor in these reactions, and their reaction products are important contributors to the special flavor of meat (Mottram, 1998). The oxidative degradation of unsaturated fatty acids produces most of the key aroma-active chemicals, such as aliphatic aldehydes, ketones and alcohols (Jayasena *et al.,* 2013; Duppeti *et al.,* 2022). Furthermore, interactions between the products of lipid oxidation and the Maillard reaction (Sohail *et al.,* 2022) can result in the formation of heterocyclic compounds, like furans, pyrazines, thiophenes, thiazoles, and pyridines with alkyl substituents, presenting a modified and species-specific overall aroma of cooked meat. Roasting meat induces protein denaturation, thus altering the structure of beef proteins.

This denaturation increases the digestibility of proteins, making it easier for the body to absorb during digestion. Goluch *et al.* (2021) thoroughly investigated the effect of various types of thermal processing techniques viz a viz pan frying, water bath cooking, grilling, and oven convection roasting on goose breast meat's nutritional composition and energy. Out of all these techniques, oven convection roasting stood out in terms of lowest energy value and retention of the highest nutritional content with respect to fat and essential minerals such as phosphorus and sodium. Roasted chicken products are particularly popular among consumers because of a unique processing procedure that can result in the development of several chemicals giving the meat an attractive color, distinctive flavor, and an appealing aroma and taste (Wang *et al.,* 2021a; Moreira *et al.,* 2019).

Similar to deep frying, the flow of dry air from the combustion of coal or charcoal in oven-roasted samples leads to surface water evaporation, causing the surface to dry and form harmful compounds such as acrylamides, PAHs and HAAs, accompanied by the aggregation on the meat surface (Modzelewska-Kapituła *et al.,* 2012) HAAs are potent mutagens and carcinogens that have been linked to an increased risk of several kinds of cancer in humans. Owing to their widespread presence in cooked food items and their potential health effects, HAAs have become an important area of research in toxicology, food science, and public health (Barzegar *et al.,* 2019; Bellamri *et al.,* 2021).

Significance of water in roasting of meat

Water has a profound impact on some sensory properties of meat and meat products, such as juiciness, texture, color and flavor (Guo *et al.,* 2020; Shao *et al.,* 2016a; Shao *et al.,* 2016b) Studying the changes in moisture and aroma during the roasting process of chicken is of great significance for better controlling the industrial production of roasted chicken. During the heating process, the aroma intensity of meats increases. Water has a larger specific heat capacity than meat and air. Water loss occurs in the samples throughout the heating process, diminishing their specific heat capacity per unit mass. This may result in a quicker heating rate in samples with the same heat per unit time and faster production of aroma compounds (Liu *et al.,* 2022).

Water transfer greatly influences meat quality (Feyissa *et al.*, 2011; Gianfrancesco *et al.*, 2012). In an experiment conducted by Kondjoyan *et al.* (2014) to explore the effect of roasting on a chicken, it was observed that when the roasting time further increased, the surface of the chicken became dry due to the evaporation of water caused by heating, resulting in greyish and darker colors, and the L^* value of the chicken decreased. Caramelization and the Maillard reactions happen throughout the roasting process as roasting time increases.

Fig. 13. *Roasting meat*
Adopted from gettyimages.com

Fig. 14. *Roasted meat*
Adopted from simplyrecipe.com

Conclusion

Meat serves as a valuable source of essential nutrients in human diets. The cooking methods employed significantly influence its nutritional quality and safety. Frying, grilling, boiling, and roasting, although enhancing flavor and texture, also pose risks due to the formation of carcinogenic compounds such as heterocyclic aromatic amines (HAAs) and polycyclic aromatic hydrocarbons (PAHs). These compounds are known to increase the risk of various cancers upon consumption. To reduce the level of these carcinogenic compounds, meat should be marinated before cooking. Reducing processing temperature, time and fat content of meat can also help reduce the level of these carcinogenic compounds.

Promoting awareness among consumers about the risks associated with certain cooking methods and advocating for safer practices in meat preparation are crucial steps towards ensuring the continued enjoyment of meat while safeguarding human health. Furthermore, research into novel approaches to reduce carcinogen formation while preserving meat's sensory properties is essential for public health.

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NUCLEIC ACIDS AND NUCLEOTIDES

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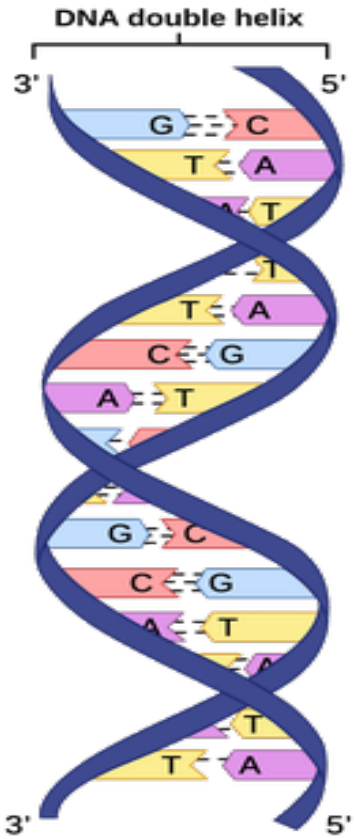
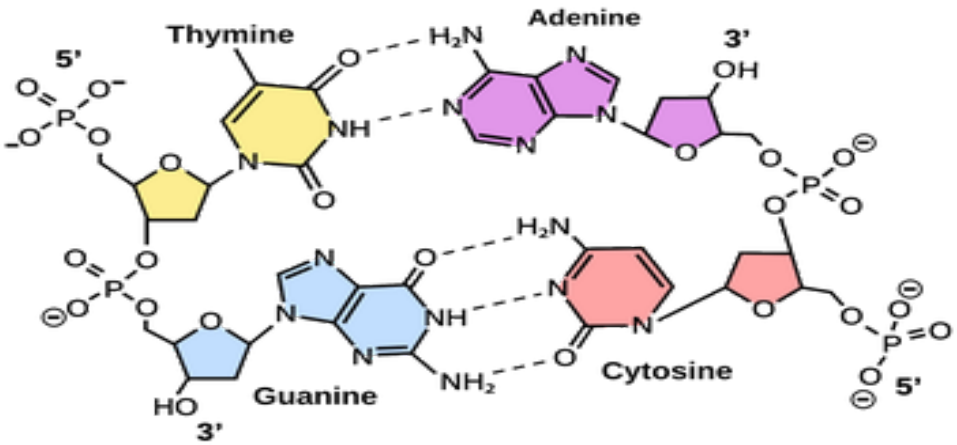




Background

Nucleic acids are macromolecules that transmit genetic information. They are mainly found in the nucleus but also in the cytoplasm. There are two types of Nucleic acids: DNA, deoxyribonucleic acids, and RNA, ribose nucleic acids.

DNA and RNA differ structurally from the sugar unit and nitrogenous base. The sugar unit in DNA is deoxyribose, while RNA's is ribose. The purine bases in both DNA and RNA are adenine and guanine. The pyrimidine bases are cytosine and thymine in DNA, but those of RNA are cytosine and uracil. In addition to these structural differences, DNA is double-stranded, while RNA is single-stranded.

The nucleotide is the basic unit of nucleic acids. Nucleotide consists of a pentose sugar, a nitrogenous base, and a phosphate group covalently linked. There are two types of purine bases: adenine and guanine. The pyrimidine bases are cytosine, thymine, or uracil.

Structure of DNA

DNA is a double-stranded helix with nitrogenous bases in the center and sugar and phosphate forming the backbone on the outside. Hydrogen bonds hold the two strands together. The chain runs in an anti-parallel direction, one in the 5' - 3' direction and the other in the 3' - 5' direction. Adenine pairs with thymine, and guanine pairs with cytosine. Adenine – Thymine is held by two hydrogen bonds, while Guanine – Cytosine is held by three hydrogen bonds. This structure of DNA was proposed by Watson and Crick in 1953.

Functions of DNA

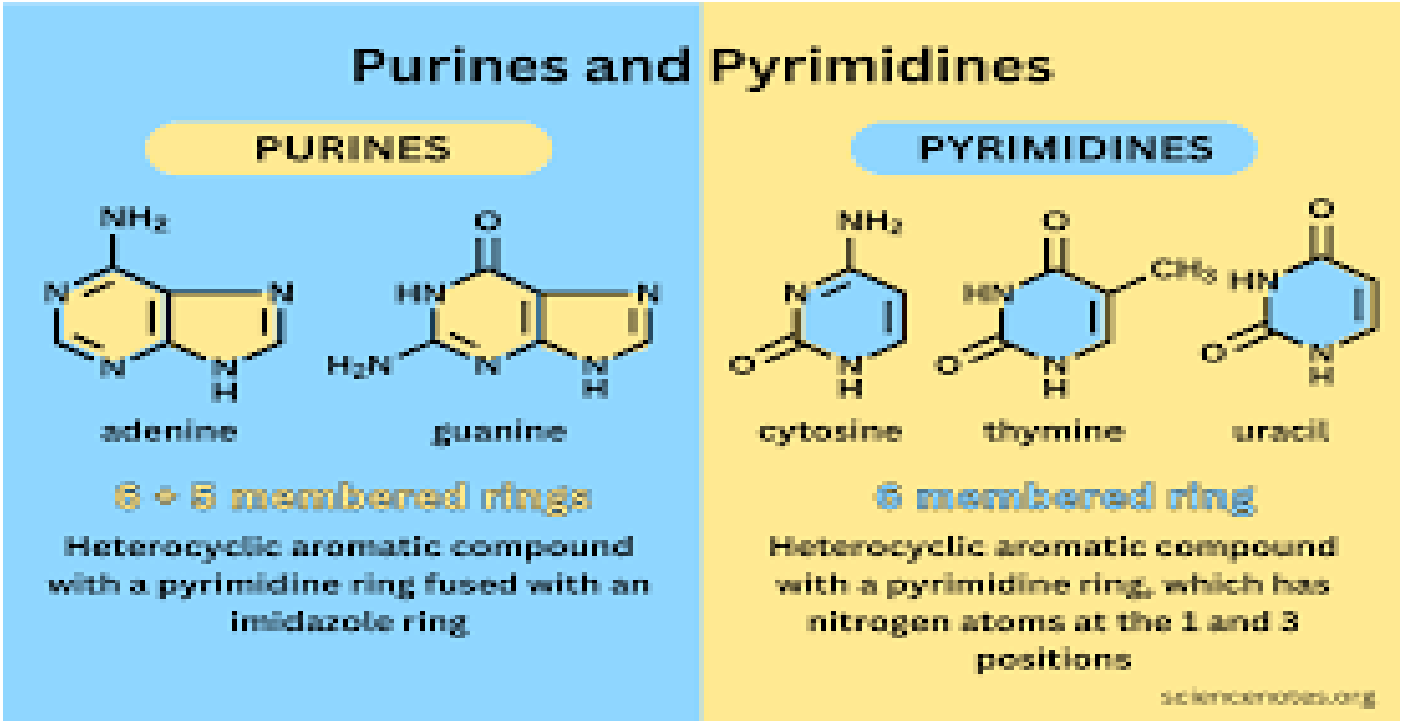
1. DNA is the carrier of genetic information
2. The sequence of bases in the DNA determines the nature and quantity of protein in a cell.

RNA

RNA, like DNA, is also a macromolecule made of nucleotides, but unlike DNA, RNA is single, a stranded molecule. There are three types of RNA: tRNA, rRNA, and mRNA. They are all involved in protein synthesis.

tRNA

tRNAs are the smallest of RNAs in the cell. There are 20 different types for each amino acid found in proteins. tRNAs are responsible for transferring proteins to ribosomes for assembly into proteins. The triplets of bases on the tRNA form complementary pairing with codons on an mRNA on the surface of ribosomes during protein synthesis. tRNAs make up about 15 % of RNA in the cell.



rRNA

They are larger molecules and the most abundant RNA in the cell. In both prokaryotes and eukaryotes, mRNAs consist of 2 subunits, a smaller and a larger sub-unit. It is the site of protein synthesis and is associated with several proteins.

mRNA

They are the least abundant of the mRNAs. It comprises 5-10 % of cellular RNAs and has the highest turnover of the 3 RNAs. The sequence of bases in the mRNA determines the order of amino acids in a protein, which, in turn, reflects the sequence of bases in the DNA codes of that particular protein.

MYTH: ALL FATS ARE UNHEALTHY

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Source: https://www.reliancehospitals.com/

For years, dietary myths have perpetuated the idea that all fats are detrimental to our health. This myth led to the fear of fats and the rise of low-fat diets. However, science has revealed a more nuanced reality - not all fats are created equal. In reality, fats play diverse roles in the body, and some are essential for overall well-being. Fats, in the form of triglycerides, serve as a concentrated source of energy that the body can access when needed. Dietary fats function as structural components in cell membranes, supporting the development of the brain, bones, vision, and the immune system.

Fats carry fat-soluble vitamins (A, D, E, K), facilitating their absorption and utilization by the body (Kono & Arai, 2014).

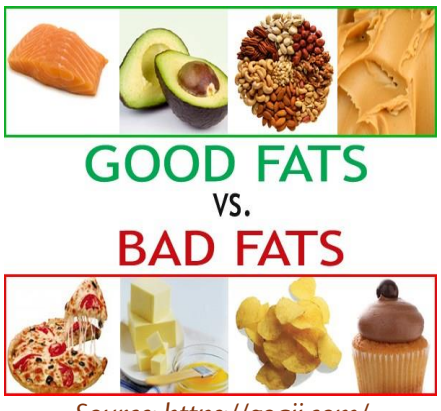
Different Types of Fat

Source: https://theteenagertoday.com/

Saturated Fats:

Saturated fats are commonly found in animal products such as meat, dairy, and eggs. Additionally, some tropical oils like coconut oil and palm oil also contain high amounts of saturated fats (Boateng et al., 2016). Excessive consumption of saturated fats has been associated with an increased risk of heart disease.

These fats can raise levels of low-density lipoprotein (LDL) cholesterol, often referred to as "bad" cholesterol. High levels of LDL cholesterol can contribute to the buildup of plaques in the arteries, leading to atherosclerosis and an increased risk of cardiovascular diseases (Siri-Tarino et al., 2010).



Source: https://goqii.com/

Trans Fats:

Trans fats are artificial fats created through the process of hydrogenation, which turns liquid oils into solid fats. They are commonly found in partially hydrogenated oils used in many processed and fried foods, such as certain baked goods, snacks, and fried fast foods (Monoj, 2017) Trans fats are considered the unhealthiest type of fat. They not only raise LDL cholesterol levels but also lower high-density lipoprotein (HDL) cholesterol, often referred to as "good" cholesterol. This double impact on cholesterol levels significantly increases the risk of heart diseases.

Source: https://drkellyann.com/

Monounsaturated Fats:

Monounsaturated fats are found in various foods, with notable sources including avocados, olive oil, nuts (such as almonds and peanuts), and seeds (such as sesame seeds). When consumed in moderation, monounsaturated fats have been associated with several health benefits. They are known to have a positive impact on heart health by helping to lower levels of low-density lipoprotein (LDL) cholesterol, the "bad" cholesterol. Additionally, they may contribute to an increase in high-density lipoprotein (HDL) cholesterol, the "good" cholesterol, which helps remove LDL cholesterol from the bloodstream.

Polyunsaturated Fats:

Polyunsaturated fats include essential fatty acids such as omega-3 and omega-6 fatty acids (Caramia, 2008). These fats are termed "essential" because the body cannot produce them and must obtain them from diet. *Omega-3 Fatty Acids:* found in fatty fish (like salmon, mackerel, and sardines), flaxseeds, chia seeds, walnuts, and certain algae. *Omega-6 Fatty Acids:* found in vegetable oils (such as soybean oil, corn oil, and sunflower oil), nuts, and seeds. Both omega-3 and omega-6 fatty acids play crucial roles in the body. Omega-3s, for example, are known for their anti-inflammatory properties and are associated with heart health, brain function, and joint health. Omega-6 fatty acids are important for growth and development and are involved in the inflammatory response. It's important to maintain a balance between omega-3 and omega-6 fatty acids in the diet.

The Importance of Good Fats

Monounsaturated and polyunsaturated fats, especially omega-3 fatty acids, can reduce the risk of heart disease by lowering bad cholesterol levels and improving overall cardiovascular health. Moreover, fats, particularly omega-3s, are essential for proper brain development and function. They can enhance cognitive function and reduce the risk of neurodegenerative diseases. Also, Fats are crucial for the structure and function of our cells. They aid in nutrient absorption; help build cell membranes and contribute to various physiological processes. Lastly, dietary fats provide a concentrated energy source aiding in sustained endurance during physical activities.

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WHY BLOOD IS NOT ALWAYS RED

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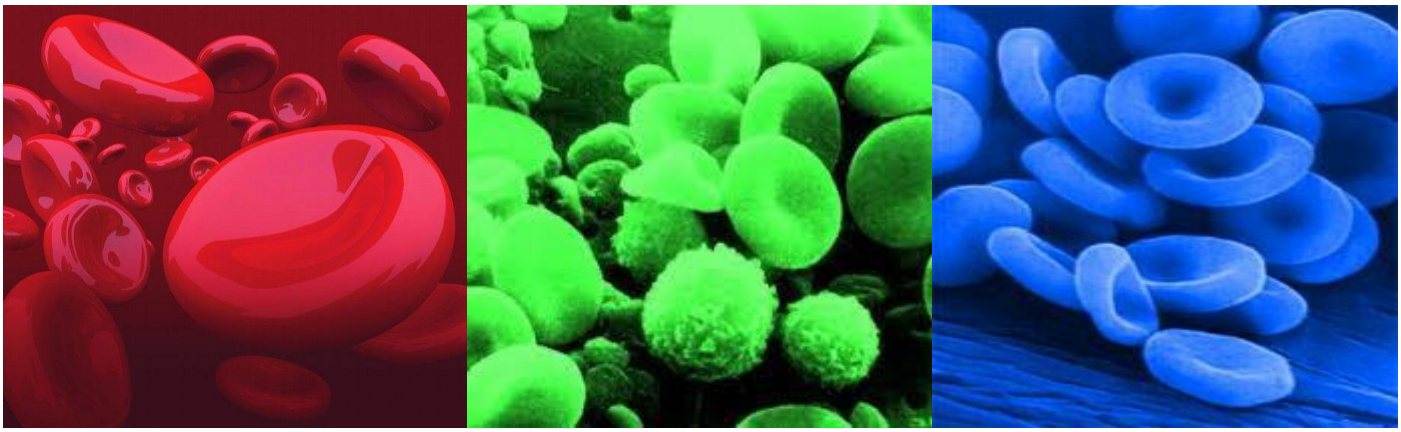
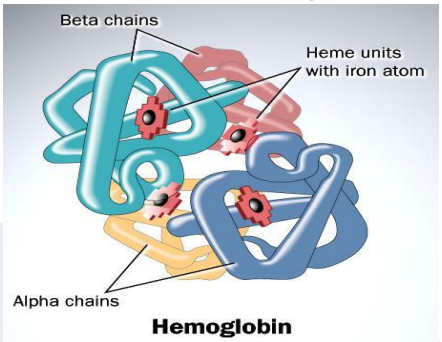


Imagine if you cut yourself and saw purple blood gush out of your skin. Now that will be the start of an alien invasion or another sign of the end times. If you're lucky to have the experience indoors, you'll save yourself the 'witch hunt' from the public. However, this may not be as strange as you think because blood is not always red.

Don't be alarmed if you come across green, blue, and even purple blood. The colour of blood is to do with the compound that transports oxygen around the body. For most mammals and vertebrates, this is haemoglobin. Haemoglobin is a protein made up of four chains known as globins, and at the centre of each globin is a molecule called haem, which contains iron.

In simple terms:

(2 alpha globins + 2 beta globins) + Haem/Iron = Haemoglobin



Hemoglobin

It is the iron at the centre of the globin chains that give blood its red colour and the intensity of the redness varies based on the interaction with oxygen. Haemoglobin carries Oxygen from the lungs to the tissues through the arteries and transports Carbon dioxide back from the tissues to the lungs through the veins. **The reaction of Oxygen with iron causes the redness**. Oxygenated blood in the artery is, therefore, bright red, whereas deoxygenated blood in the vein is dark red.

Why blood is not always red

When the iron at the centre of the haemoglobin molecule is replaced by a different molecule or interactions with the haemoglobin and certain drugs causes a change in the normal form of the iron molecule, this can cause a change in the colour of blood from red to another colour.

For example, a drug called sumatriptan which is used as a treatment for migraine contains sulphur which causes the blood of some people on the medication to go green due to the interaction of the sulphur with the iron. The condition is known as Sulfhemoglobinemia and, although rare, has been reported in some individuals.

In most species of octopus, some crabs, and other crustaceans, the blood-carrying molecule is hemocyanin with a copper-rich center, and the interaction of the copper with oxygen gives their blood a blue colour. In the absence of oxygen, the blood is colourless.

Lobsters, earthworms, and leeches have green blood. Their oxygen-carrying molecule is known as **chlorocruorin**. Also, with an iron centre, the interaction with oxygen gives the blood a green colour which turns light green when deoxygenated.

Some worms have another type of haemoglobin known as haemerythrin. In addition, with an iron centre, the difference in structure means the interaction with oxygen makes their blood purple and in the absence of oxygen this turns colourless.

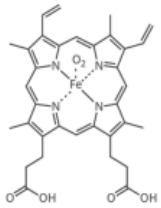
As you can see, blood is not always red and the infographic below nicely summarises the chemistry behind the colour of blood. Thanks to CompoundChem for the infographic.

THE CHEMISTRY OF THE DIFFERENT COLOURS OF BLOOD

Red

HUMANS AND THE MAJORITY OF OTHER VERTEBRATES

HAEMOGLOBIN



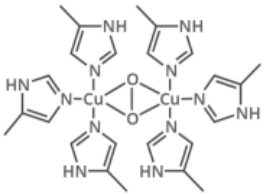
HAEM B
(oxygenated form)

Haemoglobin is a protein found in blood, built up from subunits containing 'haems'. These haems contain iron, and their structure gives blood its red colour when oxygenated. Deoxygenated blood is a deep red colour - not blue!

Blue

SPIDERS, CRUSTACEANS, SOME MOLLUSCS, OCTOPUSES & SQUID

HAEMOCYANIN



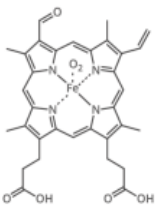
HAEMOCYANIN
(oxygenated form)

Unlike haemoglobin, which is bound to red blood cells, haemocyanin floats free in the blood. Haemocyanin contains copper instead of iron. When deoxygenated, the blood is colourless, but when oxygenated, it gives a blue colouration.

Green

SOME SEGMENTED WORMS, SOME LEECHES, & SOME MARINE WORMS

CHLOROCRUORIN



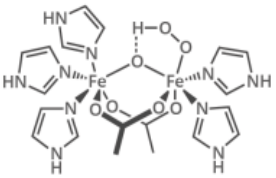
CHLOROCRUORIN
(oxygenated form)

Chemically similar to haemoglobin; the blood of some species contains both haemoglobin & chlorocruorin. Light green when deoxygenated, it is green when oxygenated, although when more concentrated it appears light red.

Violet

MARINE WORMS INCLUDING PEANUT WORMS, PENIS WORMS & BRACHIOPODS

HAEMERYTHRIN



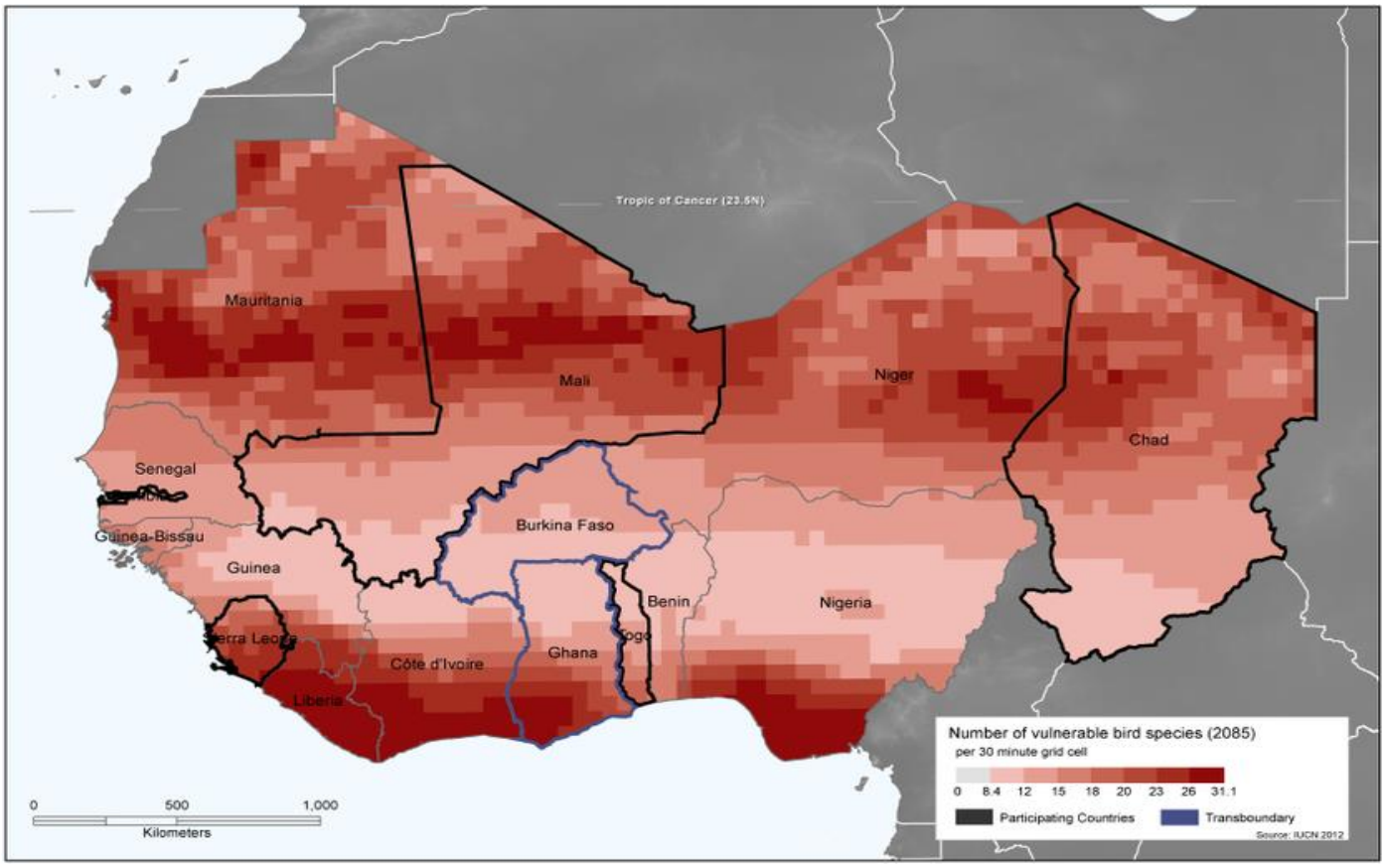
HAEMERYTHRIN
(oxygenated form)

Haemerythrin is only 1/4 as efficient at oxygen transport when compared to haemoglobin. In the deoxygenated state, haemerythtin is colourless, but it imparts a violet-pink colour when oxygenated.

UNDERSTANDING CLIMATE CHANGE AND ITS IMPACT ON LIVELIHOODS IN WEST AFRICA

Wendy Enyinnaya

Institution: *University of Ghana*



What Is Climate Change?

This article discusses how climate change affects West African communities, especially agriculture and the economy. It explores how the region is vulnerable to climate change and discusses the different impacts it has. The article also highlights the strategies to adapt and mitigate these effects. It emphasizes the importance of working together for a secure and resilient future for West Africa.

Climate change, characterized by long-term changes in Earth's atmospheric conditions, presents significant challenges on a global scale. This article focuses on its specific impact on West Africa, where human activities contribute to the accumulation of greenhouse gases, resulting in global warming. The subsequent changes in temperature, precipitation, and extreme weather events have far-reaching consequences for ecosystems and human societies.

This article synthesizes information from scientific literature, reports from international organizations, and statements from experts in climatology and agriculture. Statistical data on temperature fluctuations, rainfall patterns, and economic indicators in West Africa are analyzed to comprehensively understand the situation.

Climate Change in West Africa:

The region's heavy reliance on agriculture and natural resources makes it particularly vulnerable to the impacts of climate change. Shifts in temperature, altered rainfall patterns, and an increase in extreme weather events, such as droughts and floods, are key characteristics of climate change in West Africa. The United Nations has acknowledged the seriousness of climate change and its repercussions. The Intergovernmental Panel on Climate Change (IPCC) has issued a warning that if global temperatures continue to rise, West Africa will experience more frequent and severe droughts, floods, and heat waves. These events disrupt agricultural activities, making it increasingly difficult for farmers to predict growing seasons and harvests.

The United Nations' Sustainable Development Goals (SDGs) highlight the importance of addressing climate change and its impacts. Goal 13 specifically focuses on climate action, urging countries to take immediate measures to combat climate change and its effects.

Prominent researchers stress the urgency of addressing climate change. Renowned climatologist Dr. James Hansen states, "Climate change is here, it is dangerous, and it is growing more severe every day." This sentiment reflects the urgency expressed by many in the scientific community.

West African communities are already feeling the real effects of climate change. Coastal regions are facing rising sea levels, which threaten homes and infrastructure. The increased frequency and intensity of extreme weather events disrupt lives and worsen existing challenges in healthcare, education, and economic development.

Nobel laureate Wangari Maathai once said, "The higher the temperature, the more nature will be affected. So, we need trees for the world to be cool." This emphasizes the importance of preserving natural habitats, including the rich biodiversity in West Africa, to lessen the impacts of climate change.

Adapting to these changes is crucial for the livelihoods of West Africans. This involves implementing sustainable agricultural practices, investing in resilient infrastructure, and promoting education on climate-smart techniques. Local communities, along with national and international efforts, play a vital role in building resilience and lessening the impacts of climate change.

Effects on Agriculture:

Agriculture, a fundamental aspect of West African livelihoods, faces disruptions in traditional practices. Variability in rainfall induces water scarcity, impacting rainfed and irrigated agriculture. Elevated temperatures contribute to the proliferation of pests and diseases, making crucial crops vulnerable.

Impact on Water Resources:

Changes in precipitation patterns and increased evaporation rates challenge water availability. Rising sea levels lead to saltwater intrusion, jeopardizing freshwater resources and threatening coastal communities' access to clean water.

Economic Impacts:

The economic ramifications of climate change are profound, with agricultural losses and adaptation costs straining vulnerable economies. Smallholder farmers, constituting a significant portion of the population, are particularly affected.

Adaptation and Mitigation Strategies:

West African nations are implementing strategies such as sustainable land management, water resource management, and promoting climate-resilient crops. Diversification of livelihoods improved early warning systems, and enhanced infrastructure resilience against extreme weather events are also underway.

In conclusion, urgent and collaborative efforts are essential to mitigate the significant threats posed by climate change to West African livelihoods. Governments, international organizations, and local communities must come together to implement sustainable strategies that address the unique challenges in the region. By fostering resilience and implementing effective measures, we can ensure a more secure and resilient future for West Africa.

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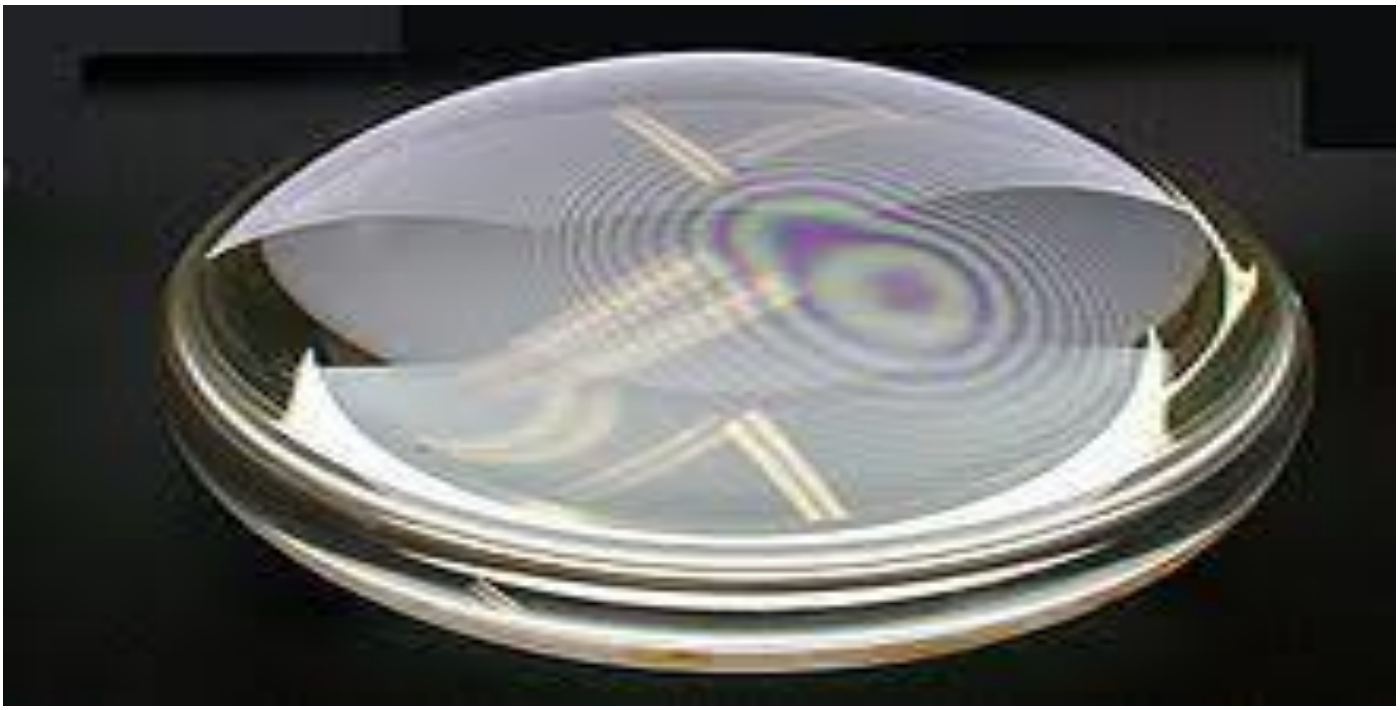
ISAAC NEWTON AND WHAT COLOR IS?

Andrew Lartey
Institution: *University of Ghana Medical School*



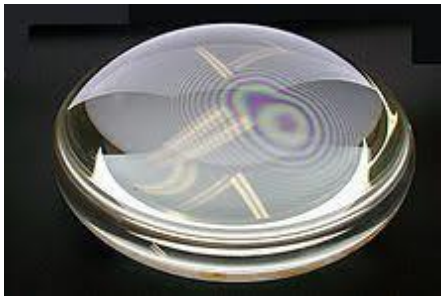
In 1665, Isaac Newton completed his studies at Trinity College, but the severe plague outbreak compelled him to seek refuge in the countryside. Confined to a family farm, Newton seized the opportunity to delve into mathematics, motion, and light. While some ancient thinkers, including Plato and certain Presocratics, once believed that light originated from the eyes, Aristotle challenged this notion, asserting that colors were a fusion of light and darkness. By Newton's era, a more lucid understanding was taking shape, and philosophers were actively shaping the refined science of optics.

In understanding the behavior of light, scholars have established that when it encounters a mirror, the angle at which it strikes equals the angle at which it reflects. Furthermore, when light travels across a transparent medium and returns to the air, it undergoes bending or refraction.

In his essay "Dioptrics," French philosopher René Descartes put forth a speculative idea suggesting that the origin of color arises from spinning globules of aether, with faster rotations resulting in redder light. Another prominent figure in this exploration was Robert Hooke, a distinguished European scientist succeeding Descartes. Renowned for his skillful manipulations of nature, Hooke served as the first curator of experiments for the Royal Society of London. Hooke confidently asserted his understanding of color and light, describing blue as an impression on the retina caused by an oblique and perplexing pulse of light, where the weakest part precedes and the strongest follows.

Experiments by Isaac Newton

Carefully examining existing knowledge and adding his insights, Isaac Newton approached the world as if seeing it for the first time, like a blind person gaining sight. He made a fascinating observation that dark or semi-transparent substances appeared lighter when ground into powder or shaved due to the multitude of reflective surfaces created in the process. Newton experimented by placing a flat lens against one with a gently curved surface, creating a mesmerizing pattern of colorful swirls known as Newton rings.



Newton Rings by Isaac Newton

Adjusting the lenses, he noted that the colored circles grew or shrank based on how closely they were pressed together, and new circles emerged in the middle. Newton then took his apparatus into a room and exposed it to a blue ray from a prism, revealing a monochromatic display of dark and light circles. While Hooke had previously described a similar phenomenon, Newton delved deeper, making it uniquely his own.

Isaac Newton's fascination with the subject intensified, leading him to conduct personal experiments using

a thin, blunt probe known as a bodkin. He meticulously inserted the bodkin and pressed it against his eyeball, observing the emergence of various white, dark, and colored circles. Repeating the experiment in daylight, with nearly closed eyes, Newton witnessed a significant, wide, bluish-dark circle with a smaller, brighter spot at its center. This personal exploration added a hands-on dimension to Newton's study of optics, providing him with unique insights into the patterns and colors perceived through direct manipulation.

Isaac Newton proceeded to delve into the anatomy of the eyes, realizing that visual vibrations travel through the optic nerves to reach the brain. He dissected the tissues around an animal's eye to understand the substance carrying these visual imageries. While some believed that animal spirits were responsible for this process, Newton conducted an experiment that ruled out such a notion. In his pursuit of eliminating the possibility of animal spirits, Newton, driven by curiosity, created a small circular hole in his window shutter one day. Using a prism in the path of a sunbeam, he projected a spectrum onto the darkened room's far wall, describing the experience as initially delightful due to the vivid and intense colors. Repeating the experiment ensured that his observations were not influenced by accidental factors, as he consistently obtained the same array of colors when placing the prism in various positions.

These experiments led to a surprising conclusion for Isaac Newton as he embarked on what he termed his Experimentum Crucis. By this point, he likely had a sense of what to expect. In one of his experiments, Newton projected the spectrum onto a wooden board, drilling a hole to allow each color to pass through the prism individually. Progressing from red to blue, each color exhibited increasing bending, leading Newton to articulate that "light consists of rays differently refrangible." Once separated, a color remained unalterable, challenging the prevailing belief that colors were quantifications of light derived from the refraction or reflection of natural bodies.

Differentiation of white light by Isaac Newton

Isaac Newton returned to Cambridge and ascended to the prestigious position of Lucasian Professor of Mathematics, where he delivered lectures on color and light. His compact yet more powerful inventions than conventional telescopes impressed the Royal Society. In 1672, the society published Newton's paper "New Theory About Light and Colour" in the Philosophical Transactions. However, Hooke attempted to undermine Newton's work, asserting that he had already conducted similar experiments with results explainable by his theory.

Isaac Newton's Legacy

In the present era, Newton's comprehension of the light spectrum became the basis for spectroscopy, a vital tool in fields like chemistry and astronomy. His findings also impacted colorimetry, crucial in photography and digital imaging. Moreover, his optical principles contributed to progress in designing lenses, optical instruments, and technologies like fiber optics, LEDs, and digital imaging devices. In summary, Isaac Newton's contributions remain highly influential in developing various technologies related to light and color.

WHAT MORE COULD THERE BE TO MENSTRUAL CRAMPS AND DISCOMFORT BESIDES AN IMPENDING (BLOOD) FLOW?

Faith Akor Ene

As a young lady, a certain Madam Lydia Quaye, the only daughter in a staunchly religious family, was regularly bedridden and prayed for during her period. Her mother would pass on before Lydia had her menarche at 12 years old. A menarche is the very first menstruation in a young girl's life. Her loved ones believed Lydia exaggerated whenever she complained of excruciating menstrual pains. It was not until after marriage at 25 that Lydia found the reason for her irregular and painful periods, which ultimately led to her frequent visits to the hospital. With Lydia being unable to conceive nor carry a pregnancy through term, she and her husband tried all they could with religious directives until they eventually sought medical advice. After a series of tests and medical exams, it was discovered that Lydia suffered from Endometriosis and Polycystic Ovarian Syndrome (PCOS). Upon receiving adequate medical assistance, Lydia finally had her children to hold.

Like Lydia, many women of childbearing ages (between 12 to 52 years) endure years of painful, heavy bleeding on the assumption that it is a normal menstrual symptom. According to Women's Health Concern, a staggering 80% of women would experience some type of menstrual discomfort at certain stages in their lifetime. In about 5% to 10% of this number, the pain is severe and could be fatal. In another study conducted out of 200 students in the School of Medical Sciences, University of Cape Coast (UCC) Ghana, 74% of them (148 women) reportedly experienced unbearable menstrual pain. Nonetheless, it is imperative to know that not all pain, irregularity, and discomfort around the menstrual period are just because of an impending flow; there could be more to the dreadful experience. As further studies show, many conditions could be the reason for the above problems associated with the menstrual cycle.

Endometriosis and Polycystic Ovarian Syndrome (PCOS)

This article focuses on two common but unpopular conditions known as Endometriosis and Polycystic ovarian syndrome (PCOS), which could contribute to irregularity, excessive pain, and heavy blood flow during that time of the month. In some instances, PCOS could result in the absence of menstruation altogether. Due to the similar nature of Endometriosis to PCOS and vice versa, their symptoms often appear to be very closely related, making it easy to confuse the two. This could result in misdiagnosis, especially

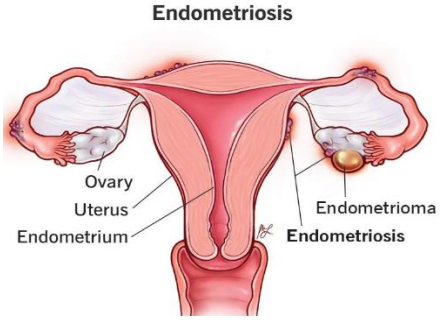
when one is self-diagnosing. However, establishing a fine line between them, as well as the right time to seek medical attention if or when necessary, is how to win.

What Makes Endometriosis and PCOS Similar?

Both conditions share a few similarities, such as:

- causing lower abdominal pain or cramping,
- excessive blood flow during menstruation
- causing difficulty with conceiving.
- having an unknown cause
- occurring in about 10% of women worldwide

Endometriosis



Endometriosis happens when the tissue that lines the inside of your uterus or womb, known as endometrium, grows elsewhere in the body, such as the fallopian tube, ovaries, or outside of the uterus. According to an article from the International Journal of Environmental Research and Public Health, it is usually diagnosed in about 20% to 90% of women who experience chronic pelvic pain or infertility issues. It is caused by excessive production of Estradiol, which is a hormone in your body.

Symptoms Of Endometriosis

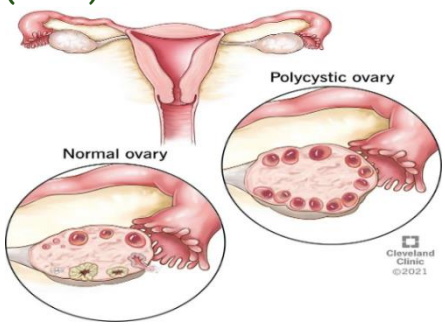
Symptoms commonly associated with endometriosis include:

- bleeding between your periods,
- having excessive pelvic pain before and during your periods,
- experiencing pain during and after sex,
- pain during urination or bowel movements
- frequent fatigue and low energy
- infertility

Foods To Avoid with Endometriosis

- Gluten
- Dairy products such as milk from goat and sheep
- Alcoholic beverages

Polycystic Ovarian Syndrome (PCOS)



PCOS is also a chronic disease that can lead to pain and discomfort during menstruation and as well cause menstruation and ovulation to cease. It occurs when there is an instability in the regulation of your body's reproductive hormones, especially when there is excessive production of androgens by the ovaries. It is primarily a hormonal disorder in women.

Symptoms of Polycystic Ovarian Syndrome (PCOS)

Some characteristics typically associated with polycystic ovarian syndrome are:

- causes growth of hair in areas where men typically grow hair. For example, chin and chest.
- infertility
- excessive menstrual pain
- pelvic pain
- no or irregular periods
- no or unpredictable ovulation
- presence of polycystic ovaries during an ultrasound scan on one or both ovaries.

PLEASE NOTE: It is also possible to have PCOS without cysts on the ovaries...

Foods To Avoid with Polycystic Ovarian Syndrome (PCOS)

- Soy milk or Soy products
- Seed oils such as vegetable oil, sunflower oil, canola oil, soybean oil, rapeseed oil, safflower oil, amongst others
- Processed foods like junk food, toffees, canned foods like tuna and sardines, biscuits, cornflakes, etc.
- Coffee

What Then, Do I Eat?

To greatly reduce the troubling side effects of Endometriosis and Polycystic Ovarian Syndrome (PCOS) over time, lean towards more leafy vegetables and oils such as:

- Kontomire
- Avocado pear
- Carrots
- Lettuce and Cabbage
- Extra virgin oil and Peanut butter
- Lemon and Lime, amongst other healthy local options.

What To Keep in Mind

Visit your doctor to seek medical attention when you experience some or all the symptoms mentioned above. Remember that early detection is key to combating endometrial and PCOS issues. With food and other lifestyle choices,

endeavor to play it safe by sticking to all kinds of originally organic foods and even better, seeking the services of a certified nutritionist or dietician is your best bet. Till next time!

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