Plant and Animal physiology

By Rémi RAKOTONDRADONA
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Introduction

This is a third year university level course for distance learning.

It is mainly intended for high school and college teachers who desire to not only improve their knowledge of the subject but also to use ICT technology in their teaching.

We strongly recommend this course to students who wish to pursue a teaching career. The incooperation of ICT in preparation of this module allows for its worldwide utilisation. The module will be updated on a regular basis by its author as approved by AVU administration.
I. Plant and Animal Physiology

By Rémi Rakotondradona

II. Prerequisites/Required Knowledge

The students must have passed courses in plant and animal biology. Background knowledge of plant and animal cell organization and function is mandatory. Basic knowledge of hormones is also required.

III. Time

120 hours divided between theory, tutorials and evaluation.

- 20 hours for homework
- 20 hours for tutorials
- 20 hours for links and reference consultation
- 20 hours for projects
- 40 hours for formative and final evaluation

IV. Materials (ressources)

http://www.fotosearch.fr/PHC006/73013870/

CD Rom
The computer and add-ons
Simulation software

V. Importance of the Module

This unit is part of a university biology course for 3rd-year students. It is meant to facilitate understanding of physical and biochemical processes that occur in living organisms right from cell level to whole plant and animal body.

For convenience, the unit is subdivided into sections. Some subjects therefore overlap since many organisms functions involve the coordination of several organs and tissues. The knowledge acquired from this course is applicable in various fields of science including agriculture and medicine.
VI. Content

6.1 Abstract

The unit studies the structure of plant and animal cells in relation to their functions.

It is important to know the ultrastructure and the chemical properties of the cell to be able to understand this relationship.

The first part of this module covers carbon and mineral nutrition (Unit 1) and the growth and development of plants (Unit 2), while the second part addresses the physiology of the principal animal systems or apparatus (Unit 3) and a comparative study between plant and animal and physiology (Unit 4). Readings are suggested in each unit though the students are encouraged to do further reading. At the end of each unit, the student will attempt a formative evaluation, which will test the acquired skills.

This unit is divided into 4 sub-units.

Unit 1: Carbon and Mineral nutrition
Unit 2: Plant growth and development
Unit 3: Physiological functions of animals
Unit 4: Comparison between plant and animal physiology

6.2 Graphic organizer
VII. General Objectives

1. General learning objectives (knowledge).
   - Learn the basic principals of plant and animal physiology.
   - Understand the differences between plant and animal physiological functions.

2. General method objective (know-how).
   - Master the steps of experimental investigation and problem solving

3. General attitude and values elucidation objectives (behaviour).
   - Make sure that respect for life is maintained

VIII. Learning activities specific objectives (Formative Objectives.)

Unit 1: Carbon and Mineral Nutrition

Specific learning objectives

Upon completion of the unit, the student will be able to:
   - define osmosis, osmotic equilibrium, osmotic pressure gradient, culture media, retention capacity, suction force...
   - recall principles of determining plant nutritional needs
   - describe method of establishing a nutritient solution

Specific method objectives

Upon completion of the unit, the student will be able to:
   - formulate a research hypothesis on plant mineral nutrition
   - set up an experiment to determine plant mineral nutrition
   - interpret results obtained from such experiments
   - explain the functioning of a physiological system
   - solve problems
   - compare diverse nutritional media
Specific attitude objectives and values clarification

Upon completion of the unit, the student will be able to:
- love plants
- take care of plants

Unit 2: Plant growth and development

1. Specific objectives:

1.1 Specific learning objectives (knowledge)

Upon completion of the second unit, the student must be able to:
- list different methods of reproduction in plants
- describe the different modes of sexual reproduction in plants
- state the factors that affect plant growth
- define important concepts such as germination, meristem, double pollination, vernalization, photoperiodism, phytochrome and phytohormone;

1.2 Specific method objectives (know-how).

Upon completion of the unit, the student will be able to:
- describe modes of reproduction in plants
- measure growth of vegetative and reproductive structures in plants
- set up experiments on germination
- use collaboration tools.

1.3 Specific attitude and values elucidation objectives (behaviour).

- conserve plant diversity
- contribute to agriculture development.

Unit 3: Physiological functions of animals

Specific objectives

Specific learning objectives

Upon completion of the unit, the student will be able to:
- define the concepts of hormone, regulation and metabolism
- recall hormonal control functioning mechanisms
- recall the role of different organs
Specific method objectives
Upon completion of the unit, the student will be able to:
- compile information on fundamental concepts of the physiological function, such as hormonal regulation, cell metabolism;
- work in collaboration with other students on a problem solving project;
- write a report on what you learned
- illustrate the feed-back steps

Unit 4: Comparision between plant and animal physiology
Specific leaning objectives
Upon completion of the unit, the student will be able to:
- identify the distinctive nature of animal and plant physiology

Specific method objectives
Upon completion of the unit, the student will be able to:
- establish comparison criteria
- draw up a comparison table

Specific attitude and values elucidation objectives
Upon completion of the unit, the student will be able to:
- raise awareness on the need to conserve plant and animal life
- participate in conservation activities
9.1 Initial evaluation

This test will allow you to evaluate your knowledge regarding this course. Technically, all of the elements contained in this test were seen in previous courses.

**True or false questions : Tick the correct answer**

1. The cellulose membrane of a plant cell is permeable to mineral elements  
   - True  - False

2. All plant cells contain plastids  
   - True  - False

3. Light can influence plant growth  
   - True  - False

**Pairing questions**

4. Relate the hormone to the corresponding gland

<table>
<thead>
<tr>
<th>Hypophysis</th>
<th>Oestrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenal medulla</td>
<td>Follicle-stimulating hormone</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Androgen</td>
</tr>
<tr>
<td>Ovary</td>
<td>Insulin</td>
</tr>
<tr>
<td>Testicle</td>
<td>Adrenalin</td>
</tr>
</tbody>
</table>

5. With the following expressions, fill in the boxes of the following vertebrate nervous system diagram: Parasympathetic system - Central nervous system - Sensory neuron - Vegetative system - Spinal cord - Sympathetic system - Brain - Peripheral system - Effector neuron - Somatic system.
Multiple choice questions: Check the correct answer

6. Fungi feeds
   ☐ on mineral substances obtained from soil
   ☐ on self-made organic substances
   ☐ on organic substances obtained from soil
   ☐ on mineral substances obtained from air

7. The necessary energy for an animal cell is produced from:
   ☐ the nucleus
   ☐ the ribosome
   ☐ the mitochondrion
   ☐ the centriole

8. The endocrine glands are:
   ☐ storage tissues and hormone reservoirs;
   ☐ tissues that use hormones produces elsewhere;
   ☐ hormone producing tissues;
   ☐ juices producing tissues

Multiple choice questions: Check the correct answer

9. Plant growth is influenced by:
   ☐ Light
   ☐ Sap
   ☐ Gravity
   ☐ Temperature
   ☐ Support

Annotations

10. Label the diagram below


Answers

1. True
2. False
3. True
4. Hypophysis (Follicle-stimulating hormone)
   - Adrenal medulla (Adrenalin)
   - Pancreas (Insulin)
   - Ovary (Oestrogen)
   - Testicle (Androgen)

5. Diagram

6. Fungi feed on organic substances obtained from soil
7. The necessary energy for an animal cell is produced from the mitochondrion
8. The endocrine glands are hormone producing tissues
9. The plant growth is influenced by light, temperature, gravity and support
10. Annotation
UNIT I
General characteristics of plant nutrition

Introduction
The understanding of plant nutrition requires knowledge of structure and function of the plant cell. In fact, cells are the basic unit of plant life. In 1855, Rudolf Virchow from Russia said “Omnis cellula e cellula”, which means that every cell comes from another cell; in other words the cell holds all the necessary information to life continuity. It is in the nucleus that we find DNA which contains the code to protein synthesis. Besides, only plant’s green cells are able to take up the autotrophic function which allows the transformation of mineral matter to organic matter.

It is the green chlorophyll contained in plastids of plant cells that gives plants the autotrophic property and makes plants an important source of nutrition for all living things of our planet. Plant nutrition can be divided into mineral nutrition and carbon nutrition; when nutrition comes from soil, such as water, macro elements and trace elements, it is referred to as mineral nutrition and when the plant uses carbon from air, it is called carbon nutrition. These two nutrition modes require structural adaptation to do specific physiological functions. The learning activity that will be used to master these nutrition modes is the reading activity.
Learning activity

Plants nutritional needs

Learning activity summary

This activity is related to plants basic nutrition, absorption and its integration. Like all living things, the plant must drink and eat and this they do simultaneously.

All nutrients are dissolved in water. The first activity of the student is to identify all the nutrients and indicate their role in plant metabolism and development. The student will review work done by renowned researchers and reproduce the experiments to confirm the results.

The student should do further reading on the topics. Group discussions and self-evaluation is encouraged.

Activity specific objectives

Specific learning objectives

Upon completion of the activity, the student will be able to:

- define osmosis, osmotic equilibrium, osmotic pressure gradient, culture media, retention capacity, suction force, macro and trace elements organic matter cycle
- recall some principles of determining plant nutrition
- describe a method of formulating a nutrient solution
- cite renowned scientists who contributed to plant nutrition evolution and related knowledge
Specific method objectives

Upon completion of the activity, the student will be able to:
- formulate a research hypothesis on plants mineral needs
- carry out an experiment to determine plant nutritional needs
- analyse results obtained from experiment
- explain the functioning of a physiological system
- solve problems related to plant nutrition
- compare nutrition media

Key concepts

1. Autotrophy: nutrition mode of a living thing which, from an exclusively mineral medium, is able to produce its own organic substances to assure its own growth and development
2. Raw sap: Liquid containing the dissolved mineral substances absorbed by the plant roots and transported by the xylem toward the leaves
3. Elaborated sap: Liquid containing the organic substances produced by leaves and distributed by the phloem toward the organs
4. Macro-element: mineral substances required by plants for their nutrition in relatively large quantity
5. Trace element: mineral substances required by plants for their nutrition in small quantity
6. Manure/Fertilizer: mineral or organic substances added to increase the quantity of nutrients in soil
7. Enrichment: Improvement of soil structure and texture by addition of mineral or organic substances
8. Manuring: Enrichment of soil by adding organic substances to improve the structure and increase nutrient quantity
9. Photosynthesis: production of organic substances from mineral substances (water, CO\textsubscript{2}) by plants using light as the energy source

Key words
- Sap
- Macro- and trace element
- Nutrition medium
- Manure
- Humidification
- Ammonization
- Nitrification
- nitrogen cycle
- Chlorophyll
- Photosynthesis
References

Readings

Reading 1: La nutrition minérale des plantes

Complete reference
Extrait de cours de Rémi Rakotondradona
Université d’Antananarivo (Madagascar)

Summary: This course addresses general characteristics of plant nutrition. Nutrients and their metabolism within the cell is discussed. Methods of determining nutrients requirements is also outlined.

Justification: Reading this module will give you basic knowledge on plant nutrition and related

Reading 2: La nutrition carbonée

Complete reference
Extrait de cours de Rémi Rakotondradona
Université d’Antananarivo (Madagascar)

Summary: This section presents organic matter cycle, illustrated by nitrogen and carbon cycles.

Then, photosynthesis will be explained, especially the work on light reactions and light-independent reactions and the related products. The functioning of the enzyme responsible for carbon dioxide absorption is shown to be a major condition of photosynthesis yield, which leads to plant categorization in C3, C4 and CAM.

Justification: This section will help the student to understand and write formulae. In particular, Calvin and Benson’s cycle and Hatch and Slack’s cycle, for photosynthesis C3 and photosynthesis C4 respectively are easy to understand and memorize.
Ressources

Ressource 1

Complete reference
Vidéo : La physiologie végétale et animale par l’UVA et Rakotondradona Rémi

Summary : This video will give information on the background of the author, and his contribution to this module.

Justification : This video is very useful to get to know the teacher along with the suggested unit.
Links

Link 1

**Summary**: This web site from the Université Pierre et Marie Curie (France) suggests various themes related to plant physiology: plant movement, growth, gravitropism.

**Justification**: This website will be helpful for complementary information on plant physiology.

**Complete reference**: [http://www.snv.jussieu.fr/bmedia/sommaires/pv.htm](http://www.snv.jussieu.fr/bmedia/sommaires/pv.htm)
Detailed description of the learning activity

The study of the general characteristics of plant nutrition is focused on the food type, its composition and metabolism. The goal is formulation of nutrition solutions and fertilizers and to test them on plants.

In this section, you will review the history of development nutrition solutions from Julius Sachs’s in 1860 to Hoagland’s in 1933. You will learn raw sap transformation to elaborated organic sap by plants.

Plant are the only living things able to carry out the genial task of autotrophy through photosynthesis. The important concepts therein will be clarified.

*Problem.* Will physiology as a discipline cover the whole characteristics of plant nutrition?

*Hypothesis:* Many disciplines are required to learn all the characteristics of plant nutrition.

The aim of this section is to confirm or reject the hypothesis by literature search via Internet and by collaborative work. The students will have three mandatory readings.

Complementary resources and links are also available but they most assuredly will find more information sources on their own. Three experiments are scheduled if the students have access to a laboratory. If not, tutorials will have to be reinforced. Students will have the opportunity to communicate via different media (forum, chat, e-mail, etc.)

A formative evaluation is scheduled at the end of the learning activities to assess performances. Forum, chat and library attendance will be marked.
Learning activity

This activity contains 6 sections:

1. Mandatory readings
2. Web-based research
3. Laboratory experiments
4. Distance tutorials
5. Production of a group report on plant nutrition characteristics and photosynthesis
6. Production of a reflexive report

The chapter is about the general characteristics of plant nutrition.

Task 1. Mandatory reading and web-based research

The available texts represent the two mandatory readings. You must consult all the links and resources suggested in the unit. You can also find more on your own. When you are done with your readings, write down a 300-word summary which you must send out via e-mail to your group members. You should also post a copy on the library platform, along with all the interesting reference material you can find for your colleagues. Read the reference material posted by your colleagues.

Task 2. Laboratory experiments

The students will have to do three experiments on plant nutrition in a laboratory, if such a facility is available.

Experiment 1: Characteristics of plants cultivated in minimum media compared to plants cultivated in nutrient media. (Sachs, Knop, Roling ou Hoagland);
Measure daily growth, and total growth and take photographs.

Experiment 2: Extraction of chlorophyll and accessory pigments.

Experiment 3: Experiment that can be done within the school to teach students that when the photosynthesis occurs, CO$_2$ is absorbed and O$_2$ is released.

A protocole will be available from the tutor as described by the course author. If a laboratory is not available, tutorials will be reinforced.

Task 3. Tutorials

Un guide sera mis à la disposition des apprenants pour la réalisation de cette activité. Ils peuvent être effectués à distance ou en présentiel lorsque cela est possible.

Il consiste à visionner les photos d’illustration du cours, à faire des schémas, à faire réaliser des planches par l’unité de production de matériels didactiques et à faire des exercices d’auto-évaluation.
Task 4 Web-based research

The suggested readings must be complemented with web-based research, in particular the suggested websites in the unit, since they are specifically related to the course content. However, it is strongly recommended that the student does own research in order to clarify the concepts.

Task 5. Production of a report on the general characteristics of plant nutrition.

The objective is to summarize all the information obtained on the subject. This will allow the elaboration of a final report on the unit, which will also constitute a personal document that will be helpful for the next unit.

Task 6. Produce a reflexive report

Self-evaluation can be done either by an individual or as a group exercise before attempting the formative tests.
Formative evaluation

**Exercise 1** – Tick the correct answer (0.5 point)
Raw sap contains only dissolved mineral substances  ☐ True ☐ False

**Exercise 2** – Tick the correct answer (1.5 point)
Plant nutrients are composed of:
- a) ☐ two element groups
- b) ☐ three element groups
- c) ☐ one element group

**Exercise 3** – Tick the correct answer (1.5 point)
The nitrogen measurement method is by:
- a) ☐ Dumas Liebig
- b) ☐ Kjeldhal
- c) ☐ Knop

**Exercise 4** – Arrows exercise (1.5 point)
Link the elements on the left side with those on the right side with arrows
- Manure → Addition of organic or mineral substance
- Enrichment → Addition of organic substance
- Manuring → Addition of organic or mineral substance

**Exercise 5** – Incomplete sentences (1 point)
Fill in the empty spaces with the following words: montmorillonite – illite - kaolinite - clayish
The ____________ minerals are grouped in different classes. The more common are:
- ____________ poor in silica content, with a minimal swelling capacity, and a poor capacity to absorb ions and bases;
- ____________ the richest in silica content, with variable splitting, thus able to swell in the presence of water, with a strong capacity to absorb ions and cations
- ____________ is of intermediate character between the two previous classes.
**Exercise 6** – Incomplete sentences (1 point)
Fill in the empty spaces with the following words: chloroplast – prosthetic group - chlorophyll
The ____________ is the ____________________ of a heteroprotein called ____________.

**Exercise 7** – Tick the correct answer (1 point)
According to Emerson’s experiment on the green algae Chlorella, the optimal wavelength that allows strong CO₂ absorption as well as a strong O₂ emission is:

a) ☐ 425 nm  
b) ☐ 490 nm  
c) ☐ 425 nm + 490 nm  
d) ☐ 680 nm + 700 nm

**Exercise 8** – Arrows exercises (2 points)
The first product of photosynthesis is:

C₃ photosynthesis  
C₄ photosynthesis  
CAM photosynthesis
Answers

Exercise 1: True

Exercise 2: b) – three element groups

Exercise 3: b) - Kjeldhal

Exercise 4

Manure organic substance
Enrichment Addition of organic or mineral substance
Manuring Addition of organic or mineral substance

Exercise 5

The clayish minerals are grouped in different classes. The more common are:

- illite poor in silica content, with a minimal swelling capacity, and a poor capacity to absorb ions and bases;

- montmorillonite the richest in silica content, with variable splitting, thus able to swell in the presence of water, with a strong capacity to absorb ions and cations

- kaolinite is of intermediate character between the two previous classes.

Exercise 6

Fill in the empty spaces with the following words: chloroplast – prosthetic group - chlorophyll

The chlorophyll is the prosthetic group of a heteroprotein called chloroplast.

Exercise 7

d) 680 nm + 700 nm

Exercise 8

C3 photosynthesis APG

C4 photosynthesis AOA

CAM photosynthesis AOA
Educational comment

The purpose of these exercises is to evaluate your knowledge regarding the activity on plants general characteristics. Different types of questions related to the entire course are asked to evaluate the general knowledge. For all the questions, you are allowed two attempts. The average from both attempts will be used as the final mark.

Your final marks will be graded and recommendation given as below:
- between 30% - 50%, retake the course
- between 50% - 75%, your knowledge is sufficient in this area.

This test will be available for two weeks.
Unit 2

Plant growth and development

Introduction

The second unit is about plant growth and development. Biologically, there is a slight difference in the meaning of these words.

The growth process comes from two complementary phenomena, cell multiplication or mitosis and increase in size or elongation. Development is a progressive transformation that leads a one-cell living thing, the egg, to an individual; in other words, cells undergo differentiation. Growth is measurable, while development is non-measurable. Often, these two words are considered as synonyms by teachers. The acquired knowledge from the first unit on plant nutrition will be helpful to understand plant growth and development. In this unit you will carry out an experiment to show relationship between plant nutrition and growth. For plants, growth does not always occur on a continuous basis but is strongly affected by climate changes. In temperate countries, growth is at its maximum during spring and summer, while in tropical countries, growth is at its maximum during the rainy season. Plant growth is also influenced by hormones.
Learning activity 2

Collaborative research project on plant hormones

1. Specific objectives:

1.1 Specific learning objectives (knowledge).
Upon completion of the unit, the student will be able to:

- describe the different modes of plant reproduction;
- describe the different steps of plants sexual reproduction;
- describe different growth factors in plants;
- define important terminologies such as germination, meristem, double pollination, vernalization, photoperiodism, phytochrom, and phytohormone.

1.2 Specific method objectives (know-how).
Upon completion of the unit, the student will be able to:

- describe plants mode of reproduction;
- measure root growth;
- use collaboration tools
- carry out experiments on germination, plant apparatus development and reproduction in plants.

1.3 General attitude and values elucidation objectives (behaviour).
- conserve plant diversity;
- contribute to agriculture development.

Learning activity summary

The first explanation on plant germination is related to heterotrophy which is the utilization of nutrients stored within the seed for the embryo’s growth and development to achieve autotrophy. To study plant growth and reproductive structures, the student will have to do designated tasks which will allow to understand the difference between growth and development, but also to understand the effect of the chosen phytohormone on either growth or development.

The student will have to use synchronous or asynchronous collaborative tools and will write personal reports on the subject. Here, the deductive method prevails.
**Key concepts**

*Growth*: mass and size of a cell, a tissue, an organ or an organism.

*Development*: progressive differenciation of cells, tissues, organs to form a complete organism.

*Vegetative reproduction*: growth of the vegetative part on a plant

*Sexual reproduction*: growth and development of a plant after double pollination

*Germination*: growth and development of the embryo

*Cell differentiation*: Refers to the process and the modification results during cell transformation, development and maturation.

*Vegetative structures*: combined organs to assure chlorophyll function

*Reproductive structures*: combined organs to assure sexual reproduction

*Double pollination*: fertilization of the main nucleus (n) and of the secondary nucleus (2n) contained in the embryo sac by the reproductive nucleus (n) from the pollen seed

*Fruit*: ovary development product after fertilization

*Growth factor*: stimulus that can modify plant growth rates

*Collaborative work*: It is an activity through which students achieve a task together using distance communication tools

**Key words**

- Propagation by cuttings
- Cell differentiation
- Vegetative and reproductive apparatus
- Double pollination
- Vernalization
- Photoperiodism
- Short-day plant and long-day plant
- Phytochrom
- Phytohormone
- Collaborative work
References

Readings :

Reading  1:  Propagation végétative

Complete reference : Extrait de cours de Rémi RAKOTONDRAĐONA Université d’Antananarivo (Madagascar)

Summary: This text is about plants tendency to self-reproduction. It contains a lot of information about the different modes of plant non-sexual reproduction. Reading this document will help you learn some vegetative propagation techniques which you can put into practise.

Justification: Reading this text will help you not only to understand the mode of plant propagation, but also to master the propagation techniques in day-to-day life. It is strongly recommended that you practice at home in your garden or backyard.

Reading # 2. Reproduction sexuée des Angiospermes

Complete reference : Extrait de cours de Rémi RAKOTONDRAĐONA Université d’Antananarivo (Madagascar)

Summary : This document presents germination physiology through to fruit maturation. You will find research results, authors and the main theory trends such as geotropism, phototropism, and the laws of organ formation.

Justification : This document will help the student to comprehend angiosperm growth .

The data contained in this document will allow you to summarize this easily by the elaboration of a flowering plants biological cycle diagram.

Reading # 3. Facteurs de croissance des végétaux

Complete reference : Extrait de cours de Rémi RAKOTONDRAĐONA Université d’Antananarivo (Madagascar)

Summary: This text is about different internal and external factors of plant growth. The effects of these factors on plants are widely discussed.

Justification: Reading this document will help you understand the main role of each factor such as vernalization, photoperiodism and phytohormones on plants growth and development. It is an important document for your research homework for this unit.
Ressources

Ressource #1

[Image of a diagram showing a photosynthesis process]


Summary: This website proposes a photosynthesis animation. It shows how photons cross chlorophyll, the way chlorophyll is thus excited, and how through chemical processes organic products are synthesized. It also shows the role of ATP in this process.

Justification: This animation is interesting because with the help of the presented images, you can easily understand the photosynthesis process. The website is highly recommended.
Ressource #2


(Site visité le 26 mars 2008 à 18h52)

Summary: This website proposes various aspects of plant growth. It is particularly important to follow the numerous links that will allow you to understand properly.

Justification: This website is constantly evolving. The various themes suggested by wikipedia allow the student to move easily from a subject to another.
Links

Link # 1:


Summary: This website from Université Pierre et Marie Curie (Paris) gives very interesting information on plant growth. In particular, you will find chapters on short-term action kinetics of auxin and acidic pH, the role of membrane ATPases, hypotheses on growth regulation, etc.

Justification: This website gives additional information that is not necessarily mentioned in other documents. It is important that you visit this website, it contains valuable information.
Link # 2


**Summary**: This website proposes a variety of educational steps to comprehend plant growth in two parts: morphological diversity of plants and biological processes that control plants phenotype. Many links to texts (meristem) or images (cell division) are available.

**Justification**: The educational approach proposed in this text along with the presented information justify that you visit this website.
Link # 3:

Complete reference: http://www2.unil.ch/lpc/images/docu04/illustr_hormones.htm

Summary: This website from Université de Lausanne presents the role of hormones in plant growth, such as auxin, cytokinin, gibberellin, ethylene, abscisic acid... It also describes tropism, movements and space orientation, flowering and sexual reproduction among other processes.

Justification: The quantity of information available on this website will allow you to have an overview of a wide range of topics on this theme. Strongly recommended.
Detailed description of the learning activity

This activity on plant growth and development is focused on plant phytohormones and is centered on research and the sharing of information.

Reading, resources and links are available to students who should be in groups of 4 or 5. You will have to consult each other in order to get an idea on the diverse phytohormones including their formula, their synthesis and physiological properties.

Each group will work on a different phytohormone and will learn on the morphological and physiological aspects of the formed organ following the phytohormone action.

This activity will encourage the acquisition of collaborative research competences.

Each student will have to perform the various tasks and the results will be shared as a part of the collaborative work.

- Task 1: Research on different phytohormones
- Task 2: 300-word summary on each phytohormone for each group
- Task 3: E-mail, chat, forum or distribution list information sharing
- Task 4: Two-page common publication
- Task 5: Production of a summary report

Learning activities

The present activity, centered on collaborative research is organized in five tasks which, in the long run, will allow the students to achieve their objectives.

Task 1: Readings and research

- Read the available resources on vegetative propagation, growth and development and vegetables growth factors.
- Search and propose 3 pertinent websites each, that you will share with the other members of your group. This is important because it emphasizes the fact that you do not restrain yourself to the suggested readings, that you are eager to learn more about the subject.
Task 2 : Summary
- Write a 300-word summary on the function of each phytohormone, illustrate with appropriate selected images.

Task 3 : Sharing of information
- Send the summary to the other members of your group for comments, and recommendations.
- Share once more this list which will serve as the framework of a phytohormone publication.

Task 4 : Twenty-page common publication
- on the framework of the publication as a group will allow you to propose a publication.
- The publication is reviewed and corrected by each member

Task 5 : Production of a feedback report
Each group member should write a feedback report on the following topics :
- What did I learn about the conception and elaboration of collaborative work ?
- How did I learn it ?
- What helped me in the learning process ?
- How much time did I spend doing this activity ?
- Have I contributed reasonable in this common publication? 
- How will my acquired skills contribute to my professional activities ?
- How can I pass on such skills to my students ?
- What difficulties did I come across ?
8. Formative evaluation: Application and concentration exercises

Exercise 1:
Check the correct answer
- Propagation by cuttings involves in planting a plant fragment which does not possess any roots and must regenerate them.
  - True  False (0.5 point)
- The goal in grafting is to propagate an interesting aerial apparatus on a wild plant.
  - True  False (0.5 point)
- Layering can only occur in the presence of plants with creeping stems.
  - True  False (0.5 point)

Exercise 2: Multiple choice question. Tick the correct answer. (1.5 point)
Flowering can occur only after:
  - flowering maturity
  - trasformation from plant meristem to floral meristem
  - floral induction

Exercise 3: Multiple choice question. Tick the correct answer. (1.5 point)
Vernalization is a technique of:
  - temporary lowering of growing temperature
  - transformation from annual plant to biennial plant
  - temporary increase of growing temperature

Exercise 4: Incomplete sentences (3 points)
Fill in the empty spaces with the following words: geotropism, photoperiodism, critical period, positive, number of exposition days, superior, inferior, phytochrom, nutritional matter

4.1 Short-day plants can only flower if the hemeroperiod duration is _________ to the value of the _____________ always respecting the minimum trophic value and the minimal number of light days.

4.2 Long-day plants can only flower if the hemeroperiod duration is _________ to the value of the _____________ always respecting the minimal number of light days.
4.3 During ________________ photoreceptive pigments are ____________ that are only sensitive to light red and far red. (light infrared and far infrared, to be confirmed)

4.4 What makes plant roots penetrate soil is mainly the law of ___________, followed by the search for ________________. Therefore, roots are of _______________ geotropism.

**Exercise 5**: Report (3 points)
Write a 1500-word maximum research report on flower and fruit formation.

**Exercise 6**: Comparison table (3 points)
Write a comparative table of the phytohormones that you know of. To highlight the differences between them, use the following criteria: vernacular name, developed formula, main function, action mode precursor.

**Exercise 7**: Chemical reaction (2,5 points)
Using the following chemical products, write down the various steps of auxin main biosynthesis pathway: tryptophan, indole acetaldehyde, indole acetic acid, pyruvic indole acid.

**Question 8**: Elaboration of a cyclic diagram (2,5 points)
Draw a diagram of the biological cycle for growth and development of a flower plant. Insert the following words or group of words accordingly in the appropriate position in the cycle. A position may be filled with more than one word.

<table>
<thead>
<tr>
<th>Flower</th>
<th>Plant</th>
<th>Fruit</th>
<th>Seed</th>
<th>Embryo development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive development</td>
<td>Vegetative growth</td>
<td>n</td>
<td>2n</td>
<td>3n</td>
</tr>
</tbody>
</table>

**Question 9**: Diagram representation (4,5 points)
Draw a diagram of an experiment carried out by Joachim Haemmerling in 1963 with *A. mediterranea* and *A. crenulata* marine algae, convincingly showing the role played by the cell nucleus in cell differentiation.
Answers

Exercise 1:
Propagation by cuttings involves planting a plant fragment which does not possess any roots.
   True
Grafting involves propagating an aerial plant structure on a wild plant.
   True
Layering can only occur in the presence of plants with creeping stems.
   False

Exercise 2: Multiple choice questions
Flowering can occur only after:
- transformation of vegetative meristem to floral meristem

Exercise 3: Multiple choice questions
Vernalization is a technique of:
- temporary lowering of temperature during plant growth

Exercise 4: Incomplete sentences:
4.1 Short-day plants can only flower if the days are shorter than their critical day length
4.2 Long-day plants can only flower if their days are longer than their critical day length.
4.3 During photoperiodism photoreceptive pigments are phytochrome that are only sensitive to light red and far red light. (light infrared and far infrared, to be confirmed)
4.4 What makes plant roots penetrate soil is the effect of geotropism followed by the search for nutrition. Therefore, roots are positively geotropic.
**Question 5**: Report

Each student produces a report accordingly with its ability to find correct information.

**Question 6**: Tableau de comparaison des phytohormones

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Developed formula</th>
<th>Main function</th>
<th>Precursor</th>
<th>Mode of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auxin</td>
<td>acetic indole acid</td>
<td>Cell growth</td>
<td>Tryptophan</td>
<td>Stimulates cell division, elongation and differentiation</td>
</tr>
<tr>
<td>Gibberellin</td>
<td>GA3</td>
<td>Gigantism</td>
<td>Mevalonic acid</td>
<td>Internod growth</td>
</tr>
<tr>
<td>Cytokin</td>
<td>Furfurylic acid</td>
<td>Cell division</td>
<td>Mevalonic acid</td>
<td>Integral part of RNA</td>
</tr>
<tr>
<td>Ethylene</td>
<td>CH$_2=CH_2$</td>
<td>Fruit maturation</td>
<td>Methionine</td>
<td>Synthesis of lytic enzymes</td>
</tr>
</tbody>
</table>

**Question 7**: Chemical reactions

Auxin biosynthesis

Precursor: tryptophan

Tryptophan deamination gives: pyruvic indole acid

Pyruvic indole acid decarboxylation gives: indole acetaldehyde

Indole acetaldehyde oxidation gives auxin: acetic indole acid

**Question 8**: Diagram of the biological cycle for flower plants
**Question 9** : Diagram of the results from Joachim Haemmerling’s experiment

![Diagram of the results from Joachim Haemmerling’s experiment](image)

**Educational comment**

The purpose of these exercises is to evaluate your knowledge on plant growth and development. The questions asked were related to the entire course to evaluate your general knowledge. Thus, you should attempt to answer the questions keenly.

If your evaluation stands:

- between 30% to 50%, retake the course
- between 50% to 75%, your knowledge is sufficient in this area.
Unit 3

Animal physiological functions

Introduction

Animal physiological functions cover many aspects including the functioning of various apparatus (respiratory, reproductive, excretory, digestive, circulatory, the nervous system), but also the interior area regulation and immunology. Growth and development are also part of physiology.

Physiological functions are made possible by both chemical and physical mechanisms. Physiology also studies the malfunctions that can occur and that can lead to various health issues. Animal physiology is a very complex subject and it will not be possible to cover it entirely in this document. However this unit will provide the student with a variety of theoretical and practical information that can be applied in day-to-day life.
Learning activity 3

Activity title: Concept appropriation and collaborative work

Activity summary

This learning activity, focus on the understanding of the fundamental scientific concepts and requires individual and collaborative approach. The student will be required to build up their own knowledge of the subject by accomplishing various tasks such as readings, document research, self-evaluation and the production of comprehensive report.

Specific objectives

Specific knowledge objectives

Upon completion of the unit, the student will be able to:

- define the terminologies: hormone, regulation, metabolism
- recall the mechanisms of hormonal control

Specific method objectives

Upon completion of the unit, the student will be able to:

- search for information on the fundamental concepts of the physiological functions, in particular hormonal regulation, cell metabolism;
- work in collaboration with other students in a problem solving project;
- write a comprehensive report on the acquired knowledge.
Key concepts

**Hormone.** A chemical substance produced by cells, tissues or organs, transported through the blood and which has an effect on one or more organs.

**Regulation.** Designates building up (anabolism) and breaking down (catabolism) of material through chemical reactions. The cell in the transforms and uses the necessary energy to survive, grow and reproduce.

**Growth factors.** Endogenous (genetic, endocrinial) and exogenous (environment, affective) elements that trigger and maintain morphological and functional transformation processes which allow animals to grow, develop and achieve physiological maturity.

**Collaborative work.** It is an activity through which students achieve a task together using distance communication tools.

**Problem solving.** It is an educational approach that relies on putting together elements that will help solve a given problem and that implies personal or team work in a strongly constructive spirit, in other words centered on learning.

Key words

Homeostasis
Endocrine, exocrine, paracrine gland
Hormone
Negative feedback
Regulation
Growth factor
Kidney
Nephron
Hypophysis
Interior environment
Readings

Reading # 1 : Homéostasie

Complete reference : Extrait de cours de Rémi RAKOTONDRAĐONA
Université d’Antananarivo (Madagascar)

Summary : This text is about homeostasis and the different steps in homeostasis feedback mechanisms. Organs involved in the system, such as the kidney and the endocrinical system are discussed. The unit focuses on endocrine glands and the hormonal control mechanism.

Justification : This text defines the equilibrium phenomenon (homeostasis) and gives valuable information about the hormonal control mechanism. Reading this document is mandatory to easily understand the notions related to hormonal regulation. It will encourage you to learn more.

Reading # 2


Summary : This document focuses on feedback mechanisms: negative and positive feedback. The author indicates that this information is contained in memory: genetic memory, immunologic memory, nervous memory and cultural memory. The author concludes with the notion of communication.

Justification : This document, filled with simple images is a good tool to understand and teach feedback mechanisms. The readings are mandatory.

Reading # 3

Complete reference : http://mon.univ-montp2.fr/L2L3ETM/document/Mireille_LAVIGNE-REBILLARD/L2S3_Hom%C3%A9ostasie_et_syst%C3%A8mes_de_r%C3%A9gulation.pdf

Lavigne-Rebillard : homéostasie et systèmes de régulation

Université de Montpellier II

Summary : This text is about homeostasis regulation systems (nervous and endocrinial), the analogies and similarities between the two systems, followed by some examples. As an illustration, the author discusses arterial pressure regulation and concludes with the interdependence of the nervous and endocrinial systems.

Justification : This text contains many images, which facilitates comprehension. It also serves as a complementary reading to other literature. The author’s approach to regulation is also quite original.
Ressources

Ressource # 1

Reference : ROUX, Jean paul : Le travail en groupe à l’école.

Summary : This document, intended for all teachers, encourages both individual and team work.

Justification : This document will provide the necessary psychological and educational tools for you to engage in team work. It suggests examples to illustrate real-life situations.
African Virtual University

Links

Link # 1

Complete reference: [http://fr.wikibooks.org/wiki/Les_principales_voies_du_m%C3%A9tabolisme](http://fr.wikibooks.org/wiki/Les_principales_voies_du_m%C3%A9tabolisme)

(Site visité le 02/04/07 à 12 h 35)

Summary: Le texte aborde le devenir des nutriments avant de définir la notion d’énergie. Une bonne partie est consacrée au métabolisme des glucides, des acides aminés et des lipides. La question des enzymes et coenzymes y est aussi développée.

Justification: This document, simply written, is interesting in the perspective of a quick comprehension of the metabolism concept. Several links to other notions are available.
This document introduces the process of metabolism followed by various related subjects, such as enzymatic reactions, anaerobic glycolysis, Krebs cycle and the respiratory chain. Many illustrations of metabolic reactions are intergrated into the text to facilitate the understanding of the subject.

Justification: This text will help you get familiar with the biochemical reaction mechanisms that occur during metabolism. It will also help you comprehend some essential metabolism processes.
Summary: This text defines the endocrinal system and reviews the different endocrine glands: hypophysis and secretion control, adrenal glands, medulla adrenal glands, cortico-adrenal glands, thyroid, ovary, etc. as well as other endocrinal tissues such as placenta, kidneys, hear. It also discusses hormonal regulation, the endocrine cycle, and endocrine related diseases.

Justification: This document is important for the comprehension of endocrinology. It will help you understand hormonal functions and the importance of hormonal regulation in the normal functioning of an organisms.
The aim of this activity is to construct a conceptual diagram of the two fundamental concepts of animal physiology: internal environment and metabolism.

The conceptual approach is a widely used tool in education, to help students comprehend different concepts. This approach consists of searching related knowledge that will help in explaining the concept above. The students will have to read various documents indicated in this module and others that they will find on their own. The students will form small working groups that will discuss via asynchronous tools (forum, e-mail) or synchronous tools (chat) available on the platform. Therefore, the students will alternate individual and brainstorming group activities. They will also support each other by sharing methods, visions.

Learning activity details

**Task 1**: Readings. You will have to read all three documents available in this document. It is also strongly recommended to read the suggested complementary references.

**Task 2**: For each document, write a 300-word summary and extract 10 key concepts contained in the document. Define each concept with three to five words (these words can be taken from the document).

**Task 3**: Search via Internet five document that are related to the subject and put them in the library on the platform. From the platform, read the documents found by your colleagues. For the documents suggested by your colleagues, extract only a couple of words that you think are important.

**Task 5**: In the forum, post at least one question and a contribution on an aspect of the subject (concern, call for help for problem solving)

**Task 6**: Compare your colleagues work with your own. Propose how you would improve your diagram from your initial production, taking into account the other productions.

**Task 7**: Review of a conceptual diagram on internal environment and metabolism after asynchronous and synchronous discussions.

**Task 8**: Review students report. You can use the following questions for guidance:

- What did I learn about the conception and initiation of collaborative work?
- How did I learn it?
- What helped me in the learning process?
- How much time did I spend doing this activity?
- Am I satisfied of my contribution in this common publication?
- What will my new competences change in my professional activities, in particular in the choice use and integration of computer tools?
- What difficulties did I come across?
- How can I pass on such skills to my students?

**Formative evaluation**

To answer these questions, you should have read not only the mandatory readings but also the suggested readings in the resources section.

**True or False questions / Tick the correct answer.**

1. The two parts of the hypophysis originate from different embryonic areas.  
   - True  [ ] False  [ ] 0.5 point

2. Somatotropin is secreted by hypophysis  
   - True  [ ] False  [ ] 0.5 point

3. The placenta is a tissue with an endocrinal function  
   - True  [ ] False  [ ] 0.5 point

4. ATP is necessary for muscular contraction  
   - True  [ ] False  [ ] 0.5 point

5. Metabolism involves two types of reactions  
   - True  [ ] False  [ ] 0.5 point

**Multiple choice questions**

6. The growth hormone is secreted during the night with peaks of: 1 point
   - one hour maximum
   - two hours maximum
   - three hours maximum
   - four hours maximum

7. Vasopressin acts on: 1 point
   - kidneys
   - arteries
   - the heart
8. All the reactions from the respiratory chain occur in:
   - mitochondrial external membrane
   - matrix space
   - mitochondrial internal membrane
   - intermembrane space

9. Link the metabolic pathways to where they occur
   - Glycolysis
   - Citric acid cycle
   - Pentose phosphate pathway
   - Gluconeogenesis
   - Glycogen degradation and synthesis
   - Fatty acid degradation and synthesis

10. Pairing questions
    Link these substances to their mean calorific value.

    Carbohydrate: 9.3 Kcal/g
    Protein: 4.1 Kcal/g
    Lipid: 5.7 Kcal/g

11. Place the following elements in the Calvin cycle diagram.

    \[3 \text{ CO}_2 \cdot 3 \text{ ATP} \rightarrow \text{CO}_2 \text{ reduction} \rightarrow 6 \text{ ADP} + 6 \text{ P} \rightarrow 6 \text{ G3P} \rightarrow \text{NADPH} + H^+ \]

    Glucose: 6 APG \rightarrow 3 \text{ ADP} + 3 \text{ P} \rightarrow \text{RubP regeneration} \rightarrow 6 \text{ ATP}
    - 5 G3P

    \text{CO}_2 \text{ fixation}: \text{NADP}^+ \rightarrow 6 \text{ ADPG} \rightarrow 3 \text{ RubiP}
Answers

1. True: the anterior hypophysis is developed in the embryo from ectoderm, while the posterior hypophysis originates from embryonic nervous tissues.

2. False: it is secreted from hypothalamus. Somatotropin, along with somatostatin regulate secretions.

3. True

4. True

5. True (anabolism and catabolism)

Multiple choice questions

6. The growth hormone is secreted during the night by peaks of two hours maximum.

7. Vasopressin acts on kidneys.

8. All the reactions from the respiratory chain occur in the mitochondrial internal membrane.

9. Link the metabolic pathways to where they occur

Cytoplasm: Glycolysis, pentose phosphate pathway, gluconeogenesis, glycogen degradation and synthesis

Mitochondrion: Citric acid cycle, fatty acid degradation and synthesis

10. Pairing questions

Link these substances to their mean calorific value.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Calorific Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>4.1 Kcal / g</td>
</tr>
<tr>
<td>Protein</td>
<td>5.7 Kcal / g</td>
</tr>
<tr>
<td>Lipid</td>
<td>9.3 Kcal / g</td>
</tr>
</tbody>
</table>
11. Place the following elements in the Calvin cycle diagram.

![Calvin cycle diagram]

**Educational comment**

The purpose of these exercises is to evaluate your knowledge. You are allowed two attempts. The average of the two attempts will be used as the final mark.
Unit 4

Comparison between plant and animal physiology

Introduction

The fourth unit will compare plant and animal physiology to help the student understand that the basic life principles are similar but some application details differ.

Cells need energy to survive and both kingdoms have their own way to satisfy this essential need. To properly carry out this comparison, knowledge of both disciplines is mandatory, you will have to review the previous units. You have learnt plant nutrition and growth in the previous units, and noted the following:

- plants only absorb dissolved elements;
- plants can survive in a minimal environment;
- they are autotrophic;
- they can reproduce in a vegetative way or a sexual way;
- diploidy and triploidy coexist.

Animals physiological functions are more complicated involving chemical and physical mechanisms and various systems. A more developed way of life can be observed for animals, which allows them to survive a more eventful life.
Learning activity 4

Activity title: Differences between plant and animal physiological functions

Activity summary

The goal of this learning activity is to reinforce the students knowledge of plant and animal physiological functions by comparing them. Structures in plants and animals that share similar functions are well adapted to their roles. For example animal cells involved in breathing and plant cells that photosynthesise have similar goal of ATP recovery. Similarly plant root hair and animal intestinal villus feed the cell. Those are only a few examples and it is up to you to discover and share more. After such studies, the student will summarize the research results by constructing a comparison table. This learning activity is centered on an educational approach and the students will be asked to build their own knowledge by accomplishment of various tasks such as readings, literature research, self-evaluations and the production of a report.

Specific objectives

Specific knowledge objectives

Upon completion of the unit, the student will be able to:

- define photosynthesis, cell respiration, glycolysis,…
- distinguish between plant physiology and animal physiology
- recall with a diagram the Krebs cycle

Specific method objectives

Upon completion of the unit, the student will be able to:

- study relatively different lessons simultaneously
- compare plant and animal physiological functions
- work on a problem solving project in collaboration with colleagues
- produce a summary report
Key concepts

Cell respiration. A biochemical process that allows the cells to recover energy from organic molecules such as carbohydrates to survive.

Photosynthesis. Designates chemical reactions that capture light energy in the form of chemical energy to synthesize an organic compound.

Intestinal villus. The small intestine is lined with a mucous membrane with microscopic finger-shaped folds called villi. Each villus is composed of a small tube of epithelial tissue, which surrounds a small lymphatic vessel as well as many capillaries.

Root hair. Superficial cell from root ends that possess extensions of their cytoplasm several centimeters long.

Collaborative work. It is an activity through which students achieve a task together using distance communication tools.

Problem solving. It is an educational approach that requires on putting together elements that will help solve a given problem. This calls for personal or team work involvement.

Key words

Cell respiration
Mitochondrion
Krebs cycle
Digestion
Fundus
Pyloric antrum
Alimentary bolus
Chyme
Chyle
Micelles
Readings

Reading 1: Respiration cellulaire

Complete reference: Extrait de cours de Rakotondradona Rémi Université d’Antananarivo

Summary: The text is about cell respiration including glycolysis I, glycolysis II and Krebs cycle. The places in the cell where they occur are well specified.

Justification: This document is quite original since it shows and explains in two different ways the various steps for the reactions in cell respiration. The first approach consists of a general overview of this phenomenon and the second explains the reaction details.

Reading 2: La fonction digestive

Complete reference: Extrait de cours de Rakotondradona Rémi Université d’Antananarivo

Summary: This course explains the various steps in digestion of food material from mouth to jejunum. Moreover, absorption functions are also discussed.

Justification: This course reinforces the students knowledge of animal physiology since the acquired concepts are once more explained and illustrated. The content describes negative feedback with saliva secretion in the mouth, HCl secretion in stomach and blood sugar level control.
**Ressources**

**Ressource # 1**

Complete reference:
Video : La physiologie végétale et animale par l’UVA et Rakotondradona Rémi

**Summary**: This video gives education background of the author. It also explains the contents of the module.

**Justification**: This video gives you background to Unit 4.

**Ressource 2**

**Complete reference**

*Gilles Furelaud* Animation cellule animale cellule végétale

http://www.snv.jussieu.fr/vie/dossiers/AnVeg/CellAnCellVeg2.html

**Summary**: It is an animation that illustrates the constituents of plant and animal cell.

**Justification**: This simplified animation shows the structural and functional units of the plant and animal cells.
Summary: This text discusses nutrients metabolism and energy production. A large part of it covers carbohydrate metabolism, amino acids and lipids. Enzymes and coenzymes are also discussed.

Justification: This document is written in a simple format to make the reader understand metabolism. Links to other relevant materials are also provided.
Detailed description of the learning activity.

The aim of this activity is to compare physiological functions between plants and animals. Students will first go through reading 1 and 2 and respectively compare them to photosynthesis and plants nutrition. The students will then work in groups to identify one plant physiological function that can be compared to an animal physiological function. To do this the students will have to read widely and practice report writing and share information with their colleagues through asynchronous (forum, e-mail) or synchronous (chat) communication tools available on the platform.

Activity details

Task 1: Reading of documents. Reading of the provided documents is mandatory as they complement the resources you find on your own.

Task 2: For each document, write a 300-word summary and extract 10 key concepts contained in the document. For each concept, try to find keywords that help you understand.

Task 3. After reading the documents, compare respiration with photosynthesis and digestion. Construct a table with three columns titled: Item for comparison, Animal physiology, Plant physiology.

Task 4. Post your comparison table in the library on the platform. Read the tables posted by your colleagues.

Task 5: Analyse your colleagues table and compare with your own. Propose an improved version of the table taking into account the two.

Task 6. In the forum, post at least one question and a contribution on an aspect of the comparison.

Task 7. Production of group work related to an animal physiological function that can be compared to a plant physiological function following asynchronous and synchronous discussion.

Task 8. Provide Individual feedback report. Use the following questions to guide you:
- What did I learn?
- How did I learn it?
- What helped me in the learning process?
- How much time did I spend doing this activity?
- Am I satisfied with my contribution in this common publication?
- How will my new skills change my professional activities especially in the choice use and integration of computer tools?
- What difficulties did I come across?
- How can I pass on such skills to my students?
Formative evaluation

True or False questions. Tick the correct answer.

1. It is the endothermic reactions consuming ATP that occur during glycolysis
   - True  - False  0.5 point

2. It is the endothermic reactions generating ATP that occur during glycolysis
   - True  - False  0.5 point

3. Kreb’s cycle is a succession of reactions that occur in the mitochondrion’s membrane.
   - True  - False  0.5 point

4. Metabolism includes two types of reactions.
   - True  - False  0.5 point

5. Krebs cycle produces 36 ATPs from a glucose molecule.
   - True  - False  0.5 point

Multiple choice questions. Tick the correct answer.

6. Within the stomach, there are ____ cell layers.  1 point
   - two
   - three
   - four
   - five

7. Insulin acts on  1 point
   - glucose
   - peptids
   - lipids
8. All the reactions in the respiratory chain occur in: 1 point
- mitochondrial external membrane
- matrix space
- mitochondrial internal membrane
- intermembrane space

9. The absorbing function occurs in: 1.5 points
- the stomach
- The mouth
- the jejunum
- the duodenum
- ileum
- the oesophagus

10. Pairing question 1 point
Relate these organs to their mean pH value:

<table>
<thead>
<tr>
<th>Organ</th>
<th>pH Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>3</td>
</tr>
<tr>
<td>Stomach</td>
<td>7.4</td>
</tr>
<tr>
<td>Duodenum</td>
<td>8</td>
</tr>
</tbody>
</table>
**Answers**

1. True
2. False: it is exothermic
3. False: it occurs in the mitochondrion matrix space
4. True
5. True

**Multiple choice questions**

6. Within the stomach, there are ____ cell layers. 1 point
   - four: mucous, submucous, muscular and serous

7. Insulin acts on 1 point
   - glucose

8. All the reactions in the respiratory chain occur in :1 point
   - matrix space

9. The absorbing function occurs in : 1.5 point
   - the jejunum

10. Pairing question 1 point
    Relate these organs to their mean pH value
    Mouth 7.4
    Stomach 3
    Duodenum 8

**Educational comment**

The purpose of these exercises is to evaluate your knowledge. You are allowed two attempts. The average of both attempts will be used as the final mark.
XI. Key concepts list

**Enrichment**: Improvement of soil structure and texture by addition of mineral or organic substances

**Reproductive apparatus**: combined organs for sexual reproduction

**Vegetative apparatus**: combined organs for growth.

**Autotrophy**: nutrition mode of a living being which, from an exclusively mineral medium, is able to produce its own organic substances to assure its own growth and development

**Growth**: mass and size augmentation of a cell, a tissue, an organ or an organism.

**Development**: progressive improvement of cells, tissues, organs to form a complete organism.

**Cell differentiation**: Refers to the process and the modification results during cell transformation, development and maturation.

**Double pollination**: fertilization of the main nucleus (n) and of the secondary nucleus (2n) contained in the embryo sac by the reproductive nucleus (n) from the pollen seed

**Manure/Fertilizer**: mineral or organic substances added to increase the quantity of nutrients in soil

**Growth factors**: Endogenous (genetic, endocrinal) and exogenous (environment, affective) factors that trigger and maintain morphological and functional processes and that allow animals to grow, develop and achieve physiological maturity.

**Fruit**: Developed ovary after fertilization.

**Manuring**: Enrichment of soil by adding mineral or organic substances to improve the structure and increase nutrient quantity

**Germination**: growth and development of the embryo

**Hormone**: A chemical substance produced by cells, tissues or organs, transported through the blood and which has an effect on one or more organs.

**Macro-element**: mineral substances required by plants for their nutrition in relatively large quantity

**Trace element**: mineral substances required by plants for their nutrition in small quantity
Photosynthesis: production of organic substances from mineral substances (water, CO₂) by plants using light as the energy source.

Root hair: Extensions of cytoplasm (several centimeters long) from root ends.

Metabolism: Chemical reactions (anabolism and catabolism) through which the cell transforms and uses the necessary energy to survive, grow and reproduce. Catabolism is the set of metabolic pathways that break down molecules into smaller units and release energy. Anabolism is the construction of large molecules from small molecules.

Vegetative reproduction: growth of the vegetative part of a plant.

Sexual reproduction: growth and development of a plant after double pollination.

Problem solving: It is an educational approach that relies on putting together knowledge that will help solve a given problem. Individual or team work in a strongly constructive spirit, in other words centered on learning.

Cell respiration: A biochemical process that allows the cells to recover energy from organic molecules such as carbohydrates to survive.

Raw sap: Liquid containing the dissolved mineral substances absorbed by plant roots and transported by the xylem towards the leaves.

Elaborated sap: Liquid containing organic substances produced by leaves and distributed by phloem to the organs.

Collaborative work: It is an activity through which students achieve a task together using distance communication tools.

Intestinal villus: The small intestine is lined with a mucous membrane of microscopic finger-shaped folds called villi. Each villus is composed of a small tube of epithelial tissue, which surrounds a small lymphatic vessel as well as many capillaries.
XII. Complete list of readings

Reading 1: La nutrition minérale des plantes

Complete reference
Extrait de cours de Rémi Rakotondradona
Université d’Antananarivo (Madagascar)

Summary: This course addresses general characteristics of plant nutrition. Nutrients and their metabolism within the cell is discussed. Methods of determining nutrients requirements is also outlined.

Justification: Reading this document will immerse you in the heart of the general characteristics of plants nutrition and related disciplines.

It will be the anchor in the research of further information that will help you confirm or reject the research hypothesis.

Reading 2: La nutrition carbonée

Complete reference
Extrait de cours de Rémi Rakotondradona
Université d’Antananarivo (Madagascar)

Summary: This section presents organic matter cycle, illustrated by nitrogen and carbon cycles.

Then, photosynthesis will be explained, especially the work on light reactions and light-independent reactions and the related products. The functioning of the enzyme responsible for carbon dioxide absorption is shown to be a major condition of photosynthesis yield, which leads to plant categorization in C3, C4 and CAM.

Justification: This section will help the student in understanding and writing of formula. In particular, Calvin and Benson’s cycle and Hatch and Slack’s cycle, for photosynthesis C3 and photosynthesis C4 respectively are easy to understand and memorize.
Reading 3: Propagation végétative

**Complete reference**: Extrait de cours de Rémi RAKOTONDRADONA Université d’Antananarivo (Madagascar)

**Summary**: This text is about plants tendency to self-reproduction. It contains a lot of information about the different modes of plants non-sexual reproduction. Reading this document will help you learn some vegetative propagation techniques which you can put into practise.

**Justification**: Reading this text will help you not only to understand the mode of plant propagation but also to master propagation techniques in day-to-day life. It is strongly recommended that you practice at home in your garden or backyard.

Reading 4: Reproduction sexuée des Angiospermes

**Complete reference**: Extrait de cours de Rémi RAKOTONDRADONA Université d’Antananarivo (Madagascar)

**Summary**: This document presents germination physiology through to fruit maturation. You will find research results, authors and the main theory trends such as geotropism, phototropism, and the laws of organ formation.

**Justification**: This document will help the student to comprehend angiosperm growth.

The data contained in this document will allow you to summarize this easily by the elaboration of a flowering plants biological cycle diagram.

Reading 5: Facteurs de croissance des végétaux

**Complete reference**: Extrait de cours de Rémi RAKOTONDRADONA Université d’Antananarivo (Madagascar)

**Summary**: This text is about different internal and external factors of plant growth. The effects of these factors on plants are widely discussed.

**Justification**: Reading this document will help you understand the main role of each factor such as vernalization, photoperiodism and phytohormones on plants growth and development. It is an important document for your research homework for this unit.
Reading 6: Homéostasie

Complete reference: Extrait de cours de Rémi RAKOTONDRAJONA
Université d’Antananarivo (Madagascar)

Summary: This text is about homeostasis and the different steps in homeostasis feedback mechanisms. Organs involved in the system such as the kidney and the endocrinal system are discussed. The unit focusses on endocrine glands and the hormonal control mechanism.

Justification: This text defines the equilibrium phenomenon (homeostasis) and gives valuable information about the hormonal control mechanism. Reading this document is mandatory to easily understand the notions related to hormonal regulation. It will encourage you to learn more.

Reading 7


Summary: This document focuses on feedback mechanisms: negative and positive feedback. The author indicates that this information is contained in memory: genetic memory, immunologic memory, nervous memory and cultural memory. The author concludes with the notion of communication.

Justification: This document, filled with simple images is a good tool to understand and teach feedback mechanisms. The readings are mandatory.

Reading 8

Complete reference: http://mon.univ-montp2.fr/L2L3ETM/document/Mireille_LAVIGNE-REBILLARD/L2S3_Hom%C3%A9ostasie_et_syst%C3%A8mes_de_r%C3%A9gulation.pdf

Lavigne-Rebillard: homéostasie et systèmes de régulation
Université de Montpellier II

Summary: This text is about homeostasis, regulation systems (nervous and endocrinal), the analogies and similarities between the two systems, followed by some regulation examples. As an illustration, the author discusses arterial pressure regulation and concludes with the interdependence of the nervous and endocrinal systems.

Justification: This texte contains many images, which facilitates comprehension. It also serves as a complementary reading to the other literature. The author’s approach to regulation is also quite original.
Reading 9 : Respiration cellulaire

Complete reference : Extrait de cours de Rakotondradona Rémi Université d’Antananarivo

Summary : The text is about cell respiration including glycolysis I, glycolysis II and Krebs cycle. The places in the cell where they occur are well specified.

Justification : This document is quite original since it shows and explains in two different ways the various steps for the reactions in cell respiration. The first approach consists of a general overview of this phenomenon and the second explains the reaction details.

Reading 10 : La fonction digestive

Complete reference : Extrait de cours de Rakotondradona Rémi Université d’Antananarivo

Summary : This course explains the various steps in digestion of food material from mouth to jejunum. Moreover, absorption functions are also discussed.

Justification : This course reinforces the students knowledge of animal physiology since the acquired concepts are once more explained and illustrated. The content describes negative feedback with saliva secretion in the mouth, HCl secretion in stomach and blood sugar level control.
XIII. Complete list of multimedia ressources

Ressource 1

Complete reference: Video: La physiologie végétale et animale par l’UVA et Rakotondradona Rémi

Summary: This video will give information about the education background of the author, and about the unit

Justification: This video is very useful to get to know the teacher along with the module he has written

Ressource 2


Summary: This website is a photosynthesis animation. It shows how photons cross chlorophyll, causing them to be excited, and how, through chemical reactions organic synthesis occurs. It also shows the role of ATP in this process.

Justification: This animation is interesting because with the help of the presented images, you can easily understand photosynthesis as a process. This website is highly recommended.
Ressource 3

Complete reference: http://fr.wikipedia.org/wiki/Croissance_v%C3%A9g%C3%A9tale
(Site visité le 26mars2008 à 18h52)

Summary: This website explains various aspects of plant growth. It is particularly important to follow the numerous links that will allow you to understand.

Justification: This website is constantly evolving. The various themes suggested by wikipedia allow the student to go easily from a subject to another.

Ressource 4

Reference: ROUX, Jean paul: Le travail en groupe à l’école.

Summary: This document, intended for all teachers, encourages team work by the students. It also states the usefulness of individual work.

Justification: This document will provide the necessary psychological and educational tools for you to engage in team work. It suggests examples to illustrate real-life situations.
Ressource 5

**Complete reference:**

Video : La physiologie végétale et animale par l’UVA et Rakotondradona Rémi

**Summary :** This video gives information on the author’s education background. It also shows the contents of physiology module.

**Justification :** This video is quite relevant to Unit 4.

Ressource 6

**Complete reference**

*Gilles Furelaud* Animation cellule animale cellule végétale

http://www.snv.jussieu.fr/vie/dossiers/AnVeg/CellAnCellVeg2.html

**Summary :** Above is an animation that shows the constituents of plant and animal cell.

**Justification :** This simplified animation gives a details of the structural and functional units that make up plant and animal cells.
XIV. Complete list of useful links

Link 1

http://www.snv.jussieu.fr/bmedia/sommaires/pv.htm


Summary: This web site from the Université Pierre et Marie Curie (France) suggests various themes related to plant physiology: vegetable movement, growth, gravitropism.

Justification: This website will be helpful for complementary information on plant physiology.
Link 2


Summary: This website from Université Pierre et Marie Curie (Paris) gives very interesting information on plant growth. In particular, you will find chapters on short-term action kinetics of auxin and acidic pH, the role of membrane ATPases, hypotheses on growth regulation, etc.

Justification: This website gives complementary information that is not necessarily developed in other documents. It is important that you visit this website, it contains valuable information.
This website proposes a variety of educational steps to comprehend plant growth in two parts: morphological diversity of vegetables and biological processes that control plants phenotype. Many links to texts (meristem) or images (cell division) are available.

**Justification:** The educational approach proposed in this text along with the presented information justify that you visit this website.
**Link 4**

**Complete reference**: [http://www2.unil.ch/lpc/images/docu04/illustr_hormones.htm](http://www2.unil.ch/lpc/images/docu04/illustr_hormones.htm)

---

**Summary**: This website from Université de Lausanne presents the role of hormones in plant growth, such as auxin, cytokinin, gibberillin, ethylene, abscisic acid. It also describes tropism, movements and space orientation, flowering and sexual reproduction and many more themes.

**Justification**: The quantity of information available on this website will allow you to overview a wide range of topics on this theme. Strongly recommended.
Link 5

**Complete reference**: [http://fr.wikibooks.org/wiki/Les_principales_voies_du_m%C3%A9tabolisme](http://fr.wikibooks.org/wiki/Les_principales_voies_du_m%C3%A9tabolisme)

(Site visité le 02/04/07 à 12 h 35)

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**Summary**: Le texte aborde le devenir des nutriments avant de définir la notion d’énergie. Une bonne partie est consacrée au métabolisme des glucides, des acides aminés et des lipides. La question des enzymes et coenzymes y est aussi développée.

**Justification**: This unit summarises metabolism. Several links to other concepts are available.
Link 6

Complete reference: Météabolisme
Laurent DELEPIN (jan 2001):
http://webiologie.free.fr/cellules/metabolisme/reactions.html

Summary: This document introduces the metabolism followed by various complementary subjects, such as enzymatic reactions, anaerobic glycolysis, Krebs cycle and the respiratory chain. Many illustrations of metabolic reactions are integrated into the text to facilitate the understanding of the subject.

Justification: This text will help you get familiar with the biochemical reaction mechanisms that occur during metabolism. It will also help you comprehend some essential metabolism notions.
Link 7

Complete reference

Summary: This text, after defining the endocrinical system, reviews the different endocrine glands: hypophysis and secretion control, adrenal glands, medulla adrenal glands, cortico-adrenal glands, thyroid, ovary, etc. as well as other endocrinical tissues such as placenta, kidneys, heart... It also discusses hormonal regulation, the endocrinical cycle, and endocrinical diseases.

Justification: This document is important for the comprehension of endocrinology. It will help you understand the hormonal connexions and the importance of hormonal regulation in the normal organism functions.
XV. Module summary

The module « plant and animal physiology » covers plant and animal physiological functions in relation to structure. The first part of the module is about mineral and carbon nutrition (Unit 1) and plants growth and development (Unit 2). Upon completion of this first section, students will have learnt that plants are autotrophic, which means that from a strictly mineral medium, they are able to produce their own organic substances to assure their growth and development. This ability comes from light induced photosynthesis. Plants absorb dissolved mineral elements as they do not possess a digestive apparatus to process bigger molecules. Plants go through vegetative and sexual reproduction. Sexual reproduction is characterized by double pollination which results into production of a fruit with a diploid seed and triploid flesh. Upon completion of the first part of this module, students will have aquired not only the knowledge but also the know-how and the appropriate behaviour toward plants. They will also acquire skills of team work which is a tool required for distance learning. The second part of the module covers organs involved in physiological processes (Unit 3) and a comparative study between plant and animal physiology (Unit 4). The students will learn that the basic principles of plant and animal life are quite similar yet their way of life is different. Animal’s way of life is more evolved than that of plants. Animals have developed homeostasis which contributes to maintaining a constant interior environment, despite changes to the exterior environment. Homeostasis is possible because of the various control systems that are characteristic to the animal kingdom. This module allow the student to comprehend the physiology discipline, by highlighting similarities and differences between the animal and plant kingdoms. Furthermore, this module introduced them to an educational approach that relies on the establishment of various elements that will help in problem solving and that emends individual work or team work strongly. In conclusion, a final evaluation is given to help you test your knowledge.
XVI. Final evaluation

True or false questions. Check the correct answer.

1. Potassium is a trace-element
   ☐ True    ☐ False    0,5 point

2. Placenta has an endocrine function
   ☐ True    ☐ False    0,5 point

3. Water’s specific heat capacity allows plants to stabilize their inner temperature
   ☐ True    ☐ False    0,5 point

4. A synapse is either electrical or chemical
   ☐ True    ☐ False    0,5 point

5. The pectocellulosic membrane of root hair is hydrophobic
   ☐ True    ☐ False    0,5 point

6. ADH is an hormone that acts in the negative feedback loop of salt level in human organisms
   ☐ True    ☐ False    0,5 point
Multiple choice questions
Check the correct answer

7. A chloroplast is composed of: 1 point
- 2 pyrrole nuclei with magnesium in the centre
- 3 pyrrole nuclei with magnesium in the centre
- 4 pyrrole nuclei with magnesium in the centre
- 5 pyrrole nuclei with magnesium in the centre

8. Carotenoid pigments contain: 1 point
- carotene only
- xanthophyll only
- carotene and xanthophyll
- none of those pigments

9. Light-harvesting complex and the photosynthetic reaction centre can be found in: 1 point
- different chlorophyllic pigments
- the same chlorophyllic pigment
- specific chlorophyllic pigments

10. CAM means: 1 point
- Carboxylic Acid Metabolism
- Crassulaceae Acid Metabolism
- Chromatic Acid Metabolism

11. The simplest reflex arc involves: 1 point
- one neuron
- two neurons
- three neurons
- four neurons
12. Vasopressin acts on:
- the heart
- the kidneys
- the liver
- the pancreas

Multiple answers questions
13. Hypophysis is:
- a pituitary gland
- a paracrine gland
- an exocrine gland

14. Three of the following criteria are to be considered to determine if a mineral element is necessary or not to plants growth and development:

1 point
- if the lack of this element prevents the completion of the biological cycle;
- if luxury consumption is done with the element
- if the element does not participate directly to plant metabolism;
- if excess of this element is non-toxic to the plant
- if this element cannot be replaced by another element with similar properties;
Annotation

15. Label the diagram using the following words: 3 points
Neurolemma - Nerve impulse direction – Nucleus – Axon terminal – Axon
– Nodes of Ranvier – Dendrite
## Answers

True or false questions. Check the correct answer.

1. Potassium is a trace-element
   - False 0,5 point

2. Placenta has an endocrine function
   - True 0,5 point

3. Water’s specific heat capacity allows plants to stabilize their inner temperature
   - True 0,5 point

4. A synapse is either electrical or chemical
   - True 0,5 point

5. The pectocellulosic membrane of root hair is hydrophobic
   - False 0,5 point

6. ADH is an hormone that acts in the negative feedback loop of salt level in human organisms
   - True 0,5 point

## Questions à choix multiples

7. A chloroplast is composed of : 1 point
   - 4 pyrrole nuclei with magnesium in the centre

8. Carotenoid pigments contain : 1 point
   - carotene and xanthophyll

9. Light-harvesting complex and the photosynthetic reaction centre can be found in : 1 point
   - the same chlorophyllic pigment
10. CAM means : 1 point
   - Crassulaceae Acid Metabolism

11. The simplest reflex arc involves : 1 point
    - two neurons

12. Vasopressin acts on : 1 point
    - the kidneys

Multiple answers questions

13. Hypophysis is : 1 point
    - a pituitary gland
    - an exocrine gland

14. Three of the following criteria are to be considered to determine if a mineral element is necessary or not to plants growth and development : 1 point
   - if the lack of this element prevents the completion of the biological cycle;
   - if the element does not participate directly to plant metabolism;
   - if this element cannot be replaced by another element with similar properties;
15.

Axon
Nodes of Ranvier
Axon terminal
Nervous impulse direction
Neurolemma
Nucleus
XVII. Références

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  http://webiologie.free.fr/cellules/metabolisme/reactions.html

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Wikipedia. (Site visité le 02 /04/07 à 12 h 35). Les principales voies du métabolisme http://fr.wikibooks.org/wiki/Les_principales_voies_du_m%C3%A9tabolisme

Zrýd, Jean-Pierre. Le rôle des hormones dans le développement des végétaux
Université de Lausane http://www2.unil.ch/lpc/images/docu04/illustr_hormones.htm
XVIII. Principal author of the module

Author of « Vegetable and animal physiology »
Author: RAKOTONDRAKOA Rémi
Maître de Conférences at l’Université d’Antananarivo,
Filière Sciences Naturelles,
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E-mail: rakotondradona@yahoo.fr

Resume

He graduated from Washington State University with a PhD in Biology in 1985, he has more than twenty years experience in natural sciences teaching (plant and animal biology) at l’Ecole Normale Supérieure and at l’Ecole Supérieure des Sciences Agronomiques de l’Université d’Antananarivo.

Hired as a research professor at l’Ecole Normale Supérieure d’Antananarivo, he was designated as chief of the Filière des Sciences Naturelles in 1990, then chief of the scientific formation department in 1995 and Director of Studies in 2003 and is still in position to this day. Internationally renowned, he was sent to Hawaii in 1992 as a consultant for microbiological treatment of Soja seeds, then in 1995 he visited universities in France and Belgium to launch the PhD program at l’ENS d’Antananarivo and in 2006, he pursued his teaching mission in Burundi as the resource person for the competences approach in the training of high school inspectors. Besides his own research, he published papers on the effects of rust pesticides on wheat physiology in the state of Washington in 1984, on the tutorial manual of biology for sixth grade in 1999 and on the concrete expression of SVT teaching in colleges and lycées of Antananarivo in 2005.

Finally, he is the president of the naturalists club of ENS and a member of the “Comité de pilotage du basculement vers le système LMD” of l’Université d’Antananarivo.
PHYSIOLOGY OF ANIMALS AND VEGETATION

Required Readings

Source: Wikipedia.org
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Plant physiology

A germination rate experiment

Plant physiology is a subdiscipline of botany concerned with the functioning, or physiology, of plants. Closely related fields include plant morphology (structure of plants), plant ecology (interactions with the environment), phytochemistry (biochemistry of plants), cell biology, and molecular biology.

Fundamental processes such as photosynthesis, respiration, plant nutrition, plant hormone functions, tropisms, nastic movements, photoperiodism, photomorphogenesis, circadian rhythms, environmental stress physiology, seed germination, dormancy and stomata function and transpiration, both part of plant water relations, are studied by plant physiologists.

[] Scope

The field of plant physiology includes the study of all the internal activities of plants—those chemical and physical processes associated with life as they occur in plants. This includes study at many levels of scale of size and time. At the smallest scale are molecular interactions of photosynthesis and internal diffusion of water, minerals, and nutrients. At the largest scale are the processes of plant development, seasonality, dormancy, and reproductive control. Major subdisciplines of plant physiology include phytochemistry (the study of the biochemistry of plants) and phytopathology (the study of disease in plants). The scope of plant physiology as a discipline may be divided into several major areas of research.
Five key areas of study within plant physiology.

First, the study of phytochemistry (plant chemistry) is included within the domain of plant physiology. In order to function and survive, plants produce a wide array of chemical compounds not found in other organisms. Photosynthesis requires a large array of pigments, enzymes, and other compounds to function. Because they cannot move, plants must also defend themselves chemically from herbivores, pathogens, and competition from other plants. They do this by producing toxins and foul-tasting or smelling chemicals. Other compounds defend plants against disease, permit survival during drought, and prepare plants for dormancy. While other compounds are used to attract pollinators or herbivores to spread ripe seeds.

Secondly, plant physiology includes the study of biological and chemical processes of individual plant cells. Plant cells have a number of features that distinguish them from cells of animals, and which lead to major differences in the way that plant life behaves and responds differently from animal life. For example, plant cells have a cell wall which restricts the shape of plant cells and thereby limits the flexibility and mobility of plants. Plant cells also contain chlorophyll, a chemical compound that interacts with light in a way that enables plants to manufacture their own nutrients rather than consuming other living things as animals do.

Thirdly, plant physiology deals with interactions between cells, tissues, and organs within a plant. Different cells and tissues are physically and chemically specialized to perform different functions. Roots and rhizoids function to anchor the plant and acquire minerals in the soil. Leaves function to catch light in order to manufacture nutrients. For both of these organs to remain living, the minerals acquired by the roots must be transported to the leaves and the nutrients manufactured in the leaves must be transported to the roots. Plants have developed a number of means by which this transport may occur, such as vascular tissue, and the functioning of the various modes of transport is studied by plant physiologists.

Fourthly, plant physiologists study the ways that plants control or regulate internal functions. Like animals, plants produce chemicals called hormones which are produced in one part of the plant to signal cells in another part of the plant to respond. Many flowering plants bloom at the appropriate time because of light-sensitive compounds that respond to the length of the night, a phenomenon known as photoperiodism. The ripening of fruit and loss of leaves in the winter are controlled in part by the production of the gas ethylene by the plant.

Finally, plant physiology includes the study of how plants respond to conditions and variation in the environment, a field known as environmental physiology. Stress from water loss, changes in air chemistry, or crowding by other plants can lead to changes in the way a plant functions. These changes may be affected by genetic, chemical, and physical factors.

[ ] Biochemistry of plants
Latex being collected from a tapped rubber tree.
Main article: Phytochemistry

The list of simple elements of which plants are primarily constructed—carbon, oxygen, hydrogen, calcium, phosphorus, etc.—is not different from similar lists for animals, fungi, or even bacteria. The fundamental atomic components of plants are the same as for all life; only the details of the way in which they are assembled differs.

Despite this underlying similarity, plants produce a vast array of chemical compounds with unusual properties which they use to cope with their environment. Pigments are used by plants to absorb or detect light, and are extracted by humans for use in dyes. Other plant products may be used for the manufacture of commercially important rubber or biofuel. Perhaps the most celebrated compounds from plants are those with pharmacological activity, such as salicylic acid (aspirin), morphine, and digitalis. Drug companies spend billions of dollars each year researching plant compounds for potential medicinal benefits.

[] Constituent elements

Further information: Plant nutrition

Plants require some nutrients, such as carbon and nitrogen, in large quantities to survive. Such nutrients are termed macronutrients, where the prefix *macro-* (large) refers to the quantity needed, not the size of the nutrient particles themselves. Other nutrients, called micronutrients, are required only in trace amounts for plants to remain healthy. Such micronutrients are usually absorbed as ions dissolved in water taken from the soil, though carnivorous plants acquire some of their micronutrients from captured prey.

The following tables list element nutrients essential to plants. Uses within plants are generalized.
### Macronutrients. (Necessary in large quantities)

<table>
<thead>
<tr>
<th>Element</th>
<th>Form of uptake</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>NO$_3^-$, NH$_4^+$</td>
<td>Nucleic acids, proteins, hormones, etc.</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O$_2$, H$_2$O</td>
<td>Cellulose, starch, other organic compounds</td>
</tr>
<tr>
<td>Carbon</td>
<td>CO$_2$</td>
<td>Cellulose, starch, other organic compounds</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H$_2$O</td>
<td>Cellulose, starch, other organic compounds</td>
</tr>
<tr>
<td>Potassium</td>
<td>K$^+$</td>
<td>Cofactor in protein synthesis, water balance, etc.</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca$^{2+}$</td>
<td>Membrane synthesis and stabilization</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg$^{2+}$</td>
<td>Element essential for chlorophyll</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>H$_2$PO$_4^-$</td>
<td>Nucleic acids, phospholipids, ATP</td>
</tr>
<tr>
<td>Sulfur</td>
<td>SO$_4^{2-}$</td>
<td>Constituent of proteins and coenzymes</td>
</tr>
</tbody>
</table>

### Micronutrients. (Necessary in small quantities)

<table>
<thead>
<tr>
<th>Element</th>
<th>Form of uptake</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine</td>
<td>Cl$^-$</td>
<td>Photosystem II and stomata function</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe$^{2+}$, Fe$^{3+}$</td>
<td>Chorophyll formation</td>
</tr>
<tr>
<td>Boron</td>
<td>HBO$_3$</td>
<td>Crosslinking pectin</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn$^{2+}$</td>
<td>Activity of some enzymes</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn$^{2+}$</td>
<td>Involved in the synthesis of enzymes and chlorophyll</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu$^+$</td>
<td>Enzymes for lignin synthesis</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>MoO$_4^{2-}$</td>
<td>Nitrogen fixation, reduction of nitrates</td>
</tr>
<tr>
<td>Nickel</td>
<td>Ni$^{2+}$</td>
<td>Enzymatic cofactor in the metabolism of nitrogen compounds</td>
</tr>
</tbody>
</table>

[] **Pigments**

![Space-filling model of the chlorophyll molecule.](image-url)
Anthocyanin gives these pansies their dark purple pigmentation. Main article: Biological pigment

Among the most important molecules for plant function are the pigments. Plant pigments include a variety of different kinds of molecules, including porphyrins, carotenoids, and anthocyanins. All biological pigments selectively absorb certain wavelengths of light while reflecting others. The light that is absorbed may be used by the plant to power chemical reactions, while the reflected wavelengths of light determine the color the pigment will appear to the eye.

Chlorophyll is the primary pigment in plants; it is a porphyrin that absorbs red and blue wavelengths of light while reflecting green. It is the presence and relative abundance of chlorophyll that gives plants their green color. All land plants and green algae possess two forms of this pigment: chlorophyll \( a \) and chlorophyll \( b \). Kelps, diatoms, and other photosynthetic heterokonts contain chlorophyll \( c \) instead of \( b \), while red algae possess only chlorophyll \( a \). All chlorophylls serve as the primary means plants use to intercept light in order to fuel photosynthesis.

Carotenoids are red, orange, or yellow tetraterpenoids. They function as accessory pigments in plants, helping to fuel photosynthesis by gathering wavelengths of light not readily absorbed by chlorophyll. The most familiar carotenoids are carotene (an orange pigment found in carrots), lutein (a yellow pigment found in fruits and vegetables), and lycopene (the red pigment responsible for the color of tomatoes). Carotenoids have been shown to act as antioxidants and to promote healthy eyesight in humans.

Anthocyanins (literally "flower blue") are water-soluble flavonoid pigments that appear red to blue, according to pH. They occur in all tissues of higher plants, providing color in leaves, stems, roots, flowers, and fruits, though not always in sufficient quantities to be noticeable. Anthocyanins are most visible in the petals of flowers, where they may make up as much as 30% of the dry weight of the tissue. They are also responsible for the purple color seen on the underside of tropical shade plants such as \( Tradescantia zebrina \); in these plants, the anthocyanin catches light that has passed through the leaf and reflects it back towards regions bearing chlorophyll, in order to maximize the use of available light.

Betalains are red or yellow pigments. Like anthocyanins they are water-soluble, but unlike anthocyanins they are indole-derived compounds synthesized from tyrosine. This class of pigments is found only in the Caryophyllales (including cactus and amaranth), and never co-occur in plants with anthocyanins. Betalains are responsible for the deep red color of beets, and are used commercially as food-coloring agents. Plant physiologists are uncertain of the function that betalains have in plants which possess them, but there is some preliminary evidence that they may have fungicidal properties.

[] Signals and regulators

8
A mutation that stops *Arabidopsis thaliana* responding to auxin causes abnormal growth (right)

Plants produce hormones and other growth regulators which act to signal a physiological response in their tissues. They also produce compounds such as phytochrome that are sensitive to light and which serve to trigger growth or development in response to environmental signals.

[] Plant hormones

Main article: Plant hormone

Plant hormones, also known as plant growth regulators (PGRs) or phytohormones, are chemicals that regulate a plant's growth. According to a standard animal definition, hormones are signal molecules produced at specific locations, that occur in very low concentrations, and cause altered processes in target cells at other locations. Unlike animals, plants lack specific hormone-producing tissues or organs. Plant hormones are often not transported to other parts of the plant and production is not limited to specific locations.

Plant hormones are chemicals that in small amounts promote and influence the growth, development and differentiation of cells and tissues. Hormones are vital to plant growth; affecting processes in plants from flowering to seed development, dormancy, and germination. They regulate which tissues grow upwards and which grow downwards, leaf formation and stem growth, fruit development and ripening, as well as leaf abscission and even plant death.

The most important plant hormones are abscissic acid (ABA), auxins, gibberellins, and cytokinins, though there are many other substances that serve to regulate plant physiology.
Photomorphogenesis

Main article: Photomorphogenesis

While most people know that light is important for photosynthesis in plants, few realize that plant sensitivity to light plays a role in the control of plant structural development (morphogenesis). The use of light to control structural development is called photomorphogenesis, and is dependent upon the presence of specialized photoreceptors, which are chemical pigments capable of absorbing specific wavelengths of light.

Plants use four kinds of photoreceptors: phytochrome, cryptochrome, a UV-B photoreceptor, and protochlorophyllide a. The first two of these, phytochrome and cryptochrome, are photoreceptor proteins, complex molecular structures formed by joining a protein with a light-sensitive pigment. Cryptochrome is also known as the UV-A photoreceptor, because it absorbs ultraviolet light in the long wave "A" region. The UV-B receptor is one or more compounds that have yet to be identified with certainty, though some evidence suggests carotene or riboflavin as candidates. Protochlorophyllide a, as its name suggests, is a chemical precursor of chlorophyll.

The most studied of the photoreceptors in plants is phytochrome. It is sensitive to light in the red and far-red region of the visible spectrum. Many flowering plants use it to regulate the time of flowering based on the length of day and night (photoperiodism) and to set circadian rhythms. It also regulates other responses including the germination of seeds, elongation of seedlings, the size, shape and number of leaves, the synthesis of chlorophyll, and the straightening of the epicotyl or hypocotyl hook of dicot seedlings.

Photoperiodism

The poinsettia is a short-day plant, requiring two months of long nights prior to blooming. Main article: Photoperiodism

Many flowering plants use the pigment phytochrome to sense seasonal changes in day length, which they take as signals to flower. This sensitivity to day length is termed photoperiodism. Broadly speaking, flowering plants can be classified as long day plants, short day plants, or day neutral plants, depending on their particular response to changes in day length. Long day plants require a certain minimum length of daylight to initiate flowering, so these plants flower in the spring or summer. Conversely, short day plants will flower when the length of daylight falls...
below a certain critical level. Day neutral plants do not initiate flowering based on photoperiodism, though some may use temperature sensitivity (vernalization) instead.

Although a short day plant cannot flower during the long days of summer, it is not actually the period of light exposure that limits flowering. Rather, a short day plant requires a minimal length of uninterrupted darkness in each 24 hour period (a short daylength) before floral development can begin. It has been determined experimentally that a short day plant (long night) will not flower if a flash of phytochrome activating light is used on the plant during the night.

Plants make use of the phytochrome system to sense day length or photoperiod. This fact is utilized by florists and greenhouse gardeners to control and even induce flowering out of season, such as the Poinsettia.

[] Environmental physiology

Phototropism in *Arabidopsis thaliana* is regulated by blue to UV light.[5]

Main article: Ecophysiology

Paradoxically, the subdiscipline of environmental physiology is on the one hand a recent field of study in plant ecology and on the other hand one of the oldest.[1] Environmental physiology is the preferred name of the subdiscipline among plant physiologists, but it goes by a number of other names in the applied sciences. It is roughly synonymous with ecophysiology, crop ecology, horticulture and agronomy. The particular name applied to the subdiscipline is specific to the viewpoint and goals of research. Whatever name is applied, it deals with the ways in which plants respond to their environment and so overlaps with the field of ecology.

Environmental physiologists examine plant response to physical factors such as radiation (including light and ultraviolet radiation), temperature, fire, and wind. Of particular importance
are water relations (which can be measured with the Pressure bomb) and the stress of drought or inundation, exchange of gases with the atmosphere, as well as the cycling of nutrients such as nitrogen and carbon.

Environmental physiologists also examine plant response to biological factors. This includes not only negative interactions, such as competition, herbivory, disease and parasitism, but also positive interactions, such as mutualism and pollination.

[] **Tropisms and nastic movements**

Main articles: Tropism and Nastic movement

Plants may respond both to directional and nondirectional stimuli. A response to a directional stimulus, such as gravity or sunlight, is called a tropism. A response to a nondirectional stimulus, such as temperature or humidity, is a nastic movement.

Tropisms in plants are the result of differential cell growth, in which the cells on one side of the plant elongate more than those on the other side, causing the part to bend toward the side with less growth. Among the common tropisms seen in plants is phototropism, the bending of the plant toward a source of light. Phototropism allows the plant to maximize light exposure in plants which require additional light for photosynthesis, or to minimize it in plants subjected to intense light and heat. Geotropism allows the roots of a plant to determine the direction of gravity and grow downwards. Tropisms generally result from an interaction between the environment and production of one or more plant hormones.

In contrast to tropisms, nastic movements result from changes in turgor pressure within plant tissues, and may occur rapidly. A familiar example is thigmonasty (response to touch) in the Venus fly trap, a carnivorous plant. The traps consist of modified leaf blades which bear sensitive trigger hairs. When the hairs are touched by an insect or other animal, the leaf folds shut. This mechanism allows the plant to trap and digest small insects for additional nutrients. Although the trap is rapidly shut by changes in internal cell pressures, the leaf must grow slowly in order to reset for a second opportunity to trap insects. [6]

[] **Plant disease**

_powdery mildew on crop leaves_
Economically, one of the most important areas of research in environmental physiology is that of phytopathology, the study of diseases in plants and the manner in which plants resist or cope with infection. Plant are susceptible to the same kinds of disease organisms as animals, including viruses, bacteria, and fungi, as well as physical invasion by insects and roundworms.

Because the biology of plants differs from animals, their symptoms and responses are quite different. In some cases, a plant can simply shed infected leaves or flowers to prevent to spread of disease, in a process called abscission. Most animals do not have this option as a means of controlling disease. Plant diseases organisms themselves also differ from those causing disease in animals because plants cannot usually spread infection through casual physical contact. Plant pathogens tend to spread via spores or are carried by animal vectors.

One of the most important advances in the control of plant disease was the discovery of Bordeaux mixture in the nineteenth century. The mixture is the first known fungicide and is a combination of copper sulfate and lime. Application of the mixture served to inhibit the growth of downy mildew that threatened to seriously damage the French wine industry.[7]

[] History

[] Early history

Jan Baptist van Helmont.

Sir Francis Bacon published one of the first plant physiology experiments in 1627 in the book, *Sylva Sylvarum*. Bacon grew several terrestrial plants, including a rose, in water and concluded that soil was only needed to keep the plant upright. Jan Baptist van Helmont published what is considered the first quantitative experiment in plant physiology in 1648. He grew a willow tree...
for five years in a pot containing 200 pounds of oven-dry soil. The soil lost just two ounces of dry weight and van Helmont concluded that plants get all their weight from water, not soil. In 1699, John Woodward published experiments on growth of spearmint in different sources of water. He found that plants grew much better in water with soil added than in distilled water.

Stephen Hales is considered the Father of Plant Physiology for the many experiments in the 1727 book[^8]; though Julius von Sachs unified the pieces of plant physiology and put them together as a discipline. His *Lehrbuch der Botanik* was the plant physiology bible of its time.[^9]

Researchers discovered in the 1800s that plants absorb essential mineral nutrients as inorganic ions in water. In natural conditions, soil acts as a mineral nutrient reservoir but the soil itself is not essential to plant growth. When the mineral nutrients in the soil are dissolved in water, plant roots absorb nutrients readily, soil is no longer required for the plant to thrive. This observation is the basis for hydroponics, the growing of plants in a water solution rather than soil, which has become a standard technique in biological research, teaching lab exercises, crop production and as a hobby.

[] Current research

One of the leading journals in the field is *Plant Physiology*, started in 1926. All its back issues are available online for free.[1] Many other journals often carry plant physiology articles, including *Physiologia Plantarum*, *Journal of Experimental Botany*, *American Journal of Botany*, *Annals of Botany*, *Journal of Plant Nutrition* and *Proceedings of the National Academy of Sciences*.

[] Economic applications

[] Food production

Further information: Agriculture and Horticulture

In horticulture and agriculture along with food science, plant physiology is an important topic relating to fruits, vegetables, and other consumable parts of plants. Topics studied include: climatic requirements, fruit drop, nutrition, ripening, fruit set. The production of food crops also hinges on the study of plant physiology covering such topics as Optimal planting and harvesting times and post harvest storage of plant products for human consumption and the production of secondary products like drugs and cosmetics.

Nutrition
**Nutrition** (also called *nourishment* or *aliment*) is the provision, to cells and organisms, of the materials necessary (in the form of food) to support life. Many common health problems can be prevented or alleviated with a healthy diet.

The diet of an organism is what it eats, and is largely determined by the perceived palatability of foods. Dietitians are health professionals who specialize in human nutrition, meal planning, economics, and preparation. They are trained to provide safe, evidence-based dietary advice and management to individuals (in health and disease), as well as to institutions.

A poor diet can have an injurious impact on health, causing deficiency diseases such as scurvy, beriberi, and kwashiorkor; health-threatening conditions like obesity and metabolic syndrome, and such common chronic systemic diseases as cardiovascular disease, diabetes, and osteoporosis.

[] **Animal nutrition**

[] **Overview**

Nutritional science investigates the metabolic and physiological responses of the body to diet. With advances in the fields of molecular biology, biochemistry, and genetics, the study of nutrition is increasingly concerned with metabolism and metabolic pathways: the sequences of biochemical steps through which substances in living things change from one form to another.

The human body contains chemical compounds, such as water, carbohydrates (sugar, starch, and fiber), amino acids (in proteins), fatty acids (in lipids), and nucleic acids (DNA and RNA). These compounds in turn consist of elements such as carbon, hydrogen, oxygen, nitrogen, phosphorus, calcium, iron, zinc, magnesium, manganese, and so on. All of these chemical compounds and elements occur in various forms and combinations (e.g. hormones, vitamins, phospholipids, hydroxyapatite), both in the human body and in the plant and animal organisms that humans eat.

The human body consists of elements and compounds ingested, digested, absorbed, and circulated through the bloodstream to feed the cells of the body. Except in the unborn fetus, the digestive system is the first system involved. In a typical adult, about seven liters of digestive juices enter the lumen of the digestive tract. These break chemical bonds in ingested molecules, and modulate their conformations and energy states. Though some molecules are absorbed into the bloodstream unchanged, digestive processes release them from the matrix of foods. Unabsorbed matter, along with some waste products of metabolism, is eliminated from the body in the feces.

Studies of nutritional status must take into account the state of the body before and after experiments, as well as the chemical composition of the whole diet and of all material excreted and eliminated from the body (in urine and feces). Comparing the food to the waste can help determine the specific compounds and elements absorbed and metabolized in the body. The effects of nutrients may only be discernible over an extended period, during which all food and waste must be analyzed. The number of variables involved in such experiments is high, making
nutritional studies time-consuming and expensive, which explains why the science of human nutrition is still slowly evolving.

In general, eating a wide variety of fresh, whole (unprocessed), foods has proven favorable compared to monotonous diets based on processed foods.[1] In particular, the consumption of whole-plant foods slows digestion and allows better absorption, and a more favorable balance of essential nutrients per Calorie, resulting in better management of cell growth, maintenance, and mitosis (cell division), as well as better regulation of appetite and blood sugar[citation needed]. Regularly scheduled meals (every few hours) have also proven more wholesome than infrequent or haphazard ones.[citation needed]

[] Nutrients

Main article: Nutrient

There are six major classes of nutrients: carbohydrates, fats, minerals, protein, vitamin, and water.

These nutrient classes can be categorized as either macronutrients (needed in relatively large amounts) or micronutrients (needed in smaller quantities). The macronutrients are carbohydrates, fats, fiber, proteins, and water. The micronutrients are minerals and vitamins.

The macronutrients (excluding fiber and water) provide structural material (amino acids from which proteins are built, and lipids from which cell membranes and some signaling molecules are built), energy. Some of the structural material can be used to generate energy internally, and in either case it is measured in Joules or kilocalories (often called "Calories" and written with a capital C to distinguish them from little 'c' calories). Carbohydrates and proteins provide 17 kJ approximately (4 kcal) of energy per gram, while fats provide 37 kJ (9 kcal) per gram,[2], though the net energy from either depends on such factors as absorption and digestive effort, which vary substantially from instance to instance. Vitamins, minerals, fiber, and water do not provide energy, but are required for other reasons. A third class dietary material, fiber (i.e., non-digestible material such as cellulose), seems also to be required, for both mechanical and biochemical reasons, though the exact reasons remain unclear.

Molecules of carbohydrates and fats consist of carbon, hydrogen, and oxygen atoms. Carbohydrates range from simple monosaccharides (glucose, fructose, galactose) to complex polysaccharides (starch). Fats are triglycerides, made of assorted fatty acid monomers bound to glycerol backbone. Some fatty acids, but not all, are essential in the diet: they cannot be synthesized in the body. Protein molecules contain nitrogen atoms in addition to carbon, oxygen, and hydrogen. The fundamental components of protein are nitrogen-containing amino acids, some of which are essential in the sense that humans cannot make them internally. Some of the amino acids are convertible (with the expenditure of energy) to glucose and can be used for energy production just as ordinary glucose. By breaking down existing protein, some glucose can be produced internally; the remaining amino acids are discarded, primarily as urea in urine. This occurs normally only during prolonged starvation.
Other micronutrients include antioxidants and phytochemicals which are said to influence (or protect) some body systems. Their necessity is not as well established as in the case of, for instance, vitamins.

Most foods contain a mix of some or all of the nutrient classes, together with other substances such as toxins or various sorts. Some nutrients can be stored internally (e.g., the fat soluble vitamins), while others are required more or less continuously. Poor health can be caused by a lack of required nutrients or, in extreme cases, too much of a required nutrient. For example, both salt and water (both absolutely required) will cause illness or even death in too large amounts.

[] Carbohydrates

Main article: Carbohydrate

Toasted bread is a cheap, high calorie nutrient (usually unbalanced, i.e., deficient in essential minerals and vitamins, largely because of removal of both germ and bran during processing) food source.

Carbohydrates may be classified as monosaccharides, disaccharides, or polysaccharides depending on the number of monomer (sugar) units they contain. They constitute a large part of foods such as rice, noodles, bread, and other grain-based products. Monosaccharides contain one sugar unit, disaccharides two, and polysaccharides three or more. Polysaccharides are often referred to as complex carbohydrates because they are typically long multiple branched chains of sugar units. The difference is that complex carbohydrates take slightly longer to digest and absorb since their sugar units must be separated from the chain before absorption. The spike in blood glucose levels after ingestion of simple sugars is thought to be related to some of the heart and vascular diseases which have become more frequent in recent times. Simple sugars form a greater part of modern diets than formerly, perhaps leading to more cardiovascular disease. The degree of causation is still not clear, however.

Simple carbohydrates are absorbed quickly, and therefore raise blood-sugar levels more rapidly than other nutrients. However, the most important plant carbohydrate nutrient, starch, varies in its absorption. Gelatinized starch (starch heated for a few minutes in the presence of water) is far more digestible than plain starch. And starch which has been divided into fine particles is also more absorbable during digestion. The increased effort and decreased availability reduces the available energy from starchy foods substantially and can be seen experimentally in rats and anecdotaly in humans. Additionally, up to a third of dietary starch may be unavailable due to mechanical or chemical difficulty.
Carbohydrates are not essential to the human diet, as they are relatively low in vitamins and minerals, and energy can be provided from excess fats and proteins in the diet.

[] Fiber

Main article: Dietary fiber

Dietary fiber is a carbohydrate (or a polysaccharide) that is incompletely absorbed in humans and in some animals. Like all carbohydrates, when it is metabolized it can produce four Calories (kilocalories) of energy per gram. But in most circumstances it accounts for less than that because of its limited absorption and digestibility. Dietary fiber consists mainly of cellulose, a large carbohydrate polymer that is indigestible because humans do not have the required enzymes to disassemble it. There are two subcategories: soluble and insoluble fiber. Whole grains, fruits (especially plums, prunes, and figs), and vegetables are good sources of dietary fiber. There are many health benefits of a high-fiber diet. Dietary fiber helps reduce the chance of gastrointestinal problems such as constipation and diarrhea by increasing the weight and size of stool and softening it. Insoluble fiber, found in whole-wheat flour, nuts and vegetables, especially stimulates peristalsis -- the rhythmic muscular contractions of the intestines which move digesta along the digestive tract. Soluble fiber, found in oats, peas, beans, and many fruits, helps dissolve water in the intestinal tract to produce a gel which slows the movement of food through the intestines. This may help lower blood glucose levels because it can slow the absorption of sugar. Additionally, fiber, perhaps especially that from whole grains, is thought to possibly help lessen insulin spikes, and therefore reduce the risk of type 2 diabetes. The link between increased fiber consumption and a decreased risk of colorectal cancer is still uncertain.[3]

[] Fat

Main article: Fat

A molecule of dietary fat typically consists of several fatty acids (containing long chains of carbon and hydrogen atoms), bonded to a glycerol. They are typically found as triglycerides (three fatty acids attached to one glycerol backbone). Fats may be classified as saturated or unsaturated depending on the detailed structure of the fatty acids involved. Saturated fats have all of the carbon atoms in their fatty acid chains bonded to hydrogen atoms, whereas unsaturated fats have some of these carbon atoms double-bonded, so their molecules have relatively fewer hydrogen atoms than a saturated fatty acid of the same length. Unsaturated fats may be further classified as monounsaturated (one double-bond) or polyunsaturated (many double-bonds). Furthermore, depending on the location of the double-bond in the fatty acid chain, unsaturated fatty acids are classified as omega-3 or omega-6 fatty acids. Trans fats are a type of unsaturated fat with trans-isomer bonds; these are rare in nature and in foods from natural sources; they are typically created in an industrial process called (partial) hydrogenation.

Saturated fats (typically from animal sources) are best in the human diet, as they have been a staple in many of the world's cultures for many millennia. Unsaturated fats, (for example,
vegetable oil) are next, while trans fats are to be avoided. Saturated and some trans fats are typically solid at room temperature (such as butter or lard), while unsaturated fats are typically liquids (such as olive oil or flaxseed oil). Trans fats are very rare in nature, but have properties useful in the food processing industry, such as rancidity resistance.\[citation needed]\]

[[] Essential fatty acids

Main article: Essential fatty acids

Most fatty acids are non-essential, meaning the body can produce them as needed, generally from other fatty acids and always by expending energy to do so. However, in humans at least two fatty acids are essential and must be included in the diet. An appropriate balance of essential fatty acids—omega-3 and omega-6 fatty acids—seems also important for health, though definitive experimental demonstration has been elusive. Both of these "omega" long-chain polyunsaturated fatty acids are substrates for a class of eicosanoids known as prostaglandins, which have roles throughout the human body. They are hormones, in some respects. The omega-3 eicosapentaenoic acid (EPA), which can be made in the human body from the omega-3 essential fatty acid alpha-linolenic acid (LNA), or taken in through marine food sources, serves as a building block for series 3 prostaglandins (e.g. weakly inflammatory PGE3). The omega-6 dihomogamma-linolenic acid (DGLA) serves as a building block for series 1 prostaglandins (e.g. anti-inflammatory PGE1), whereas arachidonic acid (AA) serves as a building block for series 2 prostaglandins (e.g. pro-inflammatory PGE 2). Both DGLA and AA can be made from the omega-6 linoleic acid (LA) in the human body, or can be taken in directly through food. An appropriately balanced intake of omega-3 and omega-6 partly determines the relative production of different prostaglandins: one reason a balance between omega-3 and omega-6 is believed important for cardiovascular health. In industrialized societies, people typically consume large amounts of processed vegetable oils, which have reduced amounts of the essential fatty acids along with too much of omega-6 fatty acids relative to omega-3 fatty acids.

The conversion rate of omega-6 DGLA to AA largely determines the production of the prostaglandins PGE1 and PGE2. Omega-3 EPA prevents AA from being released from membranes, thereby skewing prostaglandin balance away from pro-inflammatory PGE2 (made from AA) toward anti-inflammatory PGE1 (made from DGLA). Moreover, the conversion (desaturation) of DGLA to AA is controlled by the enzyme delta-5-desaturase, which in turn is controlled by hormones such as insulin (up-regulation) and glucagon (down-regulation). The amount and type of carbohydrates consumed, along with some types of amino acid, can influence processes involving insulin, glucagon, and other hormones; therefore the ratio of omega-3 versus omega-6 has wide effects on general health, and specific effects on immune function and inflammation, and mitosis (i.e. cell division).

[] Protein
Most meats such as chicken contain all the essential amino acids needed for humans
Main article: Protein in nutrition

Proteins are the basis of many animal body structures (e.g. muscles, skin, and hair). They also form the enzymes which control chemical reactions throughout the body. Each molecule is composed of amino acids which are characterized by inclusion of nitrogen and sometimes sulphur (these components are responsible for the distinctive smell of burning protein, such as the keratin in hair). The body requires amino acids to produce new proteins (protein retention) and to replace damaged proteins (maintenance). As there is no protein or amino acid storage provision, amino acids must be present in the diet. Excess amino acids are discarded, typically in the urine. For all animals, some amino acids are essential (an animal cannot produce them internally) and some are non-essential (the animal can produce them from other nitrogen-containing compounds). About twenty amino acids are found in the human body, and about ten of these are essential, and therefore must be included in the diet. A diet that contains adequate amounts of amino acids (especially those that are essential) is particularly important in some situations: during early development and maturation, pregnancy, lactation, or injury (a burn, for instance). A complete protein source contains all the essential amino acids; an incomplete protein source lacks one or more of the essential amino acids.

It is possible to combine two incomplete protein sources (e.g. rice and beans) to make a complete protein source, and characteristic combinations are the basis of distinct cultural cooking traditions. Sources of dietary protein include meats, tofu and other soy-products, eggs, legumes, and dairy products such as milk and cheese. Excess amino acids from protein can be converted into glucose and used for fuel through a process called gluconeogenesis. The amino acids remaining after such conversion are discarded.

[] Minerals

Main article: Dietary mineral

Dietary minerals are the chemical elements required by living organisms, other than the four elements carbon, hydrogen, nitrogen, and oxygen that are present in nearly all organic molecules. The term "mineral" is archaic, since the intent is to describe simply the less common elements in the diet. Some are heavier than the four just mentioned—including several metals, which often occur as ions in the body. Some dietitians recommend that these be supplied from foods in which they occur naturally, or at least as complex compounds, or sometimes even from natural inorganic sources (such as calcium carbonate from ground oyster shells). Some are absorbed much more readily in the ionic forms found in such sources. On the other hand, minerals are
often artificially added to the diet as supplements; the most famous is likely iodine in iodized salt which prevents goiter.

[] Macrominerals

Many elements are essential in relative quantity; they are usually called "bulk minerals". Some are structural, but many play a role as electrolytes. Elements with recommended dietary allowance (RDA) greater than 200 mg/day are, in alphabetical order (with informal or folk-medicine perspectives in parentheses):

- Calcium, a common electrolyte, but also needed structurally (for muscle and digestive system health, bones, some forms neutralizes acidity, may help clear toxins, and provide signaling ions for nerve and membrane functions)
- Chlorine as chloride ions; very common electrolyte; see sodium, below
- Magnesium, required for processing ATP and related reactions (builds bone, causes strong peristalsis, increases flexibility, increases alkalinity)
- Phosphorus, required component of bones; essential for energy processing
- Potassium, a very common electrolyte (heart and nerve health)
- Sodium, a very common electrolyte; not generally found in dietary supplements, despite being needed in large quantities, because the ion is very common in food: typically as sodium chloride, or common salt. Excessive sodium consumption can deplete calcium and magnesium, leading to high blood pressure and osteoporosis.
- Sulfur for three essential amino acids and therefore many proteins (skin, hair, nails, liver, and pancreas)

[] Trace minerals

Many elements are required in trace amounts, usually because they play a catalytic role in enzymes. Some trace mineral elements (RDA < 200 mg/day) are, in alphabetical order:

- Cobalt required for biosynthesis of vitamin B12 family of coenzymes
- Copper required component of many redox enzymes, including cytochrome c oxidase
- Chromium required for sugar metabolism
- Iodine required not only for the biosynthesis of thyroxin, but probably, for other important organs as breast, stomach, salivary glands, thymus etc. (see Extrathyroidal iodine); for this reason iodine is needed in larger quantities than others in this list, and sometimes classified with the macrominerals
- Iron required for many enzymes, and for hemoglobin and some other proteins
- Manganese (processing of oxygen)
- Molybdenum required for xanthine oxidase and related oxidases
- Nickel present in urease
- Selenium required for peroxidase (antioxidant proteins)
- Vanadium (Speculative: there is no established RDA for vanadium. No specific biochemical function has been identified for it in humans, although vanadium is required for some lower organisms.)
- Zinc required for several enzymes such as carboxypeptidase, liver alcohol dehydrogenase, carbonic anhydrase
Vitamins

As with the minerals discussed above, some vitamins are recognized as essential nutrients, necessary in the diet for good health. (Vitamin D is the exception: it can alternatively be synthesized in the skin, in the presence of UVB radiation.) Certain vitamin-like compounds that are recommended in the diet, such as carnitine, are thought useful for survival and health, but these are not "essential" dietary nutrients because the human body has some capacity to produce them from other compounds. Moreover, thousands of different phytochemicals have recently been discovered in food (particularly in fresh vegetables), which may have desirable properties including antioxidant activity (see below); experimental demonstration has been suggestive but inconclusive. Other essential nutrients not classed as vitamins include essential amino acids (see above), choline, essential fatty acids (see above), and the minerals discussed in the preceding section.

Vitamin deficiencies may result in disease conditions: goitre, scurvy, osteoporosis, impaired immune system, disorders of cell metabolism, certain forms of cancer, symptoms of premature aging, and poor psychological health (including eating disorders), among many others. Excess of some vitamins is also dangerous to health (notably vitamin A), and for at least one vitamin, B6, toxicity begins at levels not far above the required amount. Deficiency or excess of minerals can also have serious health consequences.

Water

It is not fully clear how much water intake is needed by healthy people, although some experts assert that 8–10 glasses of water (approximately 2 liters) daily is the minimum to maintain proper hydration. The notion that a person should consume eight glasses of water per day cannot be traced to a credible scientific source. The effect of, greater or lesser, water intake on weight loss and on constipation is also still unclear. The original water intake recommendation in 1945 by the Food and Nutrition Board of the National Research Council read: "An ordinary standard for diverse persons is 1 milliliter for each calorie of food. Most of this quantity is contained in prepared foods." The latest dietary reference intake report by the United States
National Research Council recommended, generally, (including food sources): 2.7 liters of water total for women and 3.7 liters for men.\(^{[12]}\) Specifically, pregnant and breastfeeding women need additional fluids to stay hydrated. According to the Institute of Medicine—who recommend that, on average, women consume 2.2 litres and men 3.0 litres—this is recommended to be 2.4 litres (approx. 9 cups) for pregnant women and 3 litres (approx. 12.5 cups) for breastfeeding women since an especially large amount of fluid is lost during nursing.\(^{[13]}\)

For those who have healthy kidneys, it is somewhat difficult to drink too much water,\[^{[citation needed]}\] but (especially in warm humid weather and while exercising) it is dangerous to drink too little. People can drink far more water than necessary while exercising, however, putting them at risk of water intoxication, which can be fatal. In particular large amounts of de-ionized water are dangerous.

Normally, about 20 percent of water intake comes in food, while the rest comes from drinking water and assorted beverages (caffeinated included). Water is excreted from the body in multiple forms; including urine and feces, sweating, and by water vapor in the exhaled breath.

[] Other nutrients

Other micronutrients include antioxidants and phytochemicals. These substances are generally more recent discoveries which have not yet been recognized as vitamins or as required. Phytochemicals may act as antioxidants, but not all phytochemicals are antioxidants.\[^{[citation needed]}\]

[] Antioxidants

Main article: Antioxidant

As cellular metabolism/energy production requires oxygen, potentially damaging (e.g. mutation causing) compounds known as free radicals can form. Most of these are oxidizers (i.e. acceptors of electrons) and some react very strongly. For normal cellular maintenance, growth, and division, these free radicals must be sufficiently neutralized by antioxidant compounds. Recently, some researchers suggested an interesting theory of evolution of dietary antioxidants. Some are produced by the human body with adequate precursors (glutathione, Vitamin C) and those the body cannot produce may only be obtained in the diet via direct sources (Vitamin C in humans, Vitamin A, Vitamin K) or produced by the body from other compounds (Beta-carotene converted to Vitamin A by the body, Vitamin D synthesized from cholesterol by sunlight). Phytochemicals (Section Below) and their subgroup polyphenols are the majority of antioxidants; about 4,000 are known. Different antioxidants are now known to function in a cooperative network, e.g. vitamin C can reactivate free radical-containing glutathione or vitamin E by accepting the free radical itself, and so on. Some antioxidants are more effective than others at neutralizing different free radicals. Some cannot neutralize certain free radicals. Some cannot be present in certain areas of free radical development (Vitamin A is fat-soluble and protects fat areas, Vitamin C is water soluble and protects those areas). When interacting with a free radical, some antioxidants produce a different free radical compound that is less dangerous or more dangerous than the previous compound. Having a variety of antioxidants allows any byproducts to be safely dealt with by more efficient antioxidants in neutralizing a free radical's butterfly effect.
Although initial studies suggested that antioxidant supplements might promote health, later large clinical trials did not detect any benefit and suggested instead that excess supplementation may be harmful.\[^{14}\]

[] Phytochemicals

Blackberries are a source of polyphenol antioxidants
Main article: Phytochemical

A growing area of interest is the effect upon human health of trace chemicals, collectively called phytochemicals. These nutrients are typically found in edible plants, especially colorful fruits and vegetables, but also other organisms including seafood, algae, and fungi. The effects of phytochemicals increasingly survive rigorous testing by prominent health organizations. One of the principal classes of phytochemicals are polyphenol antioxidants, chemicals which are known to provide certain health benefits to the cardiovascular system and immune system. These chemicals are known to down-regulate the formation of reactive oxygen species, key chemicals in cardiovascular disease.

Perhaps the most rigorously tested phytochemical is zeaxanthin, a yellow-pigmented carotenoid present in many yellow and orange fruits and vegetables. Repeated studies have shown a strong correlation between ingestion of zeaxanthin and the prevention and treatment of age-related macular degeneration (AMD).\[^{15}\] Less rigorous studies have proposed a correlation between zeaxanthin intake and cataracts.\[^{16}\] A second carotenoid, lutein, has also been shown to lower the risk of contracting AMD. Both compounds have been observed to collect in the retina when ingested orally, and they serve to protect the rods and cones against the destructive effects of light.

Another carotenoid, beta-cryptoxanthin, appears to protect against chronic joint inflammatory diseases, such as arthritis. While the association between serum blood levels of beta-cryptoxanthin and substantially decreased joint disease has been established, neither a convincing mechanism for such protection nor a cause-and-effect have been rigorously studied.\[^{17}\] Similarly, a red phytochemical, lycopene, has substantial credible evidence of negative association with development of prostate cancer.

The correlations between the ingestion of some phytochemicals and the prevention of disease are, in some cases, enormous in magnitude.
Even when the evidence is obtained, translating it to practical dietary advice can be difficult and counter-intuitive. Lutein, for example, occurs in many yellow and orange fruits and vegetables and protects the eyes against various diseases. However, it does not protect the eye nearly as well as zeaxanthin, and the presence of lutein in the retina will prevent zeaxanthin uptake. Additionally, evidence has shown that the lutein present in egg yolk is more readily absorbed than the lutein from vegetable sources, possibly because of fat solubility.[18] At the most basic level, the question "should you eat eggs?" is complex to the point of dismay, including misperceptions about the health effects of cholesterol in egg yolk, and its saturated fat content.

As another example, lycopene is prevalent in tomatoes (and actually is the chemical that gives tomatoes their red color). It is more highly concentrated, however, in processed tomato products such as commercial pasta sauce, or tomato soup, than in fresh "healthy" tomatoes. Yet, such sauces tend to have high amounts of salt, sugar, other substances a person may wish or even need to avoid.

The following table presents phytochemical groups and common sources, arranged by family:

<table>
<thead>
<tr>
<th>Family</th>
<th>Sources</th>
<th>Possible Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>flavonoids</td>
<td>berries, herbs, vegetables, wine, grapes, tea</td>
<td>general antioxidant, oxidation of LDLs, prevention of arteriosclerosis and heart disease</td>
</tr>
<tr>
<td>isoflavones (phytoestrogens)</td>
<td>soy, red clover, kudzu root</td>
<td>general antioxidant, prevention of arteriosclerosis and heart disease, easing symptoms of menopause, cancer prevention[19]</td>
</tr>
<tr>
<td>isothiocyanates</td>
<td>cruciferous vegetables</td>
<td>cancer prevention</td>
</tr>
<tr>
<td>monoterpenes</td>
<td>citrus peels, essential oils, herbs, spices, green plants, atmosphere[20]</td>
<td>cancer prevention, treating gallstones</td>
</tr>
<tr>
<td>organosulfur compounds</td>
<td>chives, garlic, onions</td>
<td>cancer prevention, lowered LDLs, assistance to the immune system</td>
</tr>
<tr>
<td>saponins</td>
<td>beans, cereals, herbs</td>
<td>Hypercholesterolemia, Hyperglycemia, Antioxidant, cancer prevention, Anti-inflammatory</td>
</tr>
<tr>
<td>capsaicinoids</td>
<td>all capiscum (chile) peppers</td>
<td>topical pain relief, cancer prevention, cancer cell apoptosis</td>
</tr>
</tbody>
</table>

[] Intestinal bacterial flora

Main article: Gut flora
It is now also known that animal intestines contain a large population of gut flora. In humans, these include species such as *Bacteroides, L. acidophilus* and *E. coli*, among many others. They are essential to digestion, and are also affected by the food we eat. Bacteria in the gut perform many important functions for humans, including breaking down and aiding in the absorption of otherwise indigestible food; stimulating cell growth; repressing the growth of harmful bacteria, training the immune system to respond only to pathogens; producing vitamin B12, and defending against some infectious diseases.

[] Advice and guidance

[] Governmental policies

![MyPyramid](image)

The updated USDA food pyramid, published in 2005, is a general nutrition guide for recommended food consumption for humans.

In the US, dietitians are registered (RD) or licensed (LD) with the Commission for Dietetic Registration and the American Dietetic Association, and are only able to use the title "dietitian," as described by the business and professions codes of each respective state, when they have met specific educational and experiential prerequisites and passed a national registration or licensure examination, respectively. In California, registered dietitians must abide by the "Business and Professions Code of Section 2585-2586.8". [http://www.leginfo.ca.gov/cgi-bin/displaycode?section=bpc&group=02001-03000&file=2585-2586.8](http://www.leginfo.ca.gov/cgi-bin/displaycode?section=bpc&group=02001-03000&file=2585-2586.8). Anyone may call themselves a nutritionist, including unqualified dietitians, as this term is unregulated. Some states, such as the State of Florida, have begun to include the title "nutritionist" in state licensure requirements. Most governments provide guidance on nutrition, and some also impose mandatory disclosure/labeling requirements for processed food manufacturers and restaurants to assist consumers in complying with such guidance.

In the US, nutritional standards and recommendations are established jointly by the US Department of Agriculture and US Department of Health and Human Services. Dietary and physical activity guidelines from the USDA are presented in the concept of a food pyramid, which superseded the Four Food Groups. The Senate committee currently responsible for oversight of the USDA is the *Agriculture, Nutrition and Forestry Committee*. Committee hearings are often televised on C-SPAN as seen here.
The U.S. Department of Health and Human Services provides a sample week-long menu which fulfills the nutritional recommendations of the government.[21] Canada's Food Guide is another governmental recommendation.

[] Teaching

Nutrition is taught in schools in many countries. In England and Wales the Personal and Social Education and Food Technology curricula include nutrition, stressing the importance of a balanced diet and teaching how to read nutrition labels on packaging. In many schools a Nutrition class will fall within the Family and Consumer Science or Health departments. In some American schools, students are required to take a certain number of FCS or Health related classes. Nutrition is offered at many schools, and if it is not a class of its own, nutrition is included in other FCS or Health classes such as: Life Skills, Independent Living, Single Survival, Freshmen Connection, Health etc. In many Nutrition classes, students learn about the food groups, the food pyramid, Daily Recommended Allowances, calories, vitamins, minerals, malnutrition, physical activity, healthy food choices and how to live a healthy life.

A 1985 US National Research Council report entitled Nutrition Education in US Medical Schools concluded that nutrition education in medical schools was inadequate.[22] Only 20% of the schools surveyed taught nutrition as a separate, required course. A 2006 survey found that this number had risen to 30%.[23]

[] Healthy diets

Main article: Healthy diet

[] Whole plant food diet

Heart disease, cancer, obesity, and diabetes are commonly called "Western" diseases because these maladies were once rarely seen in developing countries. One study in China found some regions had essentially no cancer or heart disease, while in other areas they reflected "up to a 100-fold increase" coincident with diets that were found to be entirely plant-based to heavily animal-based, respectively.[24] In contrast, diseases of affluence like cancer and heart disease are common throughout the United States. Adjusted for age and exercise, large regional clusters of people in China rarely suffered from these "Western" diseases possibly because their diets are rich in vegetables, fruits and whole grains.[24]

The United Healthcare/Pacificare nutrition guideline recommends a whole plant food diet, and recommends using protein only as a condiment with meals. A National Geographic cover article from November, 2005, entitled The Secrets of Living Longer, also recommends a whole plant food diet. The article is a lifestyle survey of three populations, Sardinians, Okinawans, and Adventists, who generally display longevity and "suffer a fraction of the diseases that commonly kill people in other parts of the developed world, and enjoy more healthy years of life." In sum, they offer three sets of 'best practices' to emulate. The rest is up to you. In common with all three groups is to "Eat fruits, vegetables, and whole grains."
The *National Geographic* article noted that an NIH funded study of 34,000 Seventh-day Adventists between 1976 and 1988 "...found that the Adventists' habit of consuming beans, soy milk, tomatoes, and other fruits lowered their risk of developing certain cancers. It also suggested that eating whole grain bread, drinking five glasses of water a day, and, most surprisingly, consuming four servings of nuts a week reduced their risk of heart disease."

[] **The French "paradox"**

Main article: French paradox

The French paradox is the observation that the French suffer a relatively low incidence of coronary heart disease, despite having a diet relatively rich in saturated fats. A number of explanations have been suggested:

- Reduced consumption of processed carbohydrate and other junk foods.
- Regular consumption of red wine.
- More active lifestyles involving plenty of daily exercise, especially walking; the French are much less dependent on cars than Americans are.
- Higher consumption of artificially produced trans-fats by Americans, which has been shown to have greater lipoprotein effects per gram than saturated fat.[25]

However, statistics collected by the World Health Organization from 1990-2000 show that the incidence of heart disease in France may have been underestimated and in fact be similar to that of neighboring countries.[26]

[] **Sports nutrition**

Main article: Sports nutrition

[] **Protein**

Protein milkshakes, made from protein powder (center) and milk (left), are a common bodybuilding supplement.
Protein is an important component of every cell in the body. Hair and nails are mostly made of protein. The body uses protein to build and repair tissues. Also protein is used to make enzymes, hormones, and other body chemicals. Protein is an important building block of bones, muscles, cartilage, skin, and blood.

The protein requirement for each individual differs, as do opinions about whether and to what extent physically active people require more protein. The 2005 Recommended Dietary Allowances (RDA), aimed at the general healthy adult population, provide for an intake of 0.8 - 1 grams of protein per kilogram of body weight (according to the BMI formula), with the review panel stating that "no additional dietary protein is suggested for healthy adults undertaking resistance or endurance exercise". Conversely, Di Pasquale (2008), citing recent studies, recommends a minimum protein intake of 2.2 g/kg "for anyone involved in competitive or intense recreational sports who wants to maximize lean body mass but does not wish to gain weight".

[] Water and salts

Water is one of the most important nutrients in the sports diet. It helps eliminate food waste products in the body, regulates body temperature during activity and helps with digestion. Maintaining hydration during periods of physical exertion is key to peak performance. While drinking too much water during activities can lead to physical discomfort, dehydration in excess of 2% of body mass (by weight) markedly hinders athletic performance. Additional carbohydrates and protein before, during, and after exercise increase time to exhaustion as well as speed recovery. Dosage is based on work performed, lean body mass, and environmental factors, especially ambient temperature and humidity. Maintaining the right amount is key.

[] Carbohydrates

The main fuel used by the body during exercise is carbohydrates, which is stored in muscle as glycogen—a form of sugar. During exercise, muscle glycogen reserves can be used up, especially when activities last longer than 90 min. Because the amount of glycogen stored in the body is limited, it is important for athletes to replace glycogen by consuming a diet high in carbohydrates. Meeting energy needs can help improve performance during the sport, as well as improve overall strength and endurance.

There are different kinds of carbohydrates—simple or refined, and unrefined. A typical American consumes about 50% of their carbohydrates as simple sugars, which are added to foods as opposed to sugars that come naturally in fruits and vegetables. These simple sugars come in large amounts in sodas and fast food. Over the course of a year, the average American consumes 54 gallons of soft drinks, which contain the highest amount of added sugars. Even though carbohydrates are necessary for humans to function, they are not all equally healthful. When machinery has been used to remove bits of high fiber, the carbohydrates are refined. These are the carbohydrates found in white bread and fast food.

[] Malnutrition
Main article: Malnutrition

Malnutrition refers to insufficient, excessive, or imbalanced consumption of nutrients. In developed countries, the diseases of malnutrition are most often associated with nutritional imbalances or excessive consumption. Although there are more people in the world who are malnourished due to excessive consumption, according to the United Nations World Health Organization, the real challenge in developing nations today, more than starvation, is combating insufficient nutrition — the lack of nutrients necessary for the growth and maintenance of vital functions.

[] Illnesses caused by improper nutrient consumption

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Deficiency</th>
<th>Excess</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macronutrients</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calories</td>
<td>Starvation, Marasmus</td>
<td>Obesity, diabetes mellitus, Cardiovascular disease</td>
</tr>
<tr>
<td>Simple carbohydrates</td>
<td>none</td>
<td>diabetes mellitus, Obesity</td>
</tr>
<tr>
<td>Complex carbohydrates</td>
<td>micronutrient deficiency</td>
<td>Obesity</td>
</tr>
<tr>
<td>Protein</td>
<td>kwashiorkor</td>
<td>Rabbit starvation, Ketoacidosis, kidney disease</td>
</tr>
<tr>
<td>Saturated fat</td>
<td>none</td>
<td>Obesity, Cardiovascular Disease</td>
</tr>
<tr>
<td>Trans fat</td>
<td>none</td>
<td>Obesity, Cardiovascular Disease</td>
</tr>
<tr>
<td>Unsaturated fat</td>
<td>fat-soluble vitamin deficiency</td>
<td>Obesity, Cardiovascular disease</td>
</tr>
<tr>
<td><strong>Micronutrients</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin A</td>
<td>Xerophthalmia and Night Blindness</td>
<td>Hypervitaminosis A (cirrhosis, hair loss)</td>
</tr>
<tr>
<td>Vitamin B₁</td>
<td>Beri-Beri</td>
<td></td>
</tr>
<tr>
<td>Vitamin B₂</td>
<td>Cracking of skin and Corneal Unclearation</td>
<td></td>
</tr>
<tr>
<td>Niacin</td>
<td>Pellagra</td>
<td>dyspepsia, cardiac arrhythmias, birth defects</td>
</tr>
<tr>
<td>Vitamin B₁₂</td>
<td>Pernicious Anemia</td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Scurvy</td>
<td>diarrhea causing dehydration</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>Rickets</td>
<td>Hypervitaminosis D (dehydration, vomiting, constipation)</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>neurological disease</td>
<td>Hypervitaminosis E (anticoagulant: excessive bleeding)</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>Hemorrhage</td>
<td></td>
</tr>
<tr>
<td>Omega 3 Fats</td>
<td>Cardiovascular Disease</td>
<td>Bleeding, Hemorrhages, Hemorrhagic</td>
</tr>
</tbody>
</table>
stroke, reduced glycemic control among diabetics

<table>
<thead>
<tr>
<th>Omega 6 Fats</th>
<th>none</th>
<th>Cardiovascular Disease, Cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol</td>
<td>none</td>
<td>Cardiovascular Disease</td>
</tr>
</tbody>
</table>

**Macrominerals**

<table>
<thead>
<tr>
<th></th>
<th>Osteoporosis, tetany, carpopedal spasm, laryngospasm, cardiac arrhythmias</th>
<th>Fatigue, depression, confusion, nausea, vomiting, constipation, pancreatitis, increased urination, kidney stones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Hypertension</td>
<td>Weakness, nausea, vomiting, impaired breathing, and hypotension</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Hypokalemia, cardiac arrhythmias</td>
<td>Hyperkalemia, palpitations</td>
</tr>
<tr>
<td>Potassium</td>
<td>hyponatremia</td>
<td>Hypernatremia, hypertension</td>
</tr>
</tbody>
</table>

**Trace minerals**

<table>
<thead>
<tr>
<th></th>
<th>Anemia</th>
<th>Cirrhosis, Hepatitis C, heart disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Goiter, hypothyroidism</td>
<td>Iodine Toxicity (goiter, hypothyroidism)</td>
</tr>
</tbody>
</table>

[] Mental agility

Main article: Nootropic

Research indicates that improving the awareness of nutritious meal choices and establishing long-term habits of healthy eating has a positive effect on a cognitive and spatial memory capacity, potentially increasing a student's potential to process and retain academic information.

Some organizations have begun working with teachers, policymakers, and managed foodservice contractors to mandate improved nutritional content and increased nutritional resources in school cafeterias from primary to university level institutions. Health and nutrition have been proven to have close links with overall educational success.

Currently less than 10% of American college students report that they eat the recommended five servings of fruit and vegetables daily. Better nutrition has been shown to have an impact on both cognitive and spatial memory performance; a study showed those with higher blood sugar levels performed better on certain memory tests. In another study, those who consumed yogurt performed better on thinking tasks when compared to those who consumed caffeine free diet soda or confections. Nutritional deficiencies have been shown to have a negative effect on learning behavior in mice as far back as 1951.

"Better learning performance is associated with diet induced effects on learning and memory ability." [37]

The "nutrition-learning nexus" demonstrates the correlation between diet and learning and has application in a higher education setting.
"We find that better nourished children perform significantly better in school, partly because they enter school earlier and thus have more time to learn but mostly because of greater learning productivity per year of schooling."[38]
91% of college students feel that they are in good health while only 7% eat their recommended daily allowance of fruits and vegetables.[33]
Nutritional education is an effective and workable model in a higher education setting.[39][40]
More "engaged" learning models that encompass nutrition is an idea that is picking up steam at all levels of the learning cycle.[41]

There is limited research available that directly links a student's Grade Point Average (G.P.A.) to their overall nutritional health. Additional substantive data is needed to prove that overall intellectual health is closely linked to a person's diet, rather than just another correlation fallacy.

[] Mental disorders

Nutritional supplement treatment may be appropriate for major depression, bipolar disorder, schizophrenia, and obsessive compulsive disorder, the four most common mental disorders in developed countries.[42] Supplements that have been studied most for mood elevation and stabilization include eicosapentaenoic acid and docosahexaenoic acid (each of which are an omega-3 fatty acid contained in fish oil, but not in flaxseed oil), vitamin B12, folic acid, and inositol.

[] Cancer

Cancer is now common in developing countries. According to a study by the International Agency for Research on Cancer, "In the developing world, cancers of the liver, stomach and esophagus were more common, often linked to consumption of carcinogenic preserved foods, such as smoked or salted food, and parasitic infections that attack organs." Lung cancer rates are rising rapidly in poorer nations because of increased use of tobacco. Developed countries "tended to have cancers linked to affluence or a 'Western lifestyle' — cancers of the colon, rectum, breast and prostate — that can be caused by obesity, lack of exercise, diet and age."[43]

[] Metabolic syndrome

Several lines of evidence indicate lifestyle-induced hyperinsulinemia and reduced insulin function (i.e. insulin resistance) as a decisive factor in many disease states. For example, hyperinsulinemia and insulin resistance are strongly linked to chronic inflammation, which in turn is strongly linked to a variety of adverse developments such as arterial microinjuries and clot formation (i.e. heart disease) and exaggerated cell division (i.e. cancer). Hyperinsulinemia and insulin resistance (the so-called metabolic syndrome) are characterized by a combination of abdominal obesity, elevated blood sugar, elevated blood pressure, elevated blood triglycerides, and reduced HDL cholesterol. The negative impact of hyperinsulinemia on prostaglandin PGE1/PGE2 balance may be significant.
The state of obesity clearly contributes to insulin resistance, which in turn can cause type 2 diabetes. Virtually all obese and most type 2 diabetic individuals have marked insulin resistance. Although the association between overweight and insulin resistance is clear, the exact (likely multifarious) causes of insulin resistance remain less clear. Importantly, it has been demonstrated that appropriate exercise, more regular food intake and reducing glycemic load (see below) all can reverse insulin resistance in overweight individuals (and thereby lower blood sugar levels in those who have type 2 diabetes).

Obesity can unfavourably alter hormonal and metabolic status via resistance to the hormone leptin, and a vicious cycle may occur in which insulin/leptin resistance and obesity aggravate one another. The vicious cycle is putatively fuelled by continuously high insulin/leptin stimulation and fat storage, as a result of high intake of strongly insulin/leptin stimulating foods and energy. Both insulin and leptin normally function as satiety signals to the hypothalamus in the brain; however, insulin/leptin resistance may reduce this signal and therefore allow continued overfeeding despite large body fat stores. In addition, reduced leptin signalling to the brain may reduce leptin's normal effect to maintain an appropriately high metabolic rate.

There is a debate about how and to what extent different dietary factors—such as intake of processed carbohydrates, total protein, fat, and carbohydrate intake, intake of saturated and trans fatty acids, and low intake of vitamins/minerals—contribute to the development of insulin and leptin resistance. In any case, analogous to the way modern man-made pollution may potentially overwhelm the environment's ability to maintain homeostasis, the recent explosive introduction of high glycemic index and processed foods into the human diet may potentially overwhelm the body's ability to maintain homeostasis and health (as evidenced by the metabolic syndrome epidemic).

[] Hyponatremia

Excess water intake, without replenishment of sodium and potassium salts, leads to hyponatremia, which can further lead to water intoxication at more dangerous levels. A well-publicized case occurred in 2007, when Jennifer Strange died while participating in a water-drinking contest. More usually, the condition occurs in long-distance endurance events (such as marathon or triathlon competition and training) and causes gradual mental dulling, headache, drowsiness, weakness, and confusion; extreme cases may result in coma, convulsions, and death. The primary damage comes from swelling of the brain, caused by increased osmosis as blood salinity decreases. Effective fluid replacement techniques include Water aid stations during running/cycling races, trainers providing water during team games such as Soccer and devices such as Camel Baks which can provide water for a person without making it too hard to drink the water.

[] Antinutrient

Main article: Antinutrient

Antinutrients are natural or synthetic compounds that interfere with the absorption of nutrients. Nutrition studies focus on antinutrients commonly found in food sources and beverages.
Processed foods

Main article: Food processing

Since the Industrial Revolution some two hundred years ago, the food processing industry has invented many technologies that both help keep foods fresh longer and alter the fresh state of food as they appear in nature. Cooling is the primary technology used to maintain freshness, whereas many more technologies have been invented to allow foods to last longer without becoming spoiled. These latter technologies include pasteurisation, autoclavage, drying, salting, and separation of various components, and all appear to alter the original nutritional contents of food. Pasteurisation and autoclavage (heating techniques) have no doubt improved the safety of many common foods, preventing epidemics of bacterial infection. But some of the (new) food processing technologies undoubtedly have downfalls as well.

Modern separation techniques such as milling, centrifugation, and pressing have enabled concentration of particular components of food, yielding flour, oils, juices and so on, and even separate fatty acids, amino acids, vitamins, and minerals. Inevitably, such large scale concentration changes the nutritional content of food, saving certain nutrients while removing others. Heating techniques may also reduce food's content of many heat-labile nutrients such as certain vitamins and phytochemicals, and possibly other yet to be discovered substances. Because of reduced nutritional value, processed foods are often 'enriched' or 'fortified' with some of the most critical nutrients (usually certain vitamins) that were lost during processing. Nonetheless, processed foods tend to have an inferior nutritional profile compared to whole, fresh foods, regarding content of both sugar and high GI starches, potassium/sodium, vitamins, fiber, and of intact, unoxidized (essential) fatty acids. In addition, processed foods often contain potentially harmful substances such as oxidized fats and trans fatty acids.

A dramatic example of the effect of food processing on a population's health is the history of epidemics of beri-beri in people subsisting on polished rice. Removing the outer layer of rice by polishing it removes with it the essential vitamin thiamine, causing beri-beri. Another example is the development of scurvy among infants in the late 1800s in the United States. It turned out that the vast majority of sufferers were being fed milk that had been heat-treated (as suggested by Pasteur) to control bacterial disease. Pasteurisation was effective against bacteria, but it destroyed the vitamin C.

As mentioned, lifestyle- and obesity-related diseases are becoming increasingly prevalent all around the world. There is little doubt that the increasingly widespread application of some modern food processing technologies has contributed to this development. The food processing industry is a major part of modern economy, and as such it is influential in political decisions (e.g. nutritional recommendations, agricultural subsidising). In any known profit-driven economy, health considerations are hardly a priority; effective production of cheap foods with a long shelf-life is more the trend. In general, whole, fresh foods have a relatively short shelf-life and are less profitable to produce and sell than are more processed foods. Thus the consumer is left with the choice between more expensive but nutritionally superior whole, fresh foods, and cheap, usually nutritionally inferior processed foods. Because processed foods are often cheaper, more convenient (in both purchasing, storage, and preparation), and more available, the
consumption of nutritionally inferior foods has been increasing throughout the world along with many nutrition-related health complications.

[] History

Humans have evolved as omnivorous hunter-gatherers over the past 250,000 years. The diet of early modern humans varied significantly depending on location and climate. The diet in the tropics tended to be based more heavily on plant foods, while the diet at higher latitudes tended more towards animal products. Analysis of postcranial and cranial remains of humans and animals from the Neolithic, along with detailed bone modification studies have shown that cannibalism was also prevalent among prehistoric humans.\[46\]

Agriculture developed about 10,000 years ago in multiple locations throughout the world, providing grains such as wheat, rice, potatoes, and maize, with staples such as bread, pasta, and tortillas. Farming also provided milk and dairy products, and sharply increased the availability of meats and the diversity of vegetables. The importance of food purity was recognized when bulk storage led to infestation and contamination risks. Cooking developed as an often ritualistic activity, due to efficiency and reliability concerns requiring adherence to strict recipes and procedures, and in response to demands for food purity and consistency.\[47\]

[] From antiquity to 1900

The first recorded nutritional experiment is found in the Bible's Book of Daniel. Daniel and his friends were captured by the king of Babylon during an invasion of Israel. Selected as court servants, they were to share in the king's fine foods and wine. But they objected, preferring vegetables (pulses) and water in accordance with their Jewish dietary restrictions. The king's chief steward reluctantly agreed to a trial. Daniel and his friends received their diet for 10 days and were then compared to the king's men. Appearing healthier, they were allowed to continue with their diet.\[48\]
Around 475 BC, Anaxagoras stated that food is absorbed by the human body and therefore contained "homeomerics" (generative components), suggesting the existence of nutrients.\[47\] Around 400 BC, Hippocrates said, "Let food be your medicine and medicine be your food."\[49\]

In the 1500s, scientist and artist Leonardo da Vinci compared metabolism to a burning candle. In 1747, Dr. James Lind, a physician in the British navy, performed the first scientific nutrition experiment, discovering that lime juice saved sailors who had been at sea for years from scurvy, a deadly and painful bleeding disorder. The discovery was ignored for forty years, after which British sailors became known as "limeys." The essential vitamin C within lime juice would not be identified by scientists until the 1930s.

Around 1770, Antoine Lavoisier, the "Father of Nutrition and Chemistry" discovered the details of metabolism, demonstrating that the oxidation of food is the source of body heat. In 1790, George Fordyce recognized calcium as necessary for fowl survival. In the early 1800s, the elements carbon, nitrogen, hydrogen and oxygen were recognized as the primary components of food, and methods to measure their proportions were developed.

In 1816, François Magendie discovered that dogs fed only carbohydrates and fat lost their body protein and died in a few weeks, but dogs also fed protein survived, identifying protein as an essential dietary component. In 1840, Justus Liebig discovered the chemical makeup of carbohydrates (sugars), fats (fatty acids) and proteins (amino acids.) In the 1860s, Claude Bernard discovered that body fat can be synthesized from carbohydrate and protein, showing that the energy in blood glucose can be stored as fat or as glycogen.

In the early 1880s, Kanehiro Takaki observed that Japanese sailors (whose diets consisted almost entirely of white rice) developed beriberi (or endemic neuritis, a disease causing heart problems and paralysis) but British sailors and Japanese naval officers did not. Adding various types of vegetables and meats to the diets of Japanese sailors prevented the disease.

In 1896, Baumann observed iodine in thyroid glands. In 1897, Christiaan Eijkman worked with natives of Java, who also suffered from beriberi. Eijkman observed that chickens fed the native diet of white rice developed the symptoms of beriberi, but remained healthy when fed unprocessed brown rice with the outer bran intact. Eijkman cured the natives by feeding them brown rice, discovering that food can cure disease. Over two decades later, nutritionists learned that the outer rice bran contains vitamin B1, also known as thiamine.

[] From 1900 to the present

In the early 1900s, Carl Von Voit and Max Rubner independently measured caloric energy expenditure in different species of animals, applying principles of physics in nutrition. In 1906, Wilcock and Hopkins showed that the amino acid tryptophan was necessary for the survival of rats. He fed them a special mixture of food containing all the nutrients he believed were essential for survival, but the rats died. A second group of rats to which he also fed an amount of milk containing vitamins.[50] Gowland Hopkins recognized "accessory food factors" other than calories, protein and minerals, as organic materials essential to health but which the body cannot
synthesize. In 1907, Stephen M. Babcock and Edwin B. Hart conducted the single-grain experiment. This experiment runs through 1911.

In 1912, Casimir Funk coined the term vitamin, a vital factor in the diet, from the words "vital" and "amine," because these unknown substances preventing scurvy, beriberi, and pellagra, were thought then to be derived from ammonia. The vitamins were studied in the first half of the twentieth century.

In 1913, Elmer McCollum discovered the first vitamins, fat soluble vitamin A, and water soluble vitamin B (in 1915; now known to be a complex of several water-soluble vitamins) and names vitamin C as the then-unknown substance preventing scurvy. Lafayette Mendel and Thomas Osborne also perform pioneering work on vitamin A and B. In 1919, Sir Edward Mellanby incorrectly identified rickets as a vitamin A deficiency, because he could cure it in dogs with cod liver oil. In 1922, McCollum destroyed the vitamin A in cod liver oil but finds it still cures rickets, naming vitamin D Also in 1922, H.M. Evans and L.S. Bishop discover vitamin E as essential for rat pregnancy, originally calling it "food factor X" until 1925.

In 1925, Hart discovered that trace amounts of copper are necessary for iron absorption. In 1927, Adolf Otto Reinhold Windaus synthesized vitamin D, for which he won the Nobel Prize in Chemistry in 1928. In 1928, Albert Szent-Györgyi isolated ascorbic acid, and in 1932 proves that it is vitamin C by preventing scurvy. In 1935 he synthesizes it, and in 1937 he wins a Nobel Prize for his efforts. Szent-Györgyi concurrently elucidates much of the citric acid cycle.

In the 1930s, William Cumming Rose identified essential amino acids, necessary protein components which the body cannot synthesize. In 1935, Underwood and Marston independently discover the necessity of cobalt. In 1936, Eugene Floyd Dubois showed that work and school performance are related to caloric intake. In 1938, Erhard Fernholz discovered the chemical structure of vitamin E. It was synthesised by Paul Karrer.

In 1940, rationing in the United Kingdom during and after World War II took place according to nutritional principles drawn up by Elsie Widdowson and others. In 1941, the first Recommended Dietary Allowances (RDAs) were established by the National Research Council.

In 1992, The U.S. Department of Agriculture introduced the Food Guide Pyramid. In 2002, a Natural Justice study showed a relation between nutrition and violent behavior. In 2005, a study found that obesity may be caused by adenovirus in addition to bad nutrition.

[Plant Nutrition]

Main article: Plant nutrition

Plant nutrition is the study of the chemical elements that are necessary for plant growth. There are several principles that apply to plant nutrition. Some elements are directly involved in plant metabolism. However, this principle does not account for the so-called beneficial elements, whose presence, while not required, has clear positive effects on plant growth.
A nutrient that is able to limit plant growth according to Liebig's law of the minimum, is considered an essential plant nutrient if the plant can not complete its full life cycle without it. There are 17 essential plant nutrients.

Macronutrients:

- N = Nitrogen
- P = Phosphorus
- K = Potassium
- Ca = Calcium
- Mg = Magnesium
- S = Sulfur
- Si = Silicon

Micronutrients (trace levels) include:

- Cl = Chlorine
- Fe = Iron
- B = Boron
- Mn = Manganese
- Na = Sodium
- Zn = Zinc
- Cu = Copper
- Ni = Nickel
- Mo = Molybdenum

[] Macronutrients

**Calcium**

Calcium regulates transport of other nutrients into the plant and is also involved in the activation of certain plant enzymes. Calcium deficiency results in stunting.

**Nitrogen**

Nitrogen is an essential component of all proteins. Nitrogen deficiency most often results in stunted growth.

**Phosphorus**

Phosphorus is important in plant bioenergetics. As a component of ATP, phosphorus is needed for the conversion of light energy to chemical energy (ATP) during photosynthesis. Phosphorus can also be used to modify the activity of various enzymes by phosphorylation, and can be used for cell signalling. Since ATP can be used for the biosynthesis of many plant biomolecules, phosphorus is important for plant growth and flower/seed formation.
Potassium

Potassium regulates the opening and closing of the stoma by a potassium ion pump. Since stomata are important in water regulation, potassium reduces water loss from the leaves and increases drought tolerance. Potassium deficiency may cause necrosis or interveinal chlorosis.

Silicon

Silicon is deposited in cell walls and contributes to its mechanical properties including rigidity and elasticity.

[ ] Micronutrients

Boron

Boron is important in sugar transport, cell division, and synthesizing certain enzymes. Boron deficiency causes necrosis in young leaves and stunting.

Copper

Copper is important for photosynthesis. Symptoms for copper deficiency include chlorosis. Involved in many enzyme processes. Necessary for proper photosynthesis. Involved in the manufacture of lignin (cell walls). Involved in grain production.

Chlorine

Chlorine is necessary for osmosis and ionic balance; it also plays a role in photosynthesis.

Iron

Iron is necessary for photosynthesis and is present as an enzyme cofactor in plants. Iron deficiency can result in interveinal chlorosis and necrosis.

Manganese

Manganese is necessary for building the chloroplasts. Manganese deficiency may result in coloration abnormalities, such as discolored spots on the foliage.

Molybdenum

Molybdenum is a cofactor to enzymes important in building amino acids.

Nickel
In higher plants, Nickel is essential for activation of urease, an enzyme involved with nitrogen metabolism that is required to process urea. Without Nickel, toxic levels of urea accumulate, leading to the formation of necrotic lesions. In lower plants, Nickel activates several enzymes involved in a variety of processes, and can substitute for Zinc and Iron as a cofactor in some enzymes. [citation needed]

**Sodium**

Sodium is involved in the regeneration of phosphoenolpyruvate in CAM and C4 plants. It can also substitute for potassium in some circumstances.

**Zinc**

Zinc is required in a large number of enzymes and plays an essential role in DNA transcription. A typical symptom of zinc deficiency is the stunted growth of leaves, commonly known as "little leaf" and is caused by the oxidative degradation of the growth hormone auxin.

[Processes]

Plants uptake essential elements from the soil through their roots and from the air (mainly consisting of nitrogen and oxygen) through their leaves. Nutrient uptake in the soil is achieved by cation exchange, wherein root hairs pump hydrogen ions (H+) into the soil through proton pumps. These hydrogen ions displace cations attached to negatively charged soil particles so that the cations are available for uptake by the root. In the leaves, stomata open to take in carbon dioxide and expel oxygen. The carbon dioxide molecules are used as the carbon source in photosynthesis.

Though nitrogen is plentiful in the Earth's atmosphere, relatively few plants engage in nitrogen fixation (conversion of atmospheric nitrogen to a biologically useful form). Most plants therefore require nitrogen compounds to be present in the soil in which they grow.

Plant nutrition is a difficult subject to understand completely, partially because of the variation between different plants and even between different species or individuals of a given clone. Elements present at low levels may cause deficiency symptoms, and toxicity is possible at levels that are too high. Further, deficiency of one element may present as symptoms of toxicity from another element, and vice-versa.

Carbon and oxygen are absorbed from the air, while other nutrients are absorbed from the soil. Green plants obtain their carbohydrate supply from the carbon dioxide in the air by the process of photosynthesis.

[Malnutrition]

Main article: Malnutrition
Malnutrition refers to insufficient, excessive, or imbalanced consumption of nutrients by an organism. In developed countries, the diseases of malnutrition are most often associated with nutritional imbalances or excessive consumption.

Although there are more organisms in the world who are malnourished due to insufficient consumption, increasingly more organisms suffer from excessive over-nutrition; a problem caused by an over abundance of sustenance coupled with the instinctual desire (by animals in particular) to consume all that it can

[] Insufficient

Under consumption generally refers to the long-term consumption of insufficient sustenance in relation to the energy that an organism expends or expels, leading to poor health.

[] Excessive

Over consumption generally refers to the long-term consumption of excess sustenance in relation to the energy that an organism expends or expels, leading to poor health and in animals obesity. It can cause excessive hair loss, brittle nails, and irregular premenstrual cycles for females

[] Unbalanced

When too much of one or more nutrients is present in the diet to the exclusion of the proper amount of other nutrients, the diet is said to be unbalanced.

Vegetation

Vegetation is a general term for the plant life of a region; it refers to the ground cover provided by plants. It is a general term, without specific reference to particular taxa, life forms, structure, spatial extent, or any other specific botanical or geographic characteristics. It is broader than the term flora which refers exclusively to species composition. Perhaps the closest synonym is plant community, but vegetation can, and often does, refer to a wider range of spatial scales than that term does, including scales as large as the global. Primeval redwood forests, coastal mangrove stands, sphagnum bogs, desert soil crusts, roadside weed patches, wheat fields, cultivated gardens and lawns; all are encompassed by the term vegetation.

[] Importance

Vegetation supports critical functions in the biosphere, at all possible spatial scales. First, vegetation regulates the flow of numerous biogeochemical cycles (see biogeochemistry), most critically those of water, carbon, and nitrogen; it is also of great importance in local and global energy balances. Such cycles are important not only for global patterns of vegetation but also for those of climate. Second, vegetation strongly affects soil characteristics, including soil volume, chemistry and texture, which feed back to affect various vegetational characteristics, including
productivity and structure. Third, vegetation serves as wildlife habitat and the energy source for the vast array of animal species on the planet (and, ultimately, to those that feed on these). Perhaps most importantly, and often overlooked, global vegetation (including algal communities) has been the primary source of oxygen in the atmosphere, enabling the aerobic metabolism systems to evolve and persist.

[] Classification

Much of the work on vegetation classification comes from European and North American ecologists, and they have fundamentally different approaches. In North America, vegetation types are based on a combination of the following criteria: climate pattern, plant habit, phenology and/or growth form, and dominant species. In the current US standard (adopted by the Federal Geographic Data Committee (FGDC), and originally developed by UNESCO and The Nature Conservancy), the classification is hierarchical and incorporates the non-floristic criteria into the upper (most general) five levels and limited floristic criteria only into the lower (most specific) two levels. In Europe, classification often relies much more heavily, sometimes entirely, on floristic (species) composition alone, without explicit reference to climate, phenology or growth forms. It often emphasizes indicator or diagnostic species which separate one type from another.

In the FGDC standard, the hierarchy levels, from most general to most specific, are: system, class, subclass, group, formation, alliance, and association. The lowest level, or association, is thus the most precisely defined, and incorporates the names of the dominant one to three (usually two) species of the type. An example of a vegetation type defined at the level of class might be "Forest, canopy cover > 60%"; at the level of a formation as "Winter-rain, broad-leaved, evergreen, sclerophyllous, closed-canopy forest"; at the level of alliance as "Arbutus menziesii forest"; and at the level of association as "Arbutus menziesii-Lithocarpus densiflora forest", referring to Pacific madrone-tanoak forests which occur in California and Oregon, USA. In
practice, the levels of the alliance and/or association are the most often used, particularly in vegetation mapping, just as the Latin binomial is most often used in discussing particular species in taxonomy and in general communication.

Victoria in Australia classifies its vegetation by Ecological Vegetation Class.

[] **Structure**

Structure is determined by an interacting combination of environmental and historical factors, and species composition. It is characterized primarily by the horizontal and vertical distributions of plant, particularly biomass. Horizontal distributions refer to the pattern of spacing of plant on the ground. Plants can be very uniformly (i.e. regularly) spaced, as in a tree plantation, or very non-uniformly spaced, as in many forests in rocky, mountainous terrain, where areas of high and low tree density alternate depending on the spatial pattern of soil and climatic variables. Three broad categories of spacing are recognized: uniform, random and clumped. Vegetation clumps could in turn be regularly spaced in the landscape as a consequence of self-organization (see for example the tiger bush patterns in dryland ecosystems. Vertical distributions of biomass are determined by the inherent productivity of an area, the height potential of the dominant species, and the presence/absence of species in the flora. If the vertical distribution of the foliage is broken into defined height layers, cover can be estimated for each layer.

In some vegetation types, the underground distribution of biomass can also discriminate different types. Thus a sod-forming grassland has a more continuous and connected root system, while a bunchgrass community's is much less so, with more open spaces between plants However, below-ground architecture is so much more time-consuming to measure, that vegetation structure is almost always described in relationship to the above-ground parts of the community.

[] **Dynamics**

Like all biological systems, plant communities are temporally and spatially dynamic; they change at all possible scales. Dynamism in vegetation is defined primarily as changes in species composition and/or vegetation structure.

[] **Temporal dynamics**

Temporally, a large number of processes or events can cause change, but for sake of simplicity they can be categorized roughly as either abrupt or gradual. Abrupt changes are generally referred to as disturbances; these include things like wildfires, high winds, landslides, floods, avalanches and the like. Their causes are usually external (exogenous) to the community—they are natural processes occurring (mostly) independently of the natural processes of the community (such as germination, growth, death, etc). Such events can change vegetation structure and species composition very quickly and for long time periods, and they can do so over large areas. Very few ecosystems are without some type of disturbance as a regular and recurring part of the long term system dynamic. Fire and wind disturbances are particularly common throughout many vegetation types worldwide. Fire is particularly potent because of its ability to destroy not
only living plants, but also the seeds, spores, and living meristems representing the potential next generation, and because of fire's impact on faunal populations, soil characteristics and other ecosystem elements and processes (for further discussion of this topic see fire ecology).

Temporal change at a slower pace is ubiquitous; it comprises the field of ecological succession. Succession is the relatively gradual change in structure and taxonomic composition that arises as the vegetation itself modifies various environmental variables over time, including light, water and nutrient levels. These modifications change the suite of species most adapted to grow, survive and reproduce in an area, causing floristic changes. These floristic changes contribute to structural changes that are inherent in plant growth even in the absence of species changes (especially where plants have a large maximum size, i.e. trees), causing slow and broadly predictable changes in the vegetation. Succession can be interrupted at any time by disturbance, setting the system either back to a previous state, or off on another trajectory altogether. Because of this, successional processes may or may not lead to some static, final state. Moreover, accurately predicting the characteristics of such a state, even if it does arise, is not always possible. In short, vegetative communities are subject to many variables that together set limits on the predictability of future conditions.

[[]] Spatial dynamics

A coastal dune grassland on the Pacific Coast, USA

As a general rule, the larger an area under consideration, the more likely the vegetation will be heterogeneous across it. Two main factors are at work. First, the temporal dynamics of disturbance and succession are increasingly unlikely to be in synchrony across any area as the size of that area increases. That is, different areas will be at different developmental stages due to different local histories, particularly their times since last major disturbance. This fact interacts with inherent environmental variability (e.g. in soils, climate, topography, etc.), which is also a function of area. Environmental variability constrains the suite of species that can occupy a given area, and the two factors together interact to create a mosaic of vegetation conditions across the landscape. Only in agricultural or horticultural systems does vegetation ever approach perfect
uniformity. In natural systems, there is always heterogeneity, although its scale and intensity will vary widely. A natural grassland may be homogeneous when compared to the same area of partially burned forest, but highly diverse and heterogeneous when compared to the wheat field next to it.

[] Global vegetation patterns and determinants

At regional and global scales there is predictability of certain vegetation characteristics, especially physiognomic ones, which are related to the predictability in certain environmental characteristics. Much of the variation in these global patterns is directly explainable by corresponding patterns of temperature and precipitation (sometimes referred to as the energy and moisture balances). These two factors are highly interactive in their effect on plant growth, and their relationship to each other throughout the year is critical.

[] Scientific study

Vegetation scientists study the causes of the patterns and processes observed in vegetation at various scales of space and time. Of particular interest and importance are questions of the relative roles of climate, soil, topography, and history on vegetation characteristics, including both species composition and structure. Such questions are often large scale, and so cannot easily be addressed by manipulative experimentation in a meaningful way. Observational studies supplemented by knowledge of botany, paleobotany, ecology, soil science etc, are thus very common in vegetation science.

[] History

[] Pre-1900

Vegetation science has its origins in the work of botanists and/or naturalists of the 18th century, or earlier in some cases. Many of these were world travelers on exploratory voyages in the Age of Exploration, and their work was a synthetic combination of botany and geography that today we would call plant biogeography (or phytogeography). Little was known about worldwide floristic or vegetation patterns at the time, and almost nothing about what determined them, so much of the work involved collecting, categorizing, and naming plant specimens. Little or no theoretical work occurred until the 19th century. The most productive of the early naturalists was Alexander von Humboldt, who collected 60,000 plant specimens on a five year voyage to South and Central America from 1799 to 1804. Humboldt was one of the first to document the correspondence between climate and vegetation patterns, in his massive, life-long work "Voyage to the Equinoctial Regions of the New Continent", which he wrote with Aimé Bonpland, the botanist who accompanied him. Humboldt also described vegetation in physiognomic terms rather than just taxonomically. His work presaged intensive work on environment-vegetation relationships that continues to this day (Barbour et al., 1987).

The beginnings of vegetation study as we know it today began in Europe and Russia in the late 19th century, particularly under Jozef Paczoski, a Pole, and Leonty Ramensky, a Russian.
Together they were much ahead of their time, introducing or elaborating on almost all topics germane to the field today, well before they were so in the west. These topics included plant community analysis, or phytosociology, gradient analysis, succession, and topics in plant ecophysiology and functional ecology. Due to language and/or political reasons, much of their work was unknown to much of the world, especially the English-speaking world, until well into the 20th century.

[] Post-1900

In the United States, Henry Cowles and Frederic Clements developed ideas of plant succession in the early 1900s. Clements is famous for his now discredited view of the plant community as a "superorganism". He argued that, just as all organ systems in an individual must work together for the body to function well, and which develop in concert with each other as the individual matures, so the individual species in a plant community also develop and cooperate in a very tightly coordinated and synergistic way, pushing the plant community towards a defined and predictable end state. Although Clements did a great deal of work on North American vegetation, his devotion to the superorganism theory has hurt his reputation, as much work since then by numerous researchers has shown the idea to lack empirical support.

In contrast to Clements, several ecologists have since demonstrated the validity of the individualistic hypothesis, which asserts that plant communities are simply the sum of a suite of species reacting individually to the environment, and co-occurring in time and space. Ramensky initiated this idea in Russia, and in 1926, Henry Gleason (Gleason, 1926) developed it in a paper in the United States. Gleason's ideas were categorically rejected for many years, so powerful was the influence of Clementsian ideas. However, in the 1950s and 60s, a series of well-designed studies by Robert Whittaker provided strong evidence for Gleason's arguments, and against those of Clements. Whittaker, one of the most productive of American plant ecologists, was a developer and proponent of gradient analysis, in which the abundances of individual species are measured against quantifiable environmental variables (or their well-correlated surrogates). In studies in three very different montane ecosystems, Whittaker demonstrated strongly that species respond primarily to the environment, and not necessarily in any coordination with other, co-occurring species. Other work, particularly in paleobotany, has lent support to this view at larger temporal and spatial scales.

[] Recent developments

Since the 1960s, much research into vegetation has revolved around topics in functional ecology. In a functional framework, taxonomic botany is less important; investigations center around morphological, anatomical and physiological classifications of species, having the aim of predicting how particular groups thereof will respond to various environmental variables. The underlying basis for this approach is the observation that, due to convergent evolution and (conversely) adaptive radiation, there is often not a strong relationship between phylogenetic relatedness and environmental adaptations, especially at higher levels of the phylogenetic taxonomy, and at large spatial scales. Functional classifications arguably began in the 1930s with Raunkiær's division of plants into groups based on the location of their apical meristems (buds) relative to the ground surface. This presaged later classifications such as MacArthur's r vs K
selected species (applied to all organisms, not just plants), and the C-S-R scheme proposed by Grime (1974) in which species are assigned to one or more of three strategies, each favoured by a corresponding selection pressure: competitors, stress-tolerators and ruderals.

Functional classifications are crucial in modeling vegetation-environment interactions, which has been a leading topic in vegetation ecology for the last 30 or more years. Currently, there is a strong drive to model local, regional and global vegetation changes in response to global climate change, particularly changes in temperature, precipitation and disturbance regimes. Functional classifications such as the examples above, which attempt to categorise all plant species into a very small number of groups, are unlikely to be effective for the wide variety of different modeling purposes that exist or will exist. It is generally recognized that simple, all-purpose classifications will likely have to be replaced with more detailed and function-specific classifications for the modeling purpose at hand. This will require much better understanding of the physiology, anatomy, and developmental biology than currently exists, for a great number of species, even if only the dominant species in most vegetation types are considered.

**Ecophysiology**

Ecophysiology (from Greek οἶκος, oikos, "house(hold)"; φύσις, physis, "nature, origin"; and -λογία, -logia) or environmental physiology is a biological discipline which studies the adaptation of organism's physiology to environmental conditions. It is closely related to comparative physiology and evolutionary physiology.

| Ecophysiology of plants

This section requires expansion.

Plant ecophysiology is an experimental science that seeks to describe the physiological mechanisms underlying ecological observations. In other words, ecophysiologists, or physiological ecologists, address ecological questions about the controls over the growth, reproduction, survival, abundance, and geographical distribution of plants, as these processes are affected by interactions between plants with their physical, chemical, and biotic environment. These ecophysiological patterns and mechanisms can help us understand the functional significance of specific plant traits and their evolutionary heritage. The questions addressed by ecophysiologists are derived from a higher level of integration, i.e. from “ecology” in its broadest sense, including questions originating from agriculture, horticulture, forestry, and environmental sciences. However, ecophysiological explanations often require mechanistic understanding at a lower level of integration (physiology, biochemistry, biophysics, molecular biology). It is therefore essential for an ecophysiologist to have an appreciation of both ecological questions and biophysical, biochemical, and molecular methods and processes. In addition, many societal issues, often pertaining to agriculture, environmental change or nature conservation, benefit from an ecophysiological perspective. A modern ecophysiologist thus requires a good understanding of both the molecular aspects of plant processes and the functioning of the intact plant in its environmental context.
In many cases, animals are able to escape unfavourable and changing environmental factors such as heat, cold, drought or floods, while plants are unable to move away and therefore must endure the adverse conditions or perish (animals go places, plants grow places). Plants are therefore phenotypically plastic and have an impressive array of genes which aid in adapting to changing conditions. It is hypothesized that this large number of genes can be partly explained by plant species' need to adapt to a wider range of conditions.

[] Temperature

In response to extremes of temperature plants can produce various proteins that protect them from the damaging effects of ice formation and falling rates of enzyme catalysis at low temperatures and enzyme denaturation and increased photorespiration at high temperatures. As temperatures fall production of antifreeze proteins and dehydrins rise. As temperatures rise production of heat shock proteins rise. Plants can also adapt their morphology (change their shape) to adapt to longer term temperature changes. For example to protect against frost cell walls can be made thicker and stronger (through more lignification) so that water freezes in between cells (in the apoplast) and not in the cells (in the cytoplasm). Cell membranes are also affected by changes in temperature and can cause the membrane to lose its fluid properties and become a gel in cold conditions or become leaky in hot conditions. This can affect the movement of compounds across the membrane. To prevent these changes plants can change the composition of their membranes. In cold conditions more unsaturated fatty acids are placed in the membrane and in hot conditions more saturated fatty acids are inserted.

See also: Plant adaptations to wildfires

[] Wind

Strong winds can affect plants by uprooting them or damaging their leaves. Whereas responses to temperature changes are often acclimatory there is not enough time for this to occur to wind and so plants must be permanently adapted to survive potentially damaging winds. Examples of adaptations to prevent damage include having leaves with thick cuticles, and large root systems. One reason that deciduous trees shed their leaves in the autumn is to reduce their surface area and make it less likely that they will be blown over.

[] Water

Too much or too little water can damage plants. If there is too little water then tissues will dehydrate and the plant may die. If the soil becomes waterlogged then the soil will become anoxic (low in oxygen) which could kill the roots. If tissues become dehydrated they lose turgor which in turn causes abscisic acid, a plant hormone, to be produced. This travels throughout the plant and has a number of effects. It increases the number of closed stomata, reducing water loss and also stimulates growth of the roots in an attempt to increase the supply of water. Some plants, for example maize and rice are able to produce aerenchyma in their roots if the soil they are growing in becomes waterlogged. These are hollow vessels that allow the diffusion on oxygen into the roots.
The concentration of CO₂ in the atmosphere is rising due to deforestation and the combustion of fossil fuels. Plants use CO₂ as a substrate in photosynthesis and it was previously thought that as the concentration of CO₂ rises that the efficiency of photosynthesis would increase leading to increased growth. Studies using Free-air concentration enrichment have however shown that crop yields are only increased by up to 8%. Studies of specimens in herbariums have shown that the number of stomata on leaves has decreased over the last 150 years as the concentration of CO₂ has risen. Stomata let CO₂ diffuse into the leaf but let water leave at the same time. Plants are acclimating to increased CO₂ concentrations by having fewer stomata because they allow the same amount of CO₂ into the leaf as before yet they use less water. It has also been found that the nitrogen level falls when plants are grown at elevated CO₂ due to plants needing less rubisco to fix the same amount of CO₂. The levels of other micronutrients also fall which may have consequences for human nutrition in the future.

Ecophysiology of animals: Important Scientists

George A. Bartholomew (1919-2006) was a founder of animal physiological ecology. He served on the faculty at UCLA from 1947 to 1989, and almost 1,200 individuals can trace their academic lineages to him. Knut Schmidt-Nielsen (1915-2007) was also an important contributor to this specific scientific field as well as comparative physiology.

Hermann Rahn (1912-1990) was a early leader in the field of environmental physiology. Starting out in the field of zoology with a PhD from University of Rochester (1933), Rahn began teaching physiology at the University of Rochester in 1941. It was there that he partnered with Wallace O. Fenn to publish A Graphical Analysis of the Respiratory Gas Exchange in 1955. This paper included the landmark O₂-CO₂ diagram, which formed basis for much of Rahn's future work. Rahn's research into applications of this diagram lead to the development of aerospace medicine and advancements in hyperbaric breathing and high-altitude respiration. Rahn later joined the University at Buffalo in 1956 as the Lawrence D. Bell Professor and Chairman of the...
Department of Physiology. As Chairman, Rahn surrounded himself with outstanding faculty and made the University an international research center in environmental physiology.