Biology 2

Animal Diversity

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NOTICE

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Forward

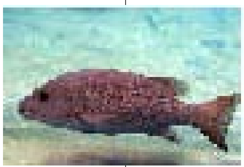
This module on Animal Diversity was developed by the African Virtual University (Université Virtuelle Africaine / Universidade Virtual Africana) (UVA) with support of the African Development Bank.

This is a first-and second-year university-level distance learning course.

It is designed for:

- Teachers working at African secondary schools and colleges who have not attended a formal teacher training program
- Students wishing to enter a teaching career at a secondary school or college
- All teachers wishing to undertake professional development

This module will be regularly updated by its developer jointly with the UVA administration



Module Summary

The lessons presented in this module on animal diversity are based on the social constructivist theory of learning. Learners construct their own understanding and develop their own skills, both individually and as part of a peer group. The activities presented here will help you, but a large part of the responsibility rests on you, in the aim of fostering learner empowerment.

This module is divided into four learning units: General Characteristics of Animals, Evolutionary Trends in Animals, Classification of animals, and The Importance of Animals.

Each learning unit contains a learning activity that integrates information and communication technologies (ICT) and collaborative learning approaches with formative assessment.

The summary assessment allows you to compare your progress with the benchmark knowledge and skills set out in the general and specific module objectives.

I. Biology 2: Animal Diversity

By Doctor Rabotovao Laurence, Université d'Antananarivo Ecole Normale Supérieure Madagascar

II. Prerequisites / Required Knowledge

This course comes after the Plant Diversity course from which students acquire knowledge about a number of concepts such as *plant organization, convergence,* and *characteristics of living organisms.*

Students must also understand the hierarchy of the biological classification of living organisms: Domain, Kingdom, Phylum, Class, Order, Family, Genus, and species.

They must also know that animals, like plants, are living organisms that have defined shape and size. They grow up, reproduce and die.

Zoology, the science that studies animals, draws on a wide variety of approaches. As an analytic science, it borrows from a number of other sciences, for instance, morphology and physiology. Zoology investigates successive evolutionary changes and adaptive diversifications. Hence, the need to classify organisms. Classification is generally based on morphology, anatomy, reproduction, physiology, genetics, paleontology, and the development cycle.

III. Time

The duration of this module is 120 hours, divided into readings, hands-on activities, tutoring, and formative and summary assessments.

The readings for the four units should take about 20 hours.

The hands-on activities should take about 20 hours.

The visits to the links and resources should take about 20 hours.

The tutoring should take about 20 hours.

The formative and summary assessments should take about 40 hours.

IV. Materials

A CD Rom
Computers
An Internet connection

Learners could also do some supplementary exercises if they have exercise software (Netquiz, Hotpotatos) or simulation software.

V. Importance of the Module

This module follows the module on Plant Diversity, and it completes the knowledge of living organisms.

It presents the rich variety of animal formswith the aim of preserving them to prevent their extinction. It also underscores the economic, social, cultural, and scientific importance of animals.

Learners are presented with interesting and useful learning activities designed to help them solve educational problems in class and acquire academic skills in the field of zoology: making drawings and schematic diagrams based on the exercises, organizing insect collections, identifying various living organisms, and so on.

VI. Content

This course examines the diversity of animal forms and highlights their distribution, life cycle, structure, and economic significance. It presents the biological diversity of the animal world and the phylogenetic relationships within it.

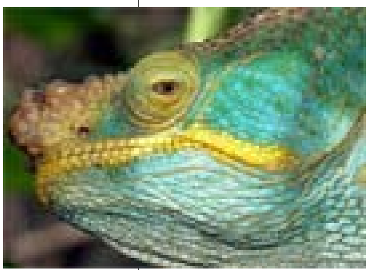
6.1 Overview

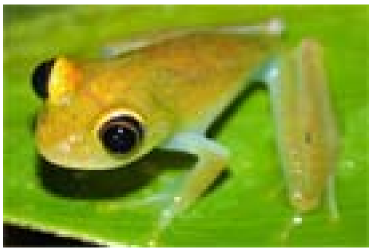
You have probably heard about animal diversity, and more recently, animal biodiversity and the arguments for the protection and conservation of biodiversity. Knowledge about animals, from the protozoa to the metazoa, their variability, their importance, and the issues and challenges involved, has become vital for everyone who cares about the future of our planet. This course is organized around four units: the characteristics, evolutionary trends, classification, and importance of animals. It will increase your understanding and appreciation of the creatures who share our Earth.

The required readings will help you grasp the key concepts and understand the issue of animal biodiversity. Other activities involving information research and problem solving will help you acquire some practical skills that should prove useful in your teaching practice.

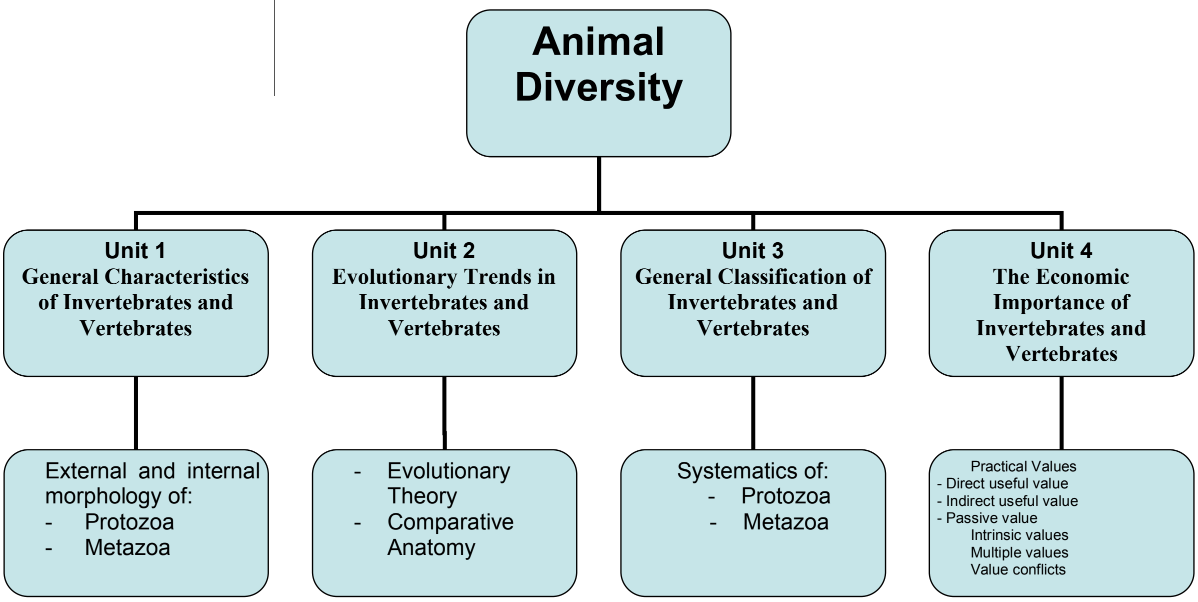
The module comprises four structured units, as follows:

- Unit 1: General Characteristics of Invertebrates and Vertebrates
- Unit 2: Classification of animals
- Unit 3: Evolutionary Trends in Animals
- Unit 4: The Economic Importance of Animals
- Conclusion
- References
- Glossary





6.2 Graphic Organizer



VII. General objectives

General knowledge objectives (understanding)

1- Know the basic concepts in zoology
2- Know the importance and utility of the Kingdom Animalia.
3- Understand the evolution of phyla in the animal world.

General method objectives (know-how)

1- Master the various steps of a scientific method in biology.
2- Master techniques of developing computer-assisted teaching tools.

General objectives for value and attitude clarification (soft-skills)

Safeguard biodiversity

VIII. Specific objectives of learning activities (training objectives)

Unit I

I **Specific knowledge objectives (understanding)**

At the completion of this unit, learners should be able to:

- Define basic concepts in zoology such as convergence, phylogenesis, and the organization plan
- Be familiar with the pioneers of zoological science and the disciplines involved
- Name the general characteristics of animal groups

Specific methodological objectives (know-how)

At the completion of this unit, learners should be able to:

- Manually or using software, develop a conceptual chart of an animal group based on a text or related concepts
- Work in a group on a project
- Develop a PowerPoint presentation on a given topic

Specific objectives for value and attitude clarification (soft skills)

- Respect the animal world.

Unit II

II **Specific knowledge objectives (understanding)**

At the completion of this unit, learners should be able to:

- Define the concepts of ontogenesis, phylogenesis, the organization plan, and metamerization
- Know the different evolutionary trends of animals based on comparative anatomy

Specific methodological objectives (know-how)

At the completion of this unit, learners should be able to:

- Describe the reproduction methods and life cycles of diverse animal groups
- Compare the phyla of animals

Specific objectives for value and attitude clarification (soft skills)

Safeguard animal conservation and biodiversity

III **Unit III**

Specific knowledge objectives (understanding)

At the completion of this unit, learners should be able to:

- Name the different subdivisions of the animal classifications

Specific methodological objectives (know-how)

At the completion of this unit, learners should be able to:

- Classify animals using a diagram
- Compare the organization plans of different phyla

IV **Unit IV**

Specific knowledge objectives (understanding)

At the completion of this unit, learners should be able to:

- Identify the different economic, scientific, cultural, and social areas in which animals are involved

Specific methodological objectives (know-how)

At the completion of this unit, learners should be able to:

- Work in a group on a project involving animal diversity
- Conduct a study on a specific topic

Specific objectives for value and attitude clarification (soft skills)

- Participate in advocacy actions for the conservation of biodiversity
- Raise awareness of the economic importance of different taxa

IX. Teaching and learning activities

Preliminary / initial assessment

Purpose:

This preliminary test assesses the learner's previous knowledge in terms of the specific learning objectives. It can also serve as a guideline for organizing and completing the activities.

Questions:

1. Rank the following subdivisions of the Kingdom Animalia:

   Species – Phylum – Class – Order – Genus – Variety – Superclass – Family

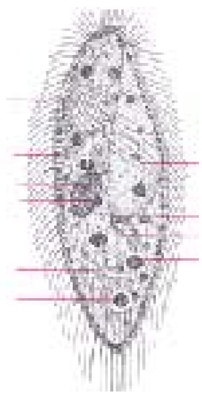
2. Conceptual flow chart of mammals:

   Organize the following words into three levels and connect them with arrows:

Bat, Lion, Ray; Bird; Mullet; Snake; Mammals; Class; Frog; Manatee; Amphibia; Crocodile; Sardine; Fish; Reptiles; Pigeon; Crow.

3. Multiple-choice questions:
   Which of these animals are mammals?
   Bat – Shark – Lion – Ostrich – Manatee – Frog

4. PowerPoint presentation on annotating a diagram of a paramecium:



5. Multiple-choice:

   Tick the correct answer

Protozoa were discovered in 1675 by:

- A- Haeckel
- B- Leeuwenhoek
- C- Linnaeus
- D- Watson

6. Multiple-choice:

   A tuicolous animal is one that:

1. Has a long tube
2. Dwells in a tube
3. Is shaped like a tube

7. Fill in the blanks:

   Replace the missing words with one of the following: differentiation, digestion, function, organelles.

   Protozoa acquired particular (1)……………. associated with specialized functions: movement, contractility, support, sensibility, (2)……………., and fluid flow, but their structural and functional (3)…………….remained at a lower level. In addition, protozoa have remained small in size, and are limited in terms of their (4)………….and psychism. They were unable to live in air.

8. True or false questions

Tick the correct answer:

8.1 The amoeba is a metazoa. ❐True ❐ False

8.2 The mesoderm and endoderm are two layers found in diploblasts.

❐ True ❐ False

8.3 Some protozoa contain chlorophyll. ❐ True ❐ False

8.4 A trinomial system was adopted to designate species.

❐ True ❐ False

8.5 Some unicellulars are visible to the naked eye ❐ True ❐ False

9. Matching question. Match each name to the correct image with an arrow.

1. Ladybug

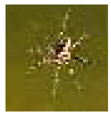
2. Virus

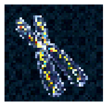
3. Spider

4. Ant

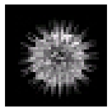
5. Chromosome

A. 

B. 

C. 

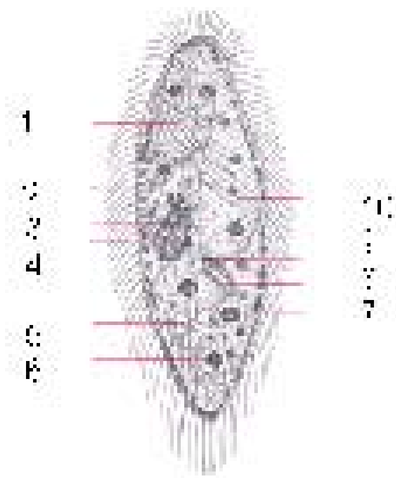
D. 

E. 

N.B.: These images were taken from the Biology CD.

10. Annotate the diagram of the paramecium

Extracted from Dorst, J. FEHRENBACH, C. HEIM, R et al. (1974): *Grande encyclopédie Alpha des sciences et des techniques Zoologie I*. Editions Kister 308 P

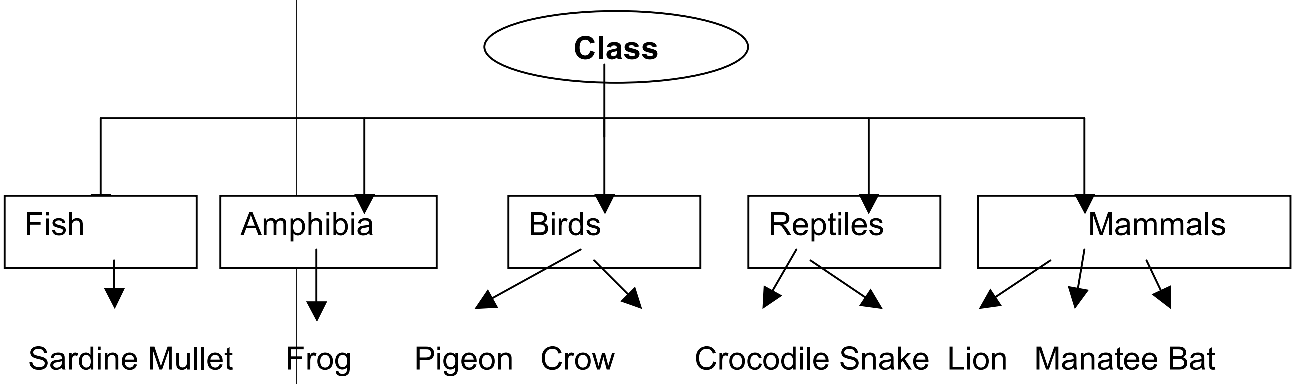


Answer key

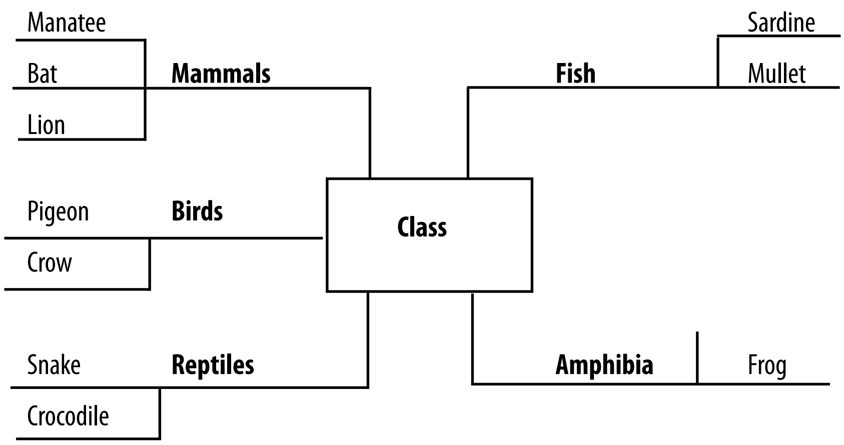
1. Phylum ▸ Superclass ▸ Class ▸ Order ▸ Family ▸ Genus ▸ species ▸ variety

2. Organize the following words into three levels and connect them with arrows:

2.1 First variant



2.2 Second variant



3. Lion – Manatee
4. PowerPoint presentation
5. Leeuwenhoek
6. Dwells in a tube
7. 1: organelles 2: digestion 3: function 4: differentiation
8. 8.1 False 8.2 False 8.3 True 8.4 False 8.5 True
9. 4 A 3 B 5 C 1 D 2 E
10. Annotation of the Paramecium: 1 Dilated contractile vacuole; 2 Trichocyst; 3 Macronucleus; 4 Micronucleus; 5 Contracted contractile vacuole; 6 Digestive vacuole; 7 Digestive vacuole; 8 Cytopharynx; 9 Cytostome; 10 Peristome.

Learning guidelines

The purpose of this test is to determine how much you have already learned concerning this unit on animal diversity. It is in form of a series of questions. You must answer them carefully. You are allowed two trials on all questions. Record the average of the two marks.

If you score between 50% and 75%, you possess substantial knowledge in this field and you should go on to complete the module. If you successfully complete the module, you will be directed to other modules and activities to reinforce your learning.

This test will be available for two weeks.

X. Key concepts (Glossary)

Analogy: two structures are said to be analogous if they perform the same or similar function but evolved separately (e.g., a bat's wing and a bird's wing), or are different (e.g., a bird's hind-wing and a horse's hind leg) when found in different types of animals but perform a similar function.

Cephalization: the evolutionary process in species whereby nervous tissue becomes concentrated toward one end of an organism, eventually producing a head region.

Convergence: in evolution, the fact that animals belonging to different groups independently acquire similar characteristics due to a common habitat. For example, sharks (fish) and whales (mammals) live in water and are hydrodynamically shaped.

Diploblast: a group of protozoa having a two-layered germ structure: the ectoblast and the endoblast.

Cellular differentiation: the process by which a less specialized cell becomes specialized during the development and maturation of a multicellular organism.

Homology: refers to phylogenetic similarities between organisms due to their shared ancestry. For example, they have the same structure, organization and have preserved the same associations with neighbouring organisms.

Metamerization: segmentation or splitting.

Ontogeny: the developmental history of an individual organism within its own lifetime.

Phylogenesis: the sequence of events involved in the evolutionary development of a species or taxonomic group of organisms, or the study of evolutionary relatedness among various groups of organisms.

Organization plan: the structural or constitutional plan of an organism.

XI. Required reading

Reading No. 1

General and systematic characteristics of animals

Complete reference: Extract from an original course by *Laurence Rabotovao, Université d'Antananarivo (Madagascar) Ecole Normale Supérieure*

Summary: This document covers the organization plan of animal bodies in terms of diverse aspects, including asymmetry, radial symmetry, and bilateral symmetry. Evolution is also addressed in terms of certain key concepts such as layers (endoderm, mesoderm, ectoderm), cavities, metamerization (body segmentation), and cephalization.

Purpose: This reading is recommended because it provides pertinent information on animal diversity and evolution. The style is straightforward, and illustrations are included to facilitate understanding.

Reading No. 2

General characteristics of animals

Complete reference: Extract from an original course by *Laurence Rabotovao, Université d'Antananarivo (Madagascar) Ecole Normale Supérieure*

Summary: This extract covers the general characteristics of protozoa and metazoa. It contains plenty of information on animal organization and systems and the phylogenetic relations between animal groups. Explanations are provided throughout on how various scientific disciplines are incorporated in the field of zoology.

Purpose: After reading this document, you will have an in-depth idea of the general characteristics of animals and the disciplines involved in their study. It will serve as a reference when you search for more information in order to confirm or reject your research hypothesis.

Reading No. 3

Extract from an original course by Laurence Rabotovao, *Université d'Antananarivo (Madagascar) Ecole Normale Supérieure*

Summary: This extract covers the physiological and ecological characteristics of animals. Topics include organ functioning, ways of life, and reproduction in animals. Anatomical features are also discussed.

Purpose: This reading will further clarify the concept of animal diversity, as it covers the key knowledge of morphological diversification in terms of anatomy, physiology, and ecology.

XII. Required resources

Resource No. 1

Complete reference: Monique Dupuis, Lycée Jean Monnet, La-Queue-les-Yvelines: *Relations de parenté entre les êtres vivants : Méthodes utilisées pour établir les relations de parenté entre les êtres vivants*

http://www.inrp.fr/Acces/biotic/evolut/parente/html/methode.htm

[Suggestion: **Classification, species concepts and their relation to conservation biology and policy**. *http://www.montana.edu/~wwwbi/staff/creel/bio480/spcon.pdf*]

Also: **Species Diversity and Phylogeny** at: http://education.sdsc.edu/teachertech/downloads/phylogeny.pdf]

Last visited on 07/09:2006 at 6 h 17 mn[For the French reference]

Summary: This text presents two methods of establishing genetic relationships among living organisms. These are: Cladistics and Phenetics methods.The methods are based on morphological, anatomical, molecular, and caryologic data.

Purpose: This text will prove very useful because it presents practical methods of establishing genetic relationships between living organisms. It provides accurate guidelines for the criteria to consider. Read this document to learn more.

Resource No. 2

Complete reference: Monique Dupuis, Lycée Jean Monnet, La-Queue-les-Yvelines *: Relations de parenté entre les êtres vivants : Lire et exploiter un arbre phylogénétique*

http://www.inrp.fr/Acces/biotic/evolut/parente/html/methode.htm *http://www.inrp.fr/Acces/biotic/evolut/parente/html/anaterm.htm*

Last visited on 07/09 :2006 at 6 h 37 mn [for the French reference]

[Suggestion: Phylogenetic tree at: http://en.wikipedia.org/wiki/Phylogenetic_tree]

[Also: **Encyclopedia of Life** at: http://en.wikipedia.org/wiki/Encyclopedia_of_Life

and **Taxonomic Classification & Phylogenetic Trees** at: http://www.mhhe.com/biosci/pae/zoology/cladogram/]

Summary: These sites present[(for the suggested English sites)] the relationships in a genealogical tree and a comparative table of the characteristics of many species, covering the following topics:

- Identification and justification of relationships
- Characteristics of common ancestors
- Definitions of monophyletic (or cladistic) groupings
- Know whether or not a tree is valid

Purpose: After reading these documents, you will have acquired some knowledge about the genealogical trees of living things. You may also be inspired to develop application exercises and formative or summary assessment questions.

XIII. Useful links

Useful link No. 1

Title: *Biogeo - Ressources pour l'enseignement des SVT*

URL: http://www.inrp.fr/Acces/Biogeo/accueil.htm

[Suggestions: **Earth Science Education Resources** at: http://www.academicinfo.net/edteachearth.html ;

And

Federal Resources for Educational Excellence at: http://free.ed.gov/index.cfm]

Description: This site of the *Institut National de la recherche pédagogique de France* (http://www.inrp.fr/) offers a number of educational resources in several scientific and technical fields. In life and earth sciences, you will find plenty of information on zoology, including software applications (for example, PhyloGene), useful data, and self-learning materials for various topics in biology.

Purpose: This information will provide you with a better understanding of species classification methods. In addition, you will find the PhyloGene software very useful to help your students draw up genealogical trees for animals.

Useful link No. 2

Title: Zoology URL: http://www.inrp.fr/ *http://www.si.edu/resource/faq/nmnh/zoology.htm*

[Suggestions: Zoology at: http://en.wikipedia.org/wiki/Zoology

and http://dir.yahoo.com/Science/Biology/Zoology/]

Description: This site provides detailed descriptions of birds, mammals, and other zoological groups such as invertebrates and vertebrates. It is very useful for documentation, classroom materials, and research projects.

Purpose: This site is recommended because it provides complementary information on almost every field relating to zoology.

Useful link No. 3

Title: Science Animations: Movies and Interactive Tutorial Links

URL: http://nhscience.lonestar.edu/bioL/animatio.htm

Description: This site presents a variety of topics and links. For example, at http://science.nhmccd.edu/biol/animal.html, [Not found] you will find different categories of animals with links to relevant information. It also offers animations on all kinds of topics.

Purpose: This site provides a variety of teaching resources, particularly animations.

Useful link No. 4

Title: Animal Diversity Web

URL: http://animaldiversity.ummz.umich.edu/site/index.html

Description: This site of the University of Michigan Museum of Zoology (USA) provides information on different animal categories: amphibians, insects, arthropods, birds, molluscs, fish, reptiles, mammals, echinoderms, and others. Information on each category is provided along with their classification. Images and sound are also available. The site is packed with useful information.

Purpose: This site contains specific information on each animal category. It is a good resource site.

Useful site No. 5

Title: Biodidac

URL: http://biodidac.bio.uottawa.ca/ [Server error: Cannot connect] [Use: http://sciencestage.com/biodidac]

Description: Biodidac is a bilingual (English and French) Canadian site that provides zoological images and documents. It also contains lessons in various presentation formats such as pdf or PowerPoint on a variety of subjects, including classification, Protozoa, Cnidarians, and Mammals.

Purpose: This site will make your classroom presentations lively. It offers a number of ways to organize and present your material.

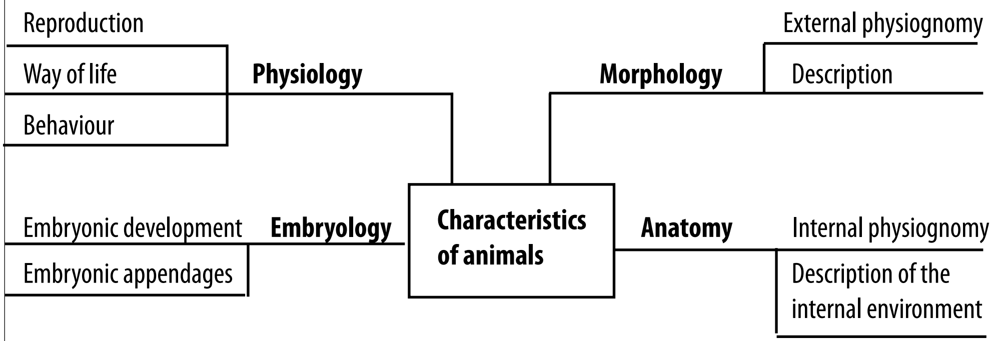
XIV. Learning activities

UNIT I

General characteristics of animals

Introduction

Animals have diverse characteristics, and this is one of the main ways to distinguish them. Historically, morphological features were practically the only determinants that identified and separated animals. However, as the sciences advanced, other characteristics enabled more subtle distinctions to be made, drawing on several scientific fields. We will therefore look at three main types of characteristics: morphological, anatomical, and physiological. For the morphological features of large phyla in the animal world, we will consider the external structure (architectural variations), size, shape, and subdivisions of the animal's body, as well as the nature and state of the superficial area (scales, feathers, skin, hair, cilia, flagella). In terms of anatomical characteristics, we will consider the internal structure, or an anatomical description: nervous system, breathing apparatus, digestive, circulatory and muscular systems, and chordata. Physiological characteristics will be approached in terms of the animal's external and internal behaviour: contractility, support, sensitivity, digestion, and fluid circulation. We will also review topics of embryology, ecology, and paleontology.



Learning activity 1

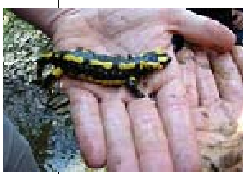
Interdisciplinary determination of animal characteristics

Specific learning and teaching objectives

1.1 Specific knowledge objectives

At the completion of this unit, learners should be able to:

- Define basic concepts of zoology such as convergence, phylogenesis, and the organization plan
- Be familiar with the pioneers of zoological science and the disciplines involved
- Name the general characteristics of animal groups
- Name the different phases in the problem solving process
- Identify the different morphological, anatomical, and physiological characteristics of animals



Le Graine Midi-Pyrénées
Maison régionale de l'environnement [regional development office]

1.2 Specific methodological objectives

At the completion of this unit, learners should be able to:

- Manually or using software, develop a conceptual chart of the disciplines involved in, or the characteristics of, an animal group based on a text or related concepts
- Work in collaboration on a group project
- Prepare a PowerPoint presentation on a given topic
- Describe the methods used by diverse disciplines to study animal characteristics
- Organize research results

1.3 Specific objectives for value and attitude clarification

At the completion of this course, learners should be able to:

- Actively participate in a collaborative project
- Respect the animal world

Summary of the learning activity

This activity demonstrates the interdisciplinary nature of the study of animal characteristics. It presents an opportunity to apply a problem-solving approach, and it also situates zoology in the determination of animal characteristics. Is zoology the only field capable of doing so?

Many disciplines are required in order to determine animal characteristics. Confirming this statement will require reading, Internet research, reports, individual writings, and importantly, information sharing among colleagues using synchronous collaboration tools (chat) or asynchronous tools (forums, email). At the end, each learner will produce a reflective essay.

Key concepts

Phylogenesis: the sequence of events involved in the evolutionary development of a species or taxonomic group of organisms, or the study of evolutionary relatedness among various groups of organisms.

Phylum: in classification, the Phylum is placed hierarchically below the Kingdom and above the Class.

Convergence: collaboration between diverse disciplines to explain anatomical resemblances between different animal groups living in the same environment.

Organization plan: all living organisms have a distinctive organization. There are three main organization plans: radial, asymmetric, and bilaterally symmetric.

Differentiation: transformation, development, cellular maturation.

Key words

- Phylogenesis
- Convergence
- Organization plan
- Clade
- Character
- Metamerization
- Cephalization
- Homology
- Analogy
- Genealogical tree

Required resources

Reading No. 1

General characteristics of animals

Complete reference: Extract from an original course by Laurence Rabotovao

Université d'Antananarivo (Madagascar)

Summary: This extract from a course addresses the general characteristics of Protozoa and Metazoa. It contains substantial information on the organization, systematic, and phylogenetic relationships of animal groups. The involvement of other scientific disciplines in zoological knowledge is noted throughout the text.

Purpose: This document provides an introduction to the general characteristics of animals and the disciplines involved in their study. It will serve as a reference and a base for future research to assist you in confirming or disconfirming your research hypothesis.

Reading No. 2

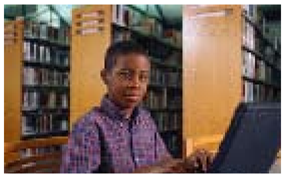
Complete reference: Extract from Charles Darwin (1859). On the Origin of the Species

An historical outline of the progress of opinion on the origin of species before the publication of the First Edition in English.

http:/www.ebooksgratuits.com [Suggestion: http://www.literature.org/authors/darwin-charles/the-origin-of-species/]

Summary: This document presents a history of zoology, including the works, the authors, and the major theoretical perspectives up to the age of Darwin. Among others, it addresses the principles of natural selection, Lamarck's laws of progressive development, and other approaches to zoology.

Purpose: This document will help the learner understand the epistemology of zoology, in particular, nascent and enduring theories with the development of science and technology.



Resource No. 3

Video produced by the UVA (3 mn)

La zoologie dans tous ses états avec Madame Laurence Rabotovao.

Summary: This three-minute video explains the interdisciplinary nature of the study of animals. Different disciplines, including morphology, descriptive and compared anatomy, physiology, reproduction, embryology, systematics, paleontolgy, and ecology are mentioned.

Each discipline has useful information that helps clarify the knowledge of animal characteristics.

Purpose: This video will be very useful. The disciplines cited provide a base from which to perform your research. Which characteristics relate to which discipline? What methods and results are relevant in zoological studies?

Required Resources

Resource No. 1

Complete reference: Biological diversity: Animals I

Biology Textbooks\INTERNET-SITES\Online-Biology-book\BioBookDiversity_7.html [Hard to find on Google]

Summary: This document addresses the organization of animal bodies, from the Protista to the nematodes. The text is accompanied by clear illustrations. It presents the evolutionary history and classification of zoological groups.

Purpose: This document was chosen for its simplicity of presentation and the illustrations, particularly the diagrams, which can be used to make drawings.

Resource No. 2

Complete reference: Biological diversity: animals II

BiologyTextbooks\INTERNET-SITES\Online-Biologybook\BioBookDiversity_8.html [Hard to find]

Summary: This document continues with the study of animals, from the coelomates to the arthropods.

Purpose: Same as for Biological diversity I

Resource No. 3

Complete reference: Biological diversity: animals III

Biology Textbooks\INTERNET-SITES\Online-Biology-book\BioBookDiversity_9.html

Summary: This document completes the study of animals. Fish and mammals are described, accompanied by magnificent illustrations.

Purpose: Same as for Biological diversity I and II

Resource No. 4

Biology Textbooks\KERALA BOOK

Complete reference: Biology Textbooks\KERALA BOOK

http://www.education.kerala.gov.in/eng_bio.htm

Summary: Chapter Seven of this seven-chapter book deals with evolutionary issues. It relates organization of animal body to chemistry. Animal and plant evolution are taken into account.

Purpose: This document will serve as a valuable resource for evolutionary issues.

Useful links

Link No. 1

Society for Experimental Biology

Complete reference: http://www.sebiology.org/index.html

Summary: The Society for Experimental Biology aims at promoting, and increasing the influence of, experimental biology in learning biology. Researchers, teachers, and students are invited to consult the site. It covers a number of different topics such as cellular, animal, and plant biology.

Purpose: This site is recommended for the information it contains, not only on animal biology, but also on their well-being. The ethical topics concerning animals should be of interest to all biology students.

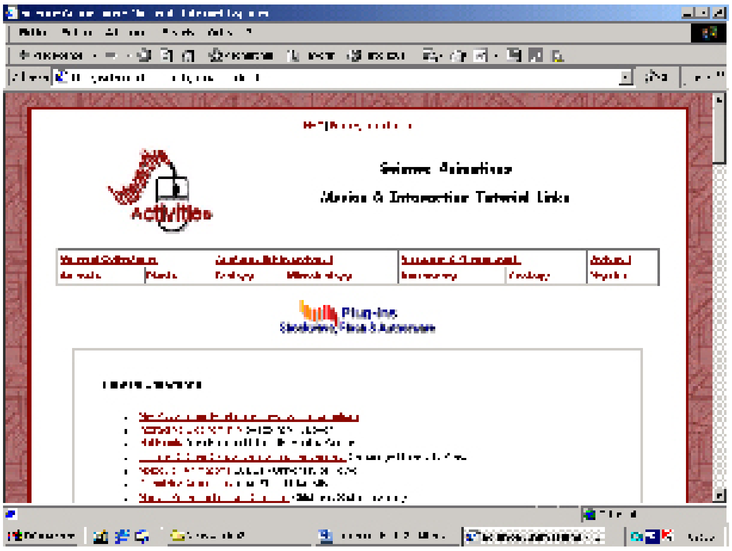
Link No. 2

Science Animations: Movies & Interactive Tutorial Links

Complete reference:

http://science.nhmccd.edu/biol/animatio.htm

http://nhscience.lonestar.edu/bioL/animatio.htm



Online labs: http://highered.mcgraw-hill.com/sites/0072437316/student_view0/online_labs.html

Virtual labs: http://www.mhhe.com/biosci/genbio/tlw3/virtual_labs/lab21/home.html

Summary: This site offers a variety of activities. There are over 30 virtual laboratories covering a range of fields, for example, the environments of amphibians, termites, snails, and many more.

Purpose: We strongly recommend that you visit this site for teaching purposes. The materials on offer are highly appropriate for distance teaching and learning activities in the field of zoology.

Link No. 3

The Sourcebook for Teaching Science

Complete reference: http://www.csun.edu/science/biology/index.html

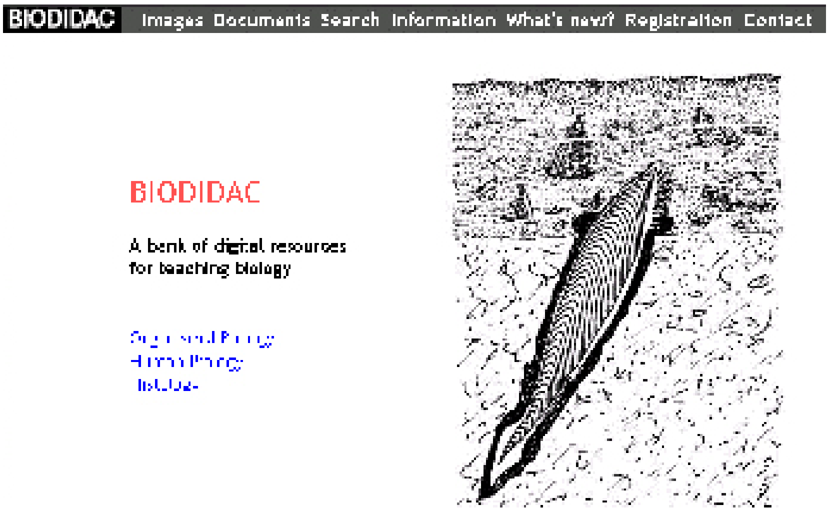
Summary: This site offers a number of topics such as zoology and marine biology and anatomy and physiology. Several titles are provided for each topic.

Purpose: This site will help you develop a bibliography. Delving into the content of each article will increase your understanding of the basics of this module.

Link No. 4

Biodidac

Complete reference: http://biodidac.bio.uottawa.ca/



Description: Biodidac is a Canadian bilingual (English and French) site that hosts a bank of digital images, videos, and animations that can be used for teaching zoology. Files are offered as diagrams or photos, in various formats such as gif or jpg, PowerPoint (zip files), and Corel Draw files. Topics include classification, protozoa, cnidarians, mammals, and so on.

Purpose: This site will inspire and enliven your classroom presentations. It offers many different possibilities of approaching and organizing information.

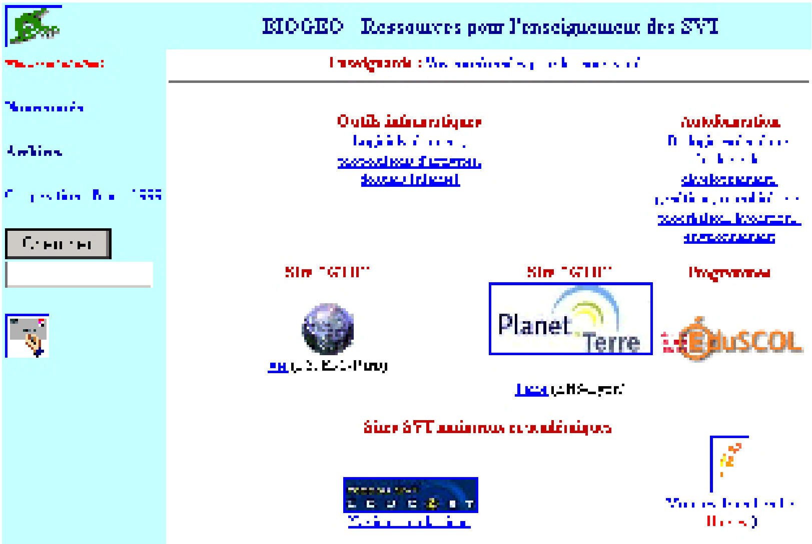
Link No. 5

Biogeo – Ressources pour l'enseignement des SVT

Complete reference:

Titre: Biogeo - Ressources pour l'enseignement des SVT

URL: http://www.inrp.fr/Acces/Biogeo/accueil.htm



Description: This site was developed by the *Institut National de la recherche scientifique de France* (http://www.inrp.fr/). It provides a variety of teaching resources in many areas of science and technology. Under life and earth sciences (*Vie* and *Terre*), you will find plenty of information on zoology, including software (for instance, PhyloGene), useful data, and self-directed training material for various biological fields.

Purpose: This site is recommended because it will enable you to understand the different methods of species classification. In addition, the PhylGene application can be used to help your students develop genealogical trees for animals.

Detailed description of the learning activity

The study of animal characteristics primarily involves morphological, anatomical, and physiological characteristics. The main concepts are clarified, including anatomical convergences and divergences, homologies and analogies. The organization plan of animals and the contribution of histology are also addressed.

This part of the course considers the history of zoology in terms of the major stages, theories (evolutionary and fixist), and the personages that have dominated the field, such as Linnaeus, Van Leeuwenhoek, Darwin, and Lamarck.

This activity also addresses the use of research tools in distance learning.

Problem

Can all animal characteristics be studied using a single discipline, such as zoology?

Hypothesis

Several disciplines are required in order to fully understand animal characteristics.

The task is to confirm or reject this hypothesis through group Internet bibliographic research project.

Learners are required to complete three mandatory readings. Other resources and links have been made available, but learners should also find additional information sources.

Three practical assignments have been provided for those with access to a laboratory. Otherwise, additional tutored work will be carried out.

Learners will communicate using diverse means (e.g., forum, chat, email).

Learners will undergo a formative assessment at the completion of the module in order to evaluate their performance. Credit will be given for participation in forums and chat rooms and the preparation of a bibliography.

Each learner will prepare a reflective report according to the guidelines provided by the course instructor or tutor.

Learning activity

This activity is divided into six parts, as follows:

1. Required reading
2. Internet research
3. Practical lab work
4. Tutored distance work
5. Production of a group report on animal characteristics
6. Preparation of a reflective report

This chapter addresses the general characteristics of animals.

Task 1 Required reading and Internet research

The available texts are the three required readings. You must consult all the recommended links and resources provided in the module. However, you can also find others. When you have completed the readings, write a 300-word summary and send it to the other members of your group by email. Deposit a copy in the platform library. You are also required to deposit all documents that your colleagues might find useful and to consult the documents that they have deposited.

Task 2 Practical lab work

Learners will conduct three tutored practical laboratory assignments on animals, if they have access to a laboratory.

PA 1: Characteristics of Protozoa: microscopic observation (morphology), drawings.

PA 2: Characteristics of Metazoan Invertebrates: dissection (anatomy), etc.

PA 3: Characteristics of Vertebrates: (morphological study – dissection of certain animal groups).

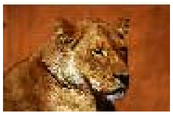
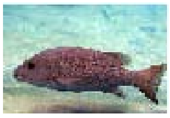
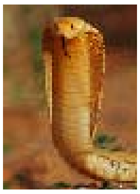
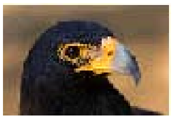
Your tutor will provide a procedural guide as necessary, after discussion with the course developer.

If no laboratory is available, learners will carry out additional tutored virtual work.

Task 3 Tutored distance work

Learners will be provided with a procedural guide for this activity. They can carry out the procedures at a distance or in the classroom when possible.

The task consists of viewing photos of course-related illustrations, drawing diagrams, preparing contact sheets for the production of teaching materials, and completing self-assessment exercises. Using the photos, you are required to observe the different animals and identify the characterization criteria. Next, what they have and do not have in common must be identified: they perform the same activities (fly, swim), live in the same place (water); are used for the same purpose; or have or do not have a feature (fur).

Animal	Characteristics
	Head, eyes, wings, fur, feathers, limbs, legs (number), fins, elytrons, antennae, teats, exterior skeleton.
	
	
	
	
	

Task 4 Internet research

The readings must be complemented by Internet research, more precisely, visits to the sites recommended in Unit I. However, learners should also do some individual research in order to deepen their understanding.

Task 5 Production of a group report on animal characteristics

This task consists of preparing a summary of the information obtained on animal characteristics. It will be used for preparing a final report on this unit. Use the same information to write an individual essay that will be useful in the next unit.

Task 6 Preparation of a reflective report

Perform a self-assessment by completing the exercises individually or in a group before attempting to properly complete the formative assessments.

Formative assessment

Exercise 1 – Pseudopods are found in metazoa.

❒ True ❒ false 0.5 points

Exercise 2 – Check the correct answer: 1.5 points

Diploblastic organisms have:

a) ❒ two embryonic cell layers

b) ❒ two legs

c) ❒ two blastophores

d) ❒ two blepharoplasts

Exercise 3 – Check the correct answer 1.5 points

Cephalization begins in the:

a) ❒ porifera

b) ❒ ctenophora

c) ❒ cnidarians

Exercise 4 – Matching exercise 1.5 points

gametogamy	fusion of two plant cells
gametogenesis	fusion of two sexual cells
gamontogamy	formation of gametes

Exercise 5 – Fill in the blanks 1 point

Fill in the blanks with the following words: informant - region - differentiate - gripper

These animals have shown a tendency to …………… an anterior ………….. that plays a dual role of ……………., using its sensory receptors, and a …………… of food using its oral orifice.

Exercise 6 – Fill in the blanks 1 point

Fill in the blanks with the following words: Parenchyma - tissue - vesicle - organ

The mesoderm is never organized as a single closed …………… in certain animals. It generally provides a diffuse intervisceral …………—the…………….—and participates in the development of the ………….. or apparatus.

Exercise 7 – Definitions 1 point

Check the correct answer

Metamerization is:

❒ a) splitting

❒ b) cracking

❒ c) segmentation

❒ d) division

Exercise 8 – Matching exercise 2 points

Match the animal to the characteristic using arrows:

Echinoderms - bilateral symmetry - polyps – coral - radial symmetry - asymmetry

Answers

Exercise 1 – False

Exercise 2 – c) having both an endoderm and an ectoderm

Exercise 3 – c) cnidarians

Exercise 4 –

gametogamy	fusion of two plant cells
gametogenesis	fusion of two sexual cells
gamontogamy	formation of gametes

Exercise 5 – These animals have shown a tendency to **differentiate** an anterior **region** that plays a dual role of **informant,** with its sensory receptors, and a **gripper** of food, using its oral orifice.

Exercise 6 – The mesoderm is never organized as a closed **vesicle** in certain animals. It generally provides a diffuse intervisceral **tissue**—the **parenchyma**—and participates in the development of the **organ** or apparatus.

Exercise 7 – Choose the correct synonym:

Metamerization means segmentation.

Exercise 8 – Matching exercise

Echinoderms	➠	radial symmetry
Polyps	➠	bilateral symmetry
Coral	➠	asymmetry

Learning guidelines

The purpose of these exercises is to determine how much you have learned in this activity on the general characteristics of animals. Various types of questions covering the course material are presented in order to assess your overall knowledge. You should therefore answer them carefully.

Two trials are allowed for all answers. The average of the two marks will be recorded.

If your score falls between:

- 30% and 50%, redo the readings.
- 50% and 75%, you have acquired a substantial amount of knowledge in this field.

This test will be available for two weeks.

Learning activity No. 1 demonstrates the wide morphological diversity of animals, both morphologically and anatomically. This variation stems from the great evolution that has been described by many authors, based on the knowledge referred to in Unit 1. We now turn to Learning activity No. 2, in which we will learn about evolutionary trends in animals.

Unit II

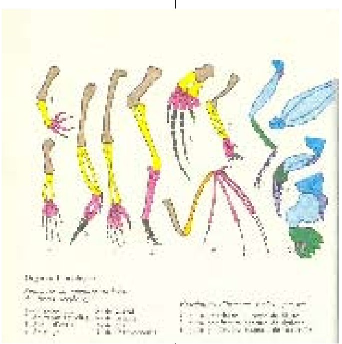
Evolutionary trends in animals

Introduction

The second unit covers evolutionary trends in animals.

We know that there are many approaches to evolution, including fixism and evolutionism. We retain evolutionism, because it is currently the most well supported approach scientifically.

The knowledge you acquired in the first learning unit will facilitate your understanding of evolutionary trends in animals. You are required to do research on the genetic relationships between animal groups. In other words, you will make use of different disciplines to identify the aspects that reveal evolutionary trends.



Learning activity 2

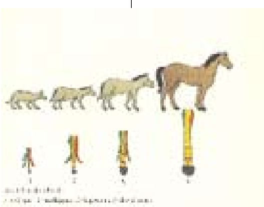
Collaborative research project on evolutionary trends

Specific objectives

1.1 Specific knowledge objectives (understanding)

On completion of this unit learners should be able to:

- Outline the various steps of a research activity
- Cite various information sources
- Define key notions such as Darwinism, fixism, and cellular differentiation
- Know the different evolutionary trends of animals based on comparative anatomy



1.2 Specific method objectives (know-how)

On completion of this unit learners should be able to:

- Describe reproduction methods and life cycles of diverse animal groups
- Compare phyla of animals
- Organize information
- Use collaborative tools

1.3 Specific objectives for value and attitude clarification (soft skills)

Uphold animal conservation and biodiversity

Summary of the learning activity

Evolutionary theories were developed based on the convictions of those who defended them, but in the end, and supported by scientific and technological advances, the evolution proposed by Darwin dominated.

Drawing on the disciplines explored in the previous activity, learners will perform tasks designed to help them understand evolutionary trends in animals and the significant aspects that enable determining degrees of genetic relationship and evolutionary history. Learners will use either synchronous or asynchronous collaborative tools, prepare a self-assessment, and draw up individual reports on the topic. In this unit, we will rely heavily on the deductive method.

Key concepts

Fixism: The theory that living species appeared in ancient times as they are today and that evolution did not occur.

Darwinism: A theory stating that all species of organisms arise and develop through the natural selection of small, inherited variations that increase the individual's ability to compete, survive, and reproduce and allow them to adapt to environmental conditions and changes.

Cellular differentiation: The process by which a less specialized cell becomes a more specialized cell type through the transformation, development, and maturation of a multicellular organism.

Collaborative learning: An activity in which learners work together using distance communication tools to accomplish tasks.

Evolutionary trend: The ability of a species to develop features that enable it to resist change (morphological and anatomical variations) and that conserve ancestral specificity.

Key words

Fixism

Darwinism

Cellular differentiation

Collaborative learning

Evolutionary trend

Theory of evolution

Useful resources

Required readings

Reading No. 1: General characteristics of animals

Complete reference: Extract from an original course by *Laurence Rabotovao, Université d'Antananarivo (Madagascar) Ecole Normale Supérieure*

Summary: This extract from a course addresses evolutionary trends in Protozoa and Metazoa. It contains substantial information on the phylogenetic relationships of animal groups.

Purpose: Reading this document will help you understand the pros and cons of theories on evolutionary trends in animals.

Reading No. 2. Extract from Charles Darwin (1859). On the Origin of the Species, 666 p.

A historical outline of the progress of opinion on the origin of species before the publication of the First Edition in English.

http:/www.ebooksgratuits.com [Suggestion: http://www.literature.org/authors/darwin-charles/the-origin-of-species/]

Summary: This document presents a history of zoology, including the works, the authors, and the major theoretical perspectives up to the age of Darwin. Among others, It addresses the principles of natural selection, Lamarck's laws of progressive development, and other approaches to zoology.

Purpose: This document will help the learner understand the epistemology of zoology, in particular, nascent and enduring theories with the development of science and technology.

Resources

Resource No. 1

Complete reference: Monique Dupuis, Lycée Jean Monnet, La-Queue-les-Yvelines: *Relations de parenté entre les êtres vivants : Méthodes utilisées pour établir les relations de parenté entre les êtres vivants*

http://www.inrp.fr/Acces/biotic/evolut/parente/html/methode.htm

[Suggestion: **Classification, species concepts and their relation to conservation biology and policy**. *http://www.montana.edu/~wwwbi/staff/creel/bio480/spcon.pdf*]

Also: **Species Diversity and Phylogeny** at: http://education.sdsc.edu/teachertech/downloads/phylogeny.pdf]

Last visited on 07/09:2006 at 6 h 17 mn[For the French reference]

Summary: This text presents two methods based on morphological, anatomical, molecular, and caryologic data to establish genetic relationships among living organisms: Cladistics and Phenetics.

Purpose: This text will prove very useful because it presents practical methods to establish genetic relationships between living organisms. It provides accurate guidelines for the criteria to consider. Read this document to learn more.

Resource No. 2

Complete reference: Monique Dupuis, Lycée Jean Monnet, La-Queue-les-Yvelines : *Relations de parenté entre les êtres vivants : Lire et exploiter un arbre phylogénétique*

http://www.inrp.fr/Acces/biotic/evolut/parente/html/methode.htm http://www.inrp.fr/Acces/biotic/evolut/parente/html/anaterm.htm

Last visited on 07/09 :2006 at 6 h 37 mn [for the French reference]

[Suggestions: Phylogenetic tree at: http://en.wikipedia.org/wiki/Phylogenetic_tree]

[Also: **Encyclopedia of Life** at: http://en.wikipedia.org/wiki/Encyclopedia_of_Life

and **Taxonomic Classification & Phylogenetic Trees** at: http://www.mhhe.com/biosci/pae/zoology/cladogram/]

Summary: These sites present the relationships among a genealogical tree and a comparative table of the characteristics of many species, covering the following topics:

- Identification and justification of relationships
- Characteristics of common ancestors
- Definitions of monophyletic (or cladistic) groupings
- Know whether or not a tree is valid

Purpose: After reading these documents, you will have acquired some knowledge about the genealogical trees of living organisms. You may also be inspired to develop application exercises and formative or summary assessment questions.

Useful links

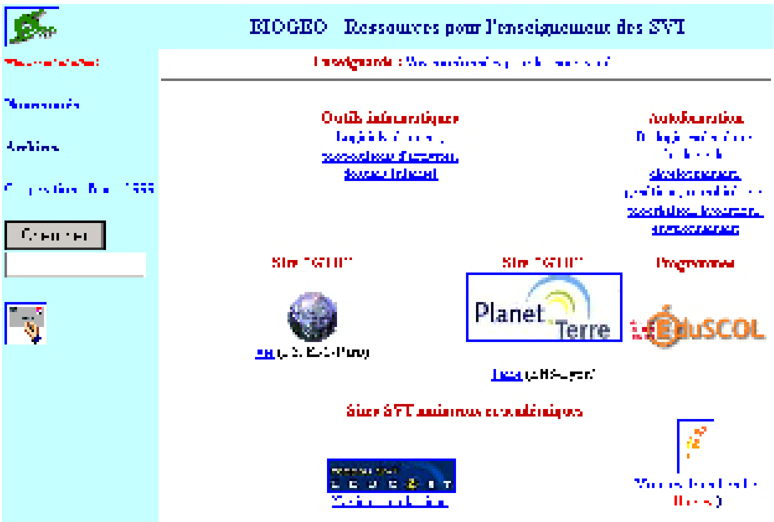
Title: ***Biogeo - Ressources pour l'enseignement des SVT***

URL: http://www.inrp.fr/Acces/Biogeo/accueil.htm

[Suggestions: **Earth Science Education Resources** at: http://www.academicinfo.net/edteachearth.html ;

And

Federal Resources for Educational Excellence at: http://free.ed.gov/index.cfm]



Description: This site of the *Institut National de la recherche pédagogique de France* (http://www.inrp.fr/) offers a number of educational resources for several scientific and technical fields. In life and earth sciences, you will find plenty of information on zoology, including software applications (for example, PhyloGene), useful data, and self-learning materials in various areas of biology.

Purpose: This information will provide you with a better understanding of the methods of classifying species. In addition, you will find the Phylogenesis software very useful to help your students draw up genealogical trees for animals.

Detailed description of the learning activity

This activity on evolutionary trends in animals is based on sharing research and information. Readings, resources, and links are available to learners, who are grouped into teams of four to five individuals. Learners must consult the information to gain a clear idea of the theories of evolution, from fixism and spontaneous generation to evolution. The research underscores the morphological, anatomical, physiological, ecological, and paleontological features of individual organisms as well as their structural and architectural divergences. This activity will help you acquire collaborative research skills.

Each learner carries out several tasks and the results are shared in a collaborative learning project.

Task 1: research on evolutionary theories

Task 2: 300-word summary of each theory, including theory defenders (authors), period, arguments, several examples, and limitations of the theory.

Task 3: sharing by email or through a forum, chat room, or mailing list

Task 4: shared two-page paper

Task 5: production of a reflective report

Learning activities

This learning activity, which involves collaborative research in order to complete five tasks, has the following objectives:

Task 1 Readings and research

- Read the required resources on evolutionary trends in animals.
- After doing the research, each learner proposes three relevant sites and shares them with the other group members. This is important, because it underscores the fact that you are not limited to what you find yourself, and that there is always something more to learn.

Task 2 Summary

- Write a summary of about 300 words for each theory and illustrate it with two appropriate images of your choice.
- You should mention 5 to 10 facts (theory defenders, arguments, etc.) that you feel are relevant for your summary.

Task 3 Shared productions

- Send the summaries to the other group members for comments, suggestions, and recommendations (feedback).
- List the items that were commented on by the other group members.

- Share this list with the other members in order to prepare an outline for a paper on evolutionary trends in animals.

Task 4 Shared five-page paper

- After your group has agreed on the outline, write a group paper on evolutionary trends in animals.
- The group paper is then reviewed and revised by each member of the group.

Task 5 Production of a reflective report

Each member of the group produces a reflective report that answers the following questions, among others:

- What have I learned about the design, technical aspects, and individual and group organization of work in collaborative learning?
- How did I learn?
- What helped me to learn?
- How much time did I spend on this activity?
- Am I satisfied with my participation in this group production?
- What will my new skills change in my professional practice, for instance, in my choice and use of simulation tools?
- What problems did I encounter?
- How could I transmit these skills to my students?

Formative assessment: Application and concentration exercises

Exercise 1

Tick the correct answer.

- The dorsal cord appeared long before the vertebral column.

❒True ❒False 0.5 point

- Bony tissue is found in vertebrates.

❒True ❒False.
0.5 point

- The Amphioxus has a vertebral column.

❒True ❒False 0.5 point

Exercise 2

Multiple choice

Tick the correct answer.

I- Bony tissue was originally 1.5 points

❒ - mesodermal

❒ - ectodermic

❒- endodermic

Exercise 3

Multiple choice 1.5 points

Tick the correct answer.

In vertebrates, the part of the body that houses the coelom is:

❒ the head

❒ the trunk

❒ the tail

Exercise 4

Fill in the blanks: 3 points

Fill in the blanks with the following words: *mesodermal, metamerization, character, cord, superposition, development, importance, levels, evolved, radial symmetry, bilateral symmetry, asymmetrical, pelagic, Cambrian, air bladder, classes, aquatic environment, land environment, respiratory system, primitive character, diblastic state, convergence, rudimentary state*.

4. 1

Their fundamental ………… lies in the …………… of the digestive tract, the aorta, the ………., and the nervous system. To this we may add the ………………… of the ……………… vesicles, or somites.

4.2

The formation of these areas stems largely from the fact that, at each of these ………., the mesodermal masses ……… differently. This reaffirms the …………………of the coelom and its derivatives in the …………………… of animal forms.

4.3

The echinoderms appeared in the……………..age in the form of a ………. animal with ……………., which subsequently …………… towards a …………… animal, with no……………………. Thereafter, they were divided into two distinct groups: the Pelmatozoa and the Eleutherozoa.

4.4

The evolution of the inferior ………….., CYCLOSTOMES and FISH, occurred entirely in an …………………… They were able to move to a ……………… thanks to their air-breathing …………………….. (lung). The starting point was the …………………….., with its pharyngeal branchiae, which was eventually replaced by the lung.

4.5

There is substantial evidence to support the …………………..of groups of the cnidarian and ctenarian sponges. For example, the …………………… of their nervous system and the absence of a third dermal layer, which leaves them in the ………………., which demonstrates their …………………. as well as a very ancient and similar origin.

Exercise 5

Prepare a research report containing 1,500 words maximum on phylogenesis, identifying the significant aspects. 3 points

Exercise 6

Build a comparative table of the main invertebrate branches. To highlight the similarities and differences among them, use the following criteria: number and name of tissues, diploblastic or triploblastic organization, name of the digestive cavity, digestion mode, name of the cavity in the mesoderm, destination of the blastopore, evolutionary pattern (protostome or deuterostome), structural plan, name and number of orifices, symmetry, presence or not of a head, exclusive characteristics, living environment, movement mode, feeding mode, breathing mode, lifestyle mode (fixed, mobile, parasitical), main representatives, segmentation (metamerization), and skeleton.

Exercise 7 2.5 points

For each of the following forms of breathing, provide the main characteristics and three examples of animals that use it. Organize your answer as a table with three columns.

Breathing type	Characteristics	Phylum/Class
Direct exchange		
Cutaneous		
Trachean		
Branchial		
Lung		

Question 8 2.5 points

Classify this list of animal body parts according to ectodermal, mesodermic, or endodermic origin: internal skin of the alimentary canal, bone, blood vessels, liver, skin, rectum, respiratory tract, nervous system, pancreas, cartilage, vessel, thyroid gland, parathyroid gland, mouth, kidneys, eye cornea, reproductive organs, thymus gland, lungs, vertebrae, part of the brain, striate muscles, and blood cells.

Dermal layer	Associated organs
Ectoderm	
Mesoderm	
Endoderm	

Question 9 4.5 points

Develop a genealogical tree based on the following list of evolutionary innovations and animals:

List of innovations in descending order: jaws, finger, amnions, mandibular window, placenta, nails.

List of animals in random order: Gorilla, bat, lamprey, crocodile, salamander, lemur, human, Saki monkey, ostrich, tuna, otary.

Answers

Exercise 1

- The dorsal cord appeared long before the vertebral column. ❒ True
- Bony tissue is found in vertebrates. ❒ False
- The Amphioxus has a vertebral column. ❒ False

Exercise 2

Multiple choice

Bony tissue was originally: ❒ mesodermal

Exercise 3

Multiple choice

In vertebrates, the part of the body that houses the coelom is: ❒ the trunk

Exercise 4

Fill in the blanks.

4. 1

Their fundamental *character* lies in the *superposition* of the digestive tract, the aorta, the *cord*, and the nervous system. To this we may add the *metamerization* of the *mesodermal* vesicles, or somites.

4.2

The formation of these areas stems largely from the fact that, at each of these *levels,* the mesodermal masses *evolved* differently. This reaffirms the *importance* of the coelom and its derivatives in the *development* of animal forms.

4.3

The echinoderms appeared in the *Cambrian* age in the form of a *pelagic* animal with *bilateral symmetry*, which subsequently *evolved* towards a *asymmetrical* animal, with no *radial symmetry*. Thereafter, they were divided into two distinct groups: the Pelmatozoa and the Eleutherozoa.

4.4

The evolution of the inferior *classes*, CYCLOSTOMES and FISH, occurred entirely in an *aquatic environment*. They were able to move to a *land environment* thanks to their air-breathing *respiratory system* (lung). The starting point was the *air bladder*, with its pharyngeal branchiae, which was eventually replaced by the lung.

4.5

There is substantial evidence to support the *convergence* of groups of the cnidarian and ctenarian sponges. For example, the *rudimentary state* of their nervous system and the absence of a third dermal layer, which leaves them in the *diblastic state*, which is a sign of their *primitive character* as well as a very ancient and similar origin.

Question 6

Answers will vary. Each learner produces an individual report according to their ability to find information.

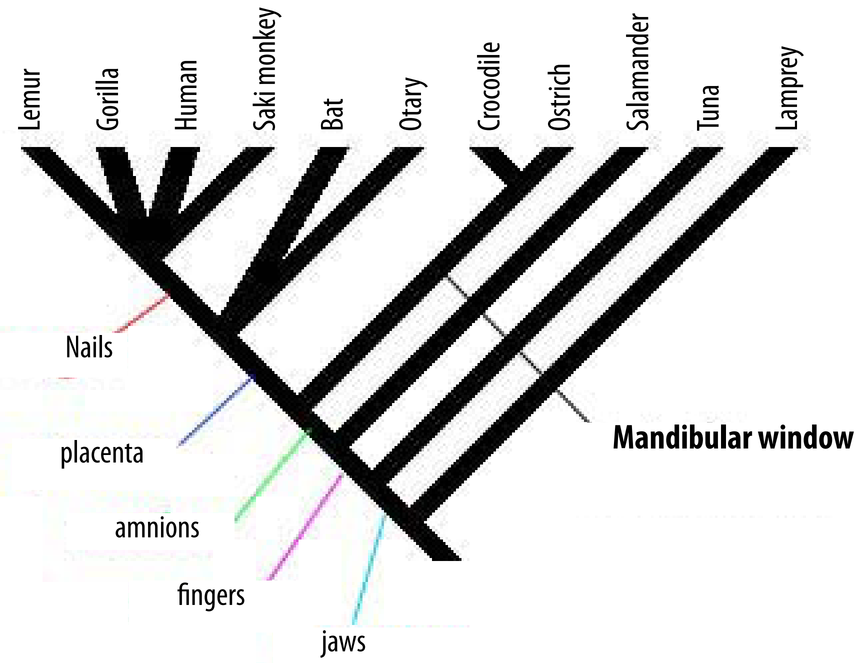
Question 7

Breathing type	Characteristics	Phylum/Class
Direct exchange		Sponges
Cutaneous		Cnidarians, Rotifers (aquatic)
		Annelids, Amphibians (land)
Trachean		Insect larvae (aquatic)
		Arachnids, Insects (land)
Branchial		Molluscs, Crustaceans,
		Echinoderms, Fish, Amphibians
Lung		Reptiles, Birds, Mammals

Question 8

Dermal layer	Associated organs
Ectoderm	Nervous system, skin, eye cornea, mouth, rectum
Mesoderm	Lungs, vertebrae, part of the brain, striated muscles, blood vessels, blood cells, kidneys, bones
Endoderm	Skin covering the digestive tract, liver, pancreas, vessel, thyroid gland, parathyroid gland, thymus, respiratory tract

Question 9



Taken from: http://www.inrp.fr/Acces/biotic/evolut/parente/html/anaterm.htm

Learning guidelines

The purpose of this test is to determine how much you have learned in this unit on evolutionary trends in animals. You are required to answer different types of questions covering the entire course content in order to assess your overall knowledge, but also your skills in research, methodology, and paper writing. You should therefore answer your questions carefully.

You are allowed two trials on all questions. The average of the two marks will be recorded.

This test will be available for two weeks.

After completing Learning activity No. 2, you will have learned about evolutionary trends in animals. This leads us to the study of animal classification based on their different overall structural and anatomical organizations. This classification, or systematics, is based on units 1 and 2.

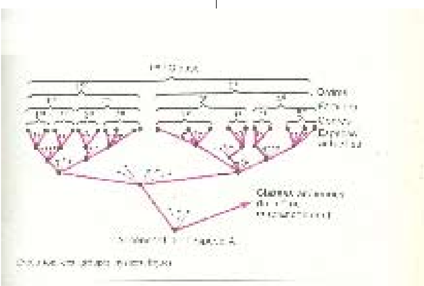
Unit III

Classification of animals

Introduction

Classifying a group or animals requires two separate operations: 1) distinguishing the group from its neighbours and accurately determining its place among them; and 2) what is properly known as classification, or subdividing the group in question. In both cases, a comparative study of the characteristics is made in the aim of identifying the most diverse features in order to establish degrees of genetic relationship.

Ever since living beings have been systematically classified, they have been divided not only as individuals in a hierarchical system of categories, called taxons, but also in terms of phylogeny, or evolutionary history. This is known as the phylogenetic evolution classification.



Learning activity No. 3

Reflective project and group discussion

Specific learning objectives

1.1 Specific knowledge objectives (understanding)

At the completion of this unit, learners should be able to:

- Name the different subdivisions of the animal classifications
- Group the animals according to their relatedness.
- Prepare a classification table of animals down to the lowest rank

1.2 Specific method objectives (know-how)

At the completion of this unit, learners should be able to:

- Classify animals using a diagram
- Compare the organization plans of various phyla
- Use collaborative learning tools to carry out a group activity

Summary of the Learning activity

This activity will demonstrate your ability to participate in collaborative learning. For successful group work, the roles, functions, and tasks of the different members must be defined.

This activity aims at providing learners with the training and skills to engage in structured distance group learning. Specific priorities are defining the tasks of each group member and organizing the work in terms of planning, follow-up, and results. You must therefore adhere to your group's decisions as far as possible.

Key concepts

Category: In zoology, the hierarchical level that determines an animal's classification rank, for example, species, genus, or phylum.

Classification: A method by which organisms are distinguished and ordered into homogeneous groups of species, genera, and phyla, according to different criteria.

Systematics: The science that studies biological diversity and the evolutionary relationships between living organisms.

Taxon: A group of organisms belonging to a biological classification category.

Divergence time: The date of the last common ancestor of two taxons.

Key concepts

1. Category
2. Classification
3. Systematics
4. Taxon
5. Divergence time
6. Features
7. Evolutionist systematics
8. Phenetic systematics
9. Phylogenetic systematics
10. Collaborative learning

Required Resources

Required readings

Texts from the course by Ms. RABOTOVAO

Reading No. 1 Classification of animals

Complete reference: Extract from an original course by Laurence Rabotovao, Université d'Antananarivo (Madagascar) Ecole Normale Supérieure

Summary: This extract addresses the classification of animals. For some groups, such as insects, it is largely a matter of traditional classification and the fundamentals of classification. There is also substantial information on the phylogenetic relationships between animal groups.

Purpose: By reading this document, you will learn about the different classes of animals. The essential concepts of classification criteria are also described.

Reading No. 2

Reading No. 2: What is Collaborative learning? by Barbara Leigh Smith and Jean T. MacGregor

Summary: This article on collaborative learning explains the origins of this education practice. Collaborative work fosters collective knowledge creation, and it socializes the learner as well. It is therefore based on a socio-constructivist approach. It can be applied to various learning situations. Approaches, objectives, and procedures can vary widely.

Purpose: This article is recommended because it presents several examples that are particularly helpful in understanding the concepts, application fields, and strategies.

Required resources

Resource No. 1

Complete reference: *Relations de parenté entre les êtres vivants : Méthodes utilisées pour établir les relations de parenté entre les êtres vivants*

http://www.inrp.fr/Acces/biotic/evolut/parente/html/methode.htm

Site visited on 07/09: 2006 at 6:17 a.m.

by Monique Dupuis, Lycée Jean Monnet, La-Queue-les-Yvelines Reread by Guillaume Lecointre, MNHN

***[Suggestions: Genetic distance**, at http://en.wikipedia.org/wiki/Genetic_distance]*

***Karyotype**, at http://en.wikipedia.org/wiki/Karyotype*

***Phenetics**, at http://en.wikipedia.org/wiki/Phenetics*

***Cladistics**, at http://en.wikipedia.org/wiki/Cladistics]*

Summary:

These texts describe two methods that are based on morphological, anatomical, molecular, and karyological data to establish the genetic relationships between living organisms: Phenetics and Cladistics.

Purpose: These texts will be very useful to help you propose practical methods of establishing genetic relationships between living organisms, as they provide accurate guidelines for the criteria to consider. Read these texts carefully to deepen your understanding.

Resource No. 2

Reference: ROUX, Jean Paul: Le travail en groupe à l'école.

http://www.cahiers-pedagogiques.com/IMG/pdf/Roux.pdf

Summary: This article addresses all teachers. Advocating a socio-constructivist approach, it describes the benefits to students of working in groups. It underscores the importance of collaborative learning for individual progress and describes the operative principles of socio-constructive learning programs.

Purpose: This article will provide moral and pedagogical support for undertaking collaborative learning projects. It provides examples of actual, usable situations.

Useful links

Link No. 1

http://www.snv.jussieu.fr

Summary: This site presents topics in high-school biology under various headings: theoretical notions, teaching materials, laboratories, diverse links, and videos on subjects such as how the spermatozoon penetrates the ovocyte.

[Suggestions: **Biology Site: A reference for teachers and students**, at http://www.cbv.ns.ca/sarty/bio/bindex.html

Topics, at http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TOC.html

Index of biology articles, at http://en.wikipedia.org/wiki/Index_of_biology_articles

Biology Topics, at http://www.thewildclassroom.com/home/nav/biologytopics.html]

Purpose: These teaching materials will help you and your students understand the rapidly developing field of life sciences. It is important for teachers to be aware of this rapid change in order to avoid misrepresentations. In addition, it is not always clear how the facts have been established.

Detailed description of the activity

This activity addresses the classification of animals. Therefore, the classification criteria must be thoroughly understood, starting with the distinction between Protozoa (unicellular) and Metazoa (multicellular) organisms. Each group is further classified, also based on relevant elements: diploblasts/triploblasts, Acanthocephala/cordata, metamerization/cephalization, and so on.

Readings on these topics are provided.

Learners will be divided into groups of from four to six members each. You are required to organize your groups by delegating roles (coordinator, reporter, information researcher, and so on) for each task that is assigned or that you identify and define, using distance exchange. You will take turns playing the different roles for the different tasks. This will both enable you to get used to working in a group and to assess all the psycho-sociological and socio-constructivist dimensions. You will also complete the self-assessment exercises and individual formative assessments.

Learning activities

The learning activities are described below:

Task 1 **Identification of the tasks to complete**

Task 2 **Definition of the roles, functions, responsibilities, and tasks associated with the learning tasks using a table, as illustrated below (to be filled in by the members of your group).**

Tasks	Roles, functions, and responsibilities		Timeframe
1. Reading and documentation			
2.			

The coordinator of this activity will ensure that all members fully understand what is expected of them.

Task 3 Each member of the group gives suggestions about the work to be done, the timeframes within a range specified by the course instructor or tutor, and discussions of the various proposals through electronic exchanges.

Task 4 Distribution of the information research work (classification criteria) according to zoological groups and the various disciplines involved (histology, physiology, anatomy, embryology, morphology, history, paleontology, etc.). The new group coordinator oversees this activity and the reporter prepares a summary of the researchers' contributions (concepts, images, data, genealogical trees, etc.). Some group members will work on preparing a glossary of terms.

Sharing the different criteria via email, chat room, or forum.

Task 5 Trial classification of the different species, the names of which will be provided by your tutor. The participants exchange information under the guidance of the coordinator and reporter. Discussion and development of an agreed-upon classification and checking against an accurate classification.

Task 6 Individual reflective work

You are required to write up an individual report on what you have learned in this unit. You may incorporate the questions presented in the reflective report in Unit 2.

Formative assessment

These are marked exercises designed to assess your knowledge.

Exercise 1

Multiple choice

A. Place the following subphyla in order of development: 1.5 points

Subphyla of Protozoa

a) Subphylum Ciliates
b) Subphylum Acnidosporidia
c) Subphylum Actnopoda
d) Subphylum Rhizopoda

B. A. Place the following classes in order of development: 1.5 points

a) Class of Monogeneans
b) Class of Cestodes
c) Class of Tubellaries
d) Class of Cestodas
e) Class of Trematoda

Exercise 2

Fill in the blanks with the following words: 3 points

Problems, subdivision, Cnidarians, define, principle, establishing, adaptation classification, nutrition, range, geological

2.1 The………………… of a given group includes two distinct operations: one consists of the ……………… of the group in relation to its neighbours, while at the same time ……………… its exact place among them. The other, considered as classification *per se*, is the …………….of the group in question.

2.2 The division of …………. is very important. In biology, for example, it enables solving ……………… the…………… of budding. The………………of these animals is very advanced. They have an important place in the …………… of marine animals, because they populate the entire ocean, and their type of carnivorous………….. places them among the predators (zooplancktons). The Cnidarians play a very important …………….role (coral reefs are made of limestone from coral polyps).

Exercise 3 4 points

List the advantages and limitations of the cladistic and phenetic animal classification methods.

Exercise 4

Complete the following table: 5 points

Animal	Criteria						
	Number of dermal layers	Locomotor organ	Respiratory organ	Skin formation	Reproductive mode	Placenta	Life environment
Sponge							
Eagle							
Amoeba							
Shark							
Dolphin							
Flatworm							
Cnidarians							
Nematode							
Centipede							
Bees							
Crocodile							
Otary							

Study guidelines

The purpose of this test is to determine how much you have learned about this unit on the classification of animals. Various types of questions cover the overall course content in order to assess your general knowledge. Therefore, you must answer them carefully.

You are allowed two trials on all questions. The average of the two marks will be recorded.

This test will be available for two weeks.

Now that we have learned about the morphological and anatomical characteristics of animals (Unit 1), outline their evolutionary trends (Unit 2), and classified them (Unit 3), we will proceed to Unit 4, which deals with the economic importance of animals in every respect.

Unit IV

The importance of animals

Introduction

The importance of animals, from the Protozoa to Metazoa, has been repeatedly proven. It is evident in every aspect of our lives: economics, medicine, culture, society, and tourism. Today, preserving biodiversity has become a major issue around the world, as testified by policies and international calls to action. In addition, teaching this aspect after the characteristics, evolutionary trends, and classification of animals shows a willingness to consider all aspects of living organisms. The study of the importance of animals also provides an opportunity to introduce the integration of ICT in biology education, more specifically by developing assessment questions.

The integration of ICT has become a fundamental issue of growing importance in teaching and learning.

This activity consists of creating a quiz using the exercise software Netquiz.

Learners should not only master the criteria for developing questionnaires, but also learn how to use Netquiz to design interactive activities. It is therefore an excellent self-assessment tool.

Self-learning tools will be made available so that learners can acquire all the skills required to use them. The goal is for learners to integrate and use teaching and learning aids in their teaching practice.

At the end of the unit, learners will complete a formative assessment and write a reflective report.

Learning activity No. 4

Project: Creating a factbook on the importance of animals

Specific objectives

1.1 Specific knowledge objectives (understanding)

On completion of this unit, learners should be able to:

- Identify the different values of animals
- Identify the operating principles of animal protection

1.2 Specific method objectives (know-how)

Oncompletion of this unit, learners should be able to:

- Perform Internet research on the importance of animals
- Prepare a research report in the form of a factbook on the importance of animals
- Share information within a collaborative learning project

1.3 Specific objectives for value and attitude clarification (soft skills)

At the completion of this unit, learners should be able to:

- Demonstrate a keen interest in the integration and use of ICT in teaching and learning on the importance of animals
- Participate in advocacy actions for the protection of animals

From Wikipedia: http://fr.wikipedia.org/wiki/Animal_de_trait [French]

http://en.wikipedia.org/wiki/Working_animal [English]

Summary of the Learning activity

This activity involves creating an education factbook based on Internet research on different aspects of the importance of animals.

Tasks include readings and practical exercises, with the aim of engaging in constructionist learning. Learners will acquire skills on Internet research.

Learners can access the resources via computer or other media support such as CD-ROMs. At the end of this unit, learners will complete a formative assessment and write a reflective report.

Key concepts

Biodiversity: The variation of life forms within a given ecosystem, biome, or for the entire Earth.

ICT integration: The introduction of ICT into teaching and learning activities.

Constructivist learning: An educational theory that places the responsibility for learning on the learner, who is actively involved in the learning process. Learners construct their own learning process, search for answers to problems, constructivist learning, based on individual motivation, confidence, and learning potential. (http://en.wikipedia.org/wiki/Constructivism_%28learning_theory%29)

Value: All the intrinsic and extrinsic qualities of an object or living organism.

Convention on Biological Diversity: The United Nations Convention on Biological Diversity was signed by many countries and international institutions. It states that, "The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding."

Education factbook: An education document containing a body of information, including texts, images, and possibly sound, covering diverse aspects of a given topic.

Key words

- the importance of biodiversity
- ICT integration
- constructivist learning
- value

- The Convention on Biological Diversity
- education factbook
- practical value
- intrinsic value
- multiple value
- value conflicts

Required resources

Required readings

Reading No. 1

Complete reference: *Importance de la biodiversite animale*

Extract from an original course by Laurence Rabotovao, Université d'Antananarivo (Madagascar) Ecole Normale Supérieure

Summary: This course addresses the multidimensional importance of animals. It emphasizes the value of animals, including their practical and intrinsic value and value conflicts in different historical, geographical, and cultural situations.

Several illustrations show examples from Madagascar and around the world.

Purpose: This seven-page document is useful for understanding people's perceptions of animals. It will also help in bringing out the economic, social, cultural, and tourism values of animal diversity.

Reading No. 2

Complete reference:

Convention on Biological Diversity

http://www.cbd.int/

http://www.cbd.int/convention/convention.shtml

Summary: The Convention contains 42 articles and 3 annexes. It covers all topics related to the conservation (in situ and ex situ) of biodiversity in terms of administration and legal issues, and so forth. Also covered are issues of research, education, and public awareness raising, as well as studies on impacts and access to genetic resources.

Purpose: Learners will find this document very useful. It describes international organizations that you can join to advocate biodiversity.

Source 3

Complete reference: Pimenta, Carlos (2006): L'homme et l'animal : Dans et pour l'économie politique In Rencontres transdisciplinaires de Saint-Léger-Sous-Beuvray 23 p

http://www.humanismolatino.online.pt/v1/pdf/HommeAnimal.pdf#search=%22Importance%20des%20animaux%22

Summary: This article deals with animals at the dawn of economic systems. It provides several references to other authors (Bernard de Mandeville, Adam smith) who used the case of animals (for example, the beehive) to describe human society, particularly in terms of economic systems.

Purpose: This article is a must read because it addresses the issue of the importance of animals through different approaches. You can deepen your understanding of the issue by looking up the cited authors.

Required resources

Resource No.1

Complete reference: Canadian Council on Animal Care (2003)

Guidelines on: the care and use of wildlife. 70 pp.

http://www.ccac.ca/en/CCAC_Programs/Guidelines_Policies/GDLINES/Wildlife/Wildlife.pdf

Site visited on January 19, 2010, at 9:35 a.m. EST.

Summary: This document presents a summary of the 52 guidelines for animal protection and collecting vertebrates, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, medical and surgical procedures, transportation, caging, and human safety. Among others, it covers topics such as ethics on the use of wildlife and wildlife regulations.

Purpose: This document will help you understand the adaptations of regional and international conventions that could be made to protect animals where you live.

Resource No. 2

Complete reference: Richard-Hansen, Cécile (). Gestion de la faunes sauvage en forêt amazonienne

http://www.terresdeguyane.fr/articles/RHC_0002/default.asp

Summary: This article deals with hunting laws and sustainable wildlife management. It recommends doing a background check of sites and territories to better understand the resources and how populations make their living.

Purpose: This article provides additional information that complements the other references. Although the setting is not African, it should prove very useful.

Resource No.3

Complete reference: FAO: Chapter 5. Can wildlife contribute to food security in Africa? Issues and conclusions

http://www.fao.org/docrep/w7540e/w7540e0j.htm#chapter%205.%20%20%20can%20wildlife%20contribute%20to%20food%20security%20in%20africa%20issues%20and%20concl

Summary: This publication deals with the problems inherent in using wildlife for food in Africa. The main problem is overexploitation and the destruction of wildlife habitats. The book recommends putting appropriate environmental policies in place to optimize wildlife resource management.

Purpose: This publication is very useful for understanding the reasons for managing wildlife reserves and the rational use of wildlife for food, particularly in rural settings.

Useful links

Link No. 1

Poissons et crocodiles d'Afrique : des pharaons à nos jours

http://www.ird.fr/fr/info/expo/poissoncroco/visite_virtuelle/03/index.htm

Summary: This site provides a virtual exhibit of fish and crocodiles, including a number of tables and descriptions of the lives of animals and their importance from the time of the pharaohs up to today. The presentation is simple and attractive.

Purpose: This presentation would be very useful to complete your historical approach to the importance of animals. It has excellent illustrations and examples.

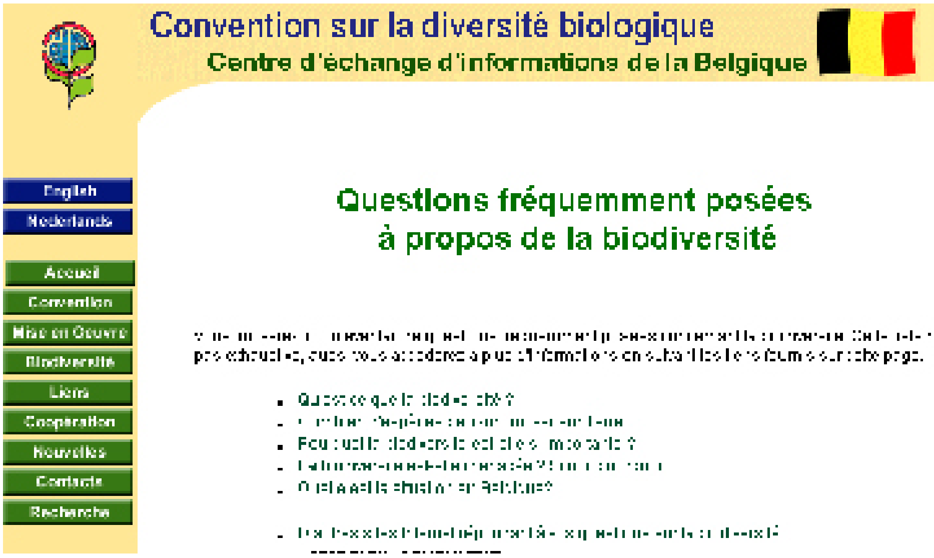
Link No. 2

Complete reference: Belgian Clearing House Mechanism

About the Convention (on Biological Diversity)

FAQ (Frequently asked questions)

http://www.biodiv.be/convention/cbd-faq



Site visited on January 19, 2010, at 10:07 a.m. EST

Summary: This site provides the answers to frequently asked questions on biodiversity (species, genetic, and ecosystems), including their importance. For each question, the site directs you to other sites containing very useful information.

Purpose: This site is recommended for its educational value. It will help you anticipate potentially difficult questions, such as the number of living species in each group on Earth, threats to biodiversity, and so on.

Link No. 3

Animaux de trait [*http://fr.wikipedia.org/wiki/Animal_de_trait*](http://fr.wikipedia.org/wiki/Animal_de_trait)

[Suggestion: Working animal: http://en.wikipedia.org/wiki/Working_animal]

Visited on January 19, 2010, at 12:40 p.m. EST

Summary: This site deals with working animals, particularly animals used in agriculture, for transportation (draught animals), sport, recreation, and more.

The main working animals are presented (e.g., horse, camel, mule, dogs, and so on). For each animal, links to sites with further information are provided.

Purpose: This site is recommended for its usefulness in finding as much information as possible on the importance of animals, and it is very well organized.

Detailed description of the activity

In this activity, you will alternate between individual and group work. You are required to perform a number of tasks. You must read all the required readings and consult the available resources and proposed sites. The information you gather will be completed by other resources that you will find on your own. Each group member must search the Internet to find other relevant information. This is therefore an individual task.

Next, in the group work, you will share this information with the other group members. You will prepare a group project consisting of an education factbook on the importance of animals. This will mean distributing the work, finding enough information, and organizing it in written form so that the group can discuss and approve it. Writing guidelines and quality control criteria will be clearly defined by the group.

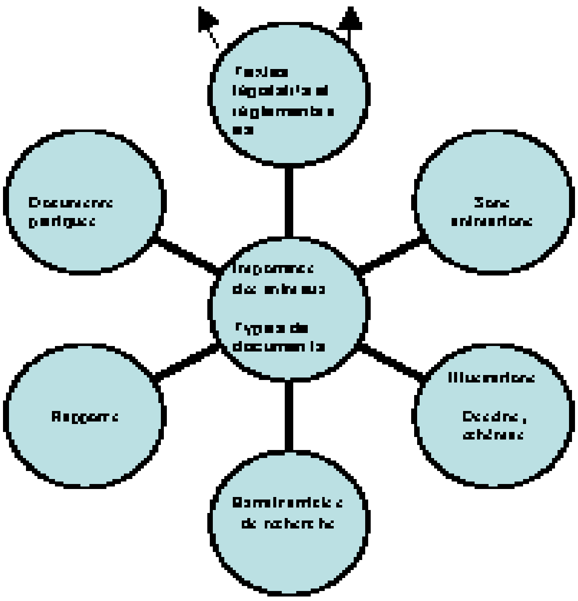
Finally, you will complete a formative assessment and write a reflective report on how you constructed your knowledge.

Learning activities

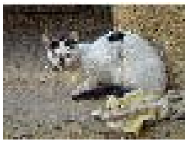
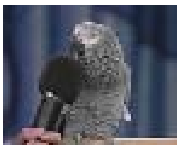
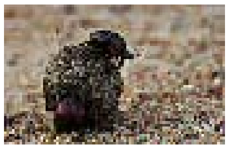
Task 1

Individual reading of the required texts and resources and exploration of the links. You will develop a note-taking system to retain the key concepts, important terms, and expressions. Individual preparation of a first draft of the conceptual map.

Convention on Biological Diversity Leagues for the protection of birds (LPO)



In addition to this conceptual map, you may develop another one on the areas of importance of animals. For example, you can elaborate on the dimensions of work (draughting, tourism), economics (agriculture), culture (totems, mascots), scientific research (guinea pigs), companionship (dogs, cats), and decoration (parrot).


Task 2

Perform a search for relevant links on the importance of animals. Be sure to diversify the forms of importance: economic, cultural, medical, legal, research purposes, and so forth. You should also vary the key words (importance of animals, wildlife sanctuary management, wildlife, etc.) that you enter in your search engine (for example, Google).

Task 3

Development of draft guidelines for a writing plan, work distribution, and timeframe.

Sample writing plan (first draft)

Tittle of the education factbook

Introduction

Part One

Part Two

Part Three: Education file

Conclusion

References

Writing guidelines (first draft)

- Consistent character font and size
- Each page shall contain at least one illustration
- Short citations are in Italics
- 1.5 line spacing

Task 4

Information sharing with other group members via email, chat room, or forum. Discussion of the various proposals and approval of a writing outline and writing guidelines.

Task 5

Individual production on the aspect (e.g., economics, tourism) that you were assigned as part of the group, according to the outline and guidelines.

Task 6

Assessment of each production by the other group members, according to the predefined criteria. Feedback.

Task 7

Production of an informative education factbook.

Task 8

Individual reflective report.

Formative assessment

Exercise 1

List the animals that are protected in your country and the laws that protect them. 4 points

Exercise 2

Develop a conceptual map depicting the importance of an animal of your choice, and give practical examples. 5 points

Exercise 3

Some countries have not yet ratified the Convention on Biological Diversity. Cite the reasons they have for not supporting the Convention, and support your answer with references.

3 points

Exercise 4

Draw up an animal protection code containing a preamble and 10 articles.

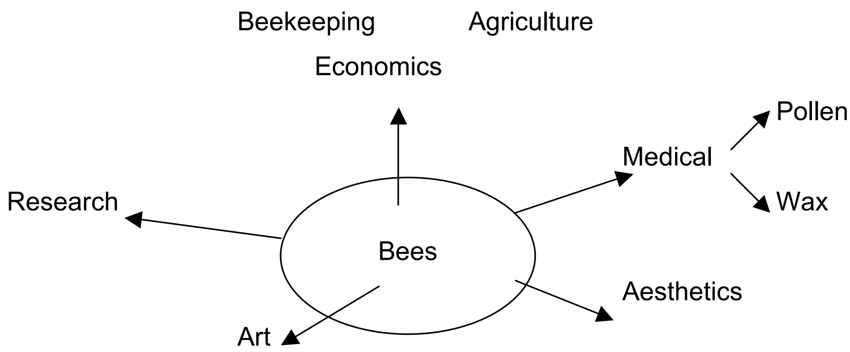
8 points

Answers

Exercise 1: Answers will vary depending on the results of your Internet research and investigation.

Example: lion, elephant, pelican, etc.

Exercise 2: Develop a conceptual map concerning the importance of an animal of your choice and give practical examples.



Learning guidelines

Unlike the previous exercises, this one involves open-ended learning. What we are looking for is open-mindedness and a capacity to develop a solid argument.

XV. Synthesis of the Module

This module deals with zoology. The objective is to study animals using diverse approaches. Several disciplines are mentioned in this module:

- Microscopic and macroscopic anatomy are used to study animal structures.
- Physiology is used to determine the functions of diverse animal groups.
- Ecology is used to determine the relationships of living organisms with their environment.
- Ethology is used to study animal behaviours. It is combined with other disciplines such as systematics, evolution, and other associated disciplines. We may group these into four convenient categories under the general heading of zoology:

  a) – Characteristics of animals

  b) – Evolutionary trends in animals

  c) – Classification of animals

  d) – The importance of animals

I) The unit on the characteristics of animals shows us how biological sciences dominate in areas that address the essential living processes, whereas research discoveries are generally zoological in nature.[??]

II) The issue of evolution, which dominates general biology, cannot be properly studied without a solid knowledge of animal characteristics, which constitute evidence and serve as the bases for data on different animals, whether living organisms or fossils. Paleontology and zoology combine forces to do this.

III) A proper classification of the animal world requires an understanding of evolutionary trends: a system based on the general characteristics of animals. The animal world is divided into phyla, which correspond to different types of organization. These phyla are subdivided into classes, followed by orders, families, genuses, and finally species.

Lastly, it is critical to relate *their importance* in all areas because

IV) We know that all animals have considerable importance, whether direct or indirect. This importance is described in the readings on the multidimensional aspects of animals, underscoring the value of animals, including their practical and intrinsic value and value conflicts throughout history and across geographies and cultures. This unit will help learners better appreciate and respect animals.

You are required to complete a summary assessment to help measure your progress in terms of the knowledge and skills targeted in the general and specific objectives of this module.

XVI. Summary assessment

1. Which of the following groups are diploblastic? 0.75 point

❏- Sponges
❏- Cestodas
❏- Cnidarians
❏- Sporozoa
❏- Plankton
❏- Rotifers

2. Colloblasts are used to capture prey by 0.25 point

❏- Plankton
❏- Cnidarians
❏- Nematodes

3. Which one of these platyhelminthes is not a parasite? 0.25 point

❏- Turbellaria
❏- Monogenea
❏- Cestodes
❏- Trematodes

4. Which of these scientists attributes a coelom to Nermatea? 0.25 point

❏- Anatomist
❏- Embryologist
❏- Biologist

5. In protosomes, the blastopore opens into 0.25 point

❏- only the mouth
❏- only the anus
❏- the mouth and the anus
❏- Neither the mouth nor the anus

6. The leech is 0.25 point

❏- An annelid
❏- A polychaete
❏- An acheta
❏- An oligochaete

7. In arthropods, coelomoduct is genital ❑- True ❑- False 0.25 point

8. Bryozoa are characterized by colonial growth: ❑- True ❑- False 0.25 point

9. The skin of vertebrates is pluristratified ❑- True ❑- False 0.25 point

Multiple choice questions

Check the correct answer.

10. The splanchnopleure lines 0.25 point

❑- the internal part of the skin
❑- the external part of the skin
❑- the internal part of the viscera
❑- the external part of the viscera

11. Analogy implies a shared ancestry. ❑- True ❑- False 0.25 point

12. A plasmodium contains a single nucleus. ❑- True ❑- False 0.25 point

Multiple choice questions

Check the correct answer

13. The fibrils of the membrane of Tripanosomes impart 0.25 point

❑- Rigidity
❑- Contractility
❑- Reproducibility
❑- Sensitivity

14. In a pleuromitotic nucleus, the interphase chromosomes are 0.25 point

❑- weblike
❑- spiral
❑- circular

15. The cell is the structural and functional unit of living organisms.

❑- True ❑- False 0.25 point

16. Linnaeus grouped reptiles and amphibians in the same class

❏- True ❏- False 0.25 point

Check the correct answer

17.The book *Zoological Philosophy* was written by Lamarck in 0.25 point

❏- 1809
❏- 1909
❏- 1709

18. The term “patent” was used for the first time by 0.25 point

❏- Linnaeus
❏- Darwin
❏- Lamarck

19. What differentiates the evolutionary theories of Linnaeus, Lamarck, and Darwin?

3 points

20. Define these terms, which appear throughout the progress of evolution: rudiment, anamorphosis, atavism 1.75 points

Check the correct answer

21. The Convention on Biological Diversity was signed in 0.25 points

❏- 1991
❏- 1992
❏- 1993

22. Discuss this statement: All pests have a certain usefulness. 3 points

23. The practical value is also called the contributive value.

❏- True ❏- False 0.25 points

Check the correct answer

24. The number of primates sold annually is estimated at 0.25 point

❑- 50,000 to 55,000
❑- 25,000 to 30,000
❑- 10,000 to 15,000

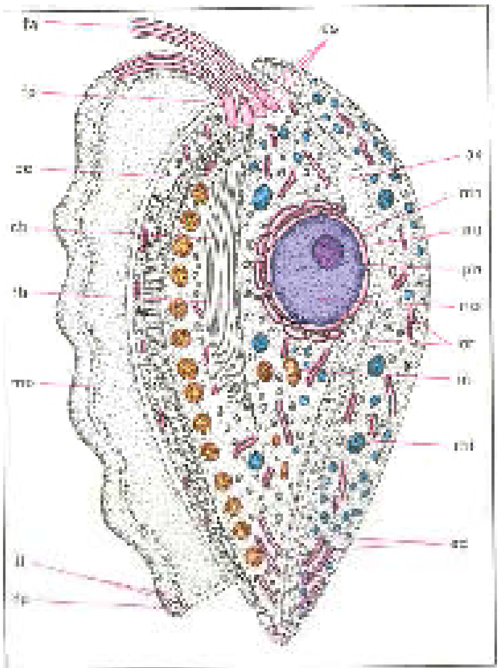
25. CITES stands for: 0.25 point

❑- International Cooperation for the Conservation of Wild Fauna
❑- International Convention of Trade in Endangered Species
❑- International Convention on the Conservation of Wild Species
❑- Convention on International Trade in Endangered Species of Wild Fauna and Flora

26. What is the difference between a "key species" and a "dominant species"? 0.75 point

27. Write a 300-word text on humans and animals 2 points

28. Label the following diagram 2 points



Extract from Dorst J et al Zoologie I P 31

29. Matching exercise

To which phylum do the following classes belong? 1.5 points

Phylum Plathelminthes	Class Dicyemida
Phylum Mesozoa	Class Nematoda
Phylum Nemathelminthes	Class Acheta
Phylum Nematorhyncha	Class Ectoprocta
Phylum Annelida	Class Trematoda
Phylum Lophorina	Class Echinoidea

.

Answer key

R1 Sponges, cnidarians, plankton

R 2 Plankton

R 3 Tubellaria

R 4 Embryologist

R 5 The mouth and the anus

R 6 Acheta

R 7 False. It is genital

R 8 True

R 9 True

R 10 The external part of the viscera

R 11 False

R 12 False

R 13 Contractility

R 14 Spiral

R 15 True

R 16 True

R 17 1809

R 18 Lamarck

R 19 (answers vary)

R 20 (answers vary)

R 21 1992 Rio de Janeiro

R 22 (answers vary)

R 23 True

R 24 25,000 to 30,000

R 25 Convention on International Trade in Endangered Species of Wild Fauna and Flora

R 26

R 27

R 28 ax: axostyle; nm: nuclear membrane; nu: nucleolus; er: ergastoplasm; np: nuclear pore; ns: nucleus; in: inclusion; mi: mitochondria; ec: elements of the chromatic annulus; af: anterior flagella; pf: posterior flagella; rb: rib; pb: parabasal body or Golgi apparatus; pbf: parabasal fibrilla; um: undulant membrane; pff; paraflagellar fibrilla.

R 29

Phylum Plathelminthes	Class Trematoda
Phylum Mesozoa	Class Dicyemida
Phylum Nemathelminthes	Class Nematoda
Phylum Nematorhyncha	Class Echinoidea
Phylum Annelida	Class Acheta
Phylum Lophorina	Class Ectoprocta

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Professor Rabotovao studied at the Université d'Antananarivo, specializing in Natural Sciences, and completed a master's degree in Applied Biology. She has taught for over six years at the Lycée in the area of Natural Sciences (plant and animal biology as well as geology).

She obtained a DEA in 1987 for her research on an immunostimulant plant, including the extraction, isolation of the active ingredient, and diverse tests of the effects on animals, leading to a Doctoral Degree in Applied Biological Sciences. Hired as a teacher/researcher at the École Normale Superieure d'Antananarivo, she was named Director of the Study and Research Centre, where she does her research on phytodrugs. Apart from her own research, she supervises studies in biology and environmental education under DEA programs. She has participated in numerous projects, including FADES, UVA, and publications of research results. Currently, she is working on an AUF-funded project: RESATICE, an online collaboration with high school teachers. She is also seeking funding for a project on the integration of environmental education (ERE) in high schools and universities involving ICT integration.

BIOLOGY 2: ANIMAL DIVERSITY

Required Readings

Source: Wikipedia.org

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Biodiversity

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Some of the biodiversity of a coral reef

Rainforests are an example of biodiversity on the planet, and typically possess a great deal of species biodiversity. This is the Gambia River in Senegal's Niokolo-Koba National Park.

A great deal of work is occurring to preserve the natural characteristics of Hopetoun Falls, Australia while continuing to allow visitor access.

Biodiversity is the variation of life forms within a given ecosystem, biome, or for the entire Earth. Biodiversity is often used as a measure of the health of biological systems. The biodiversity found on Earth today consists of many millions of distinct biological species, which is the product of nearly 3.5 billion years of evolution.[1][2]

2010 is the International Year of Biodiversity.

[] Etymology

The term was used first by wildlife scientist and conservationist Raymond F. Dasmann in a lay book[3] advocating nature conservation. The term was not widely adopted for more than a decade, when in the 1980s it and "biodiversity" came into common usage in science and environmental policy. Use of the term by Thomas Lovejoy in the Foreword to the book[4] cred with launching the field of conservation biology introduced the term along with "conservation biology" to the scientific community. Until then the term "natural diversity" was used in conservation science circles, including by The Science Division of The Nature Conservancy in an important 1975 study, "The Preservation of Natural Diversity." By the early 1980s TNC's Science program and its head Robert E. Jenkins, Lovejoy, and other leading conservation scientists at the time in America advocated the use of "biological diversity" to embrace the object of biological conservation.

The term's contracted form ***biodiversity*** may have been coined by W.G. Rosen in 1985 while planning the *National Forum on Biological Diversity* organized by the National Research Council (NRC) which was to be held in 1986, and first appeared in a publication in 1988 when entomologist E. O. Wilson used it as the title of the proceedings[5] of that forum.[6]

Since this period both terms and the concept have achieved widespread use among biologists, environmentalists, political leaders, and concerned citizens worldwide. The term is sometimes used to equate to a concern for the natural environment and nature conservation. This use has coincided with the expansion of concern over extinction observed in the last decades of the 20th century.

A similar concept in use in the United States, besides natural diversity, is the term "natural heritage." It pre-dates both terms though it is a less scientific term and more easily comprehended in some ways by the wider audience interested in conservation. Furthermore it may be misleading if used to refer only to biodiversity, as natural heritage also includes geology and landforms (geodiversity). The term "Natural Heritage" was used when Jimmy Carter set up the Georgia Heritage Trust while he was governor of Georgia; Carter's trust dealt with both natural and cultural heritage. It would appear that Carter picked the term up from Lyndon Johnson, who used it in a 1966 Message to Congress. "Natural Heritage" was picked up by the

Science Division of the US Nature Conservancy when, under Jenkins, it launched in 1974 the network of State Natural Heritage Programs. When this network was extended outside the USA, the term "Conservation Data Center" was suggested by Guillermo Mann and came to be preferred.

[] Definitions

A Sampling of fungi collected during summer 2008 in Northern Saskatchewan mixed woods, near LaRonge is an example regarding the species diversity of fungi. In this photo, there are also leaf lichens and mosses.

"Biological diversity" or "biodiversity" can have many interpretations and it is most commonly used to replace the more clearly defined and long established terms, species diversity and species richness. Biologists most often define biodiversity as the "totality of genes, species, and ecosystems of a region". An advantage of this definition is that it seems to describe most circumstances and present a unified view of the traditional three levels at which biological variety has been identified:

- genetic diversity
- species diversity
- ecosystem diversity

This multilevel conception is consistent with the early use of "biological diversity" in Washington. D.C. and international conservation organizations in the late 1960s through 1970's, by Raymond F. Dasmann who apparently coined the term and Thomas E. Lovejoy who later introduced it to the wider conservation and science communities. An explicit definition consistent with this interpretation was first given in a paper by Bruce A. Wilcox commissioned by the International Union for the Conservation of Nature and Natural Resources (IUCN) for the 1982 World National Parks Conference in Bali [7] The definition Wilcox gave is "Biological diversity is the variety of life forms...at all levels of biological systems (i.e., molecular, organismic, population, species and ecosystem)..." Subsequently, the 1992 United Nations Earth Summit in Rio de Janeiro defined "biological diversity" as "the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". This is, in fact, the closest thing to a single legally accepted definition of biodiversity, since it is the definition adopted by the United Nations Convention on Biological Diversity.

The current textbook definition of "biodiversity" is "variation of life at all levels of biological organization".[8]

For geneticists, *biodiversity* is the diversity of genes and organisms. They study processes such as mutations, gene exchanges, and genome dynamics that occur at the DNA level and generate evolution. Consistent with this, along with the above definition the Wilcox paper stated "genes are the ultimate source of biological organization at all levels of biological systems..."

There are three established types of biodiversity: 1. Diversity of species 2. Diversity of genetics 3. Diversity of habitats

But Professor Anthony Campbell at Cardiff University, UK and the Darwin Centre, Pembrokeshire, has defined a fourth, and critical one: Molecular biodiversity (see Campbell, AK J Applied Ecology 2003,40,193-203; Save those molecules: molecular biodiversity and life).

[] Measurement

: Measurement of biodiversity

A variety of objective measures have been created in order to empirically measure biodiversity. Each measure of biodiversity relates to a particular use of the data. For practical conservationists, measurements should include a quantification of values that are commonly-shared among locally affected organisms, including humans. For others, a more economically defensible definition should allow the ensuring of continued possibilities for both adaptation and future use by humans, assuring environmental sustainability.

[] Distribution

A conifer forest in the Swiss Alps (National Park).

Selection bias amongst researchers may contribute to biased empirical research for modern estimates of biodiversity. In 1768 Rev. Gilbert White succinctly observed of his Selborne, Hampshire "all nature is so full, that that district produces the most variety which is the most examined."[9]

Nevertheless, biodiversity is not distributed evenly on Earth. It is consistently richer in the tropics and in other localized regions such as the Cape Floristic Province. As one approaches polar regions one generally finds fewer species. Flora and fauna diversity depends on climate, altitude, soils and the presence of other species. In the year 2006 large numbers of the Earth's species were formally classified as rare or endangered or threatened species; moreover, many scientists have estimated that there are millions more species actually endangered which have not yet been formally recognized. About 40 percent of the 40,177 species assessed using the IUCN Red List criteria, are now listed as threatened species with extinction - a total of 16,119 species.[10]

Even though biodiversity declines from the equator to the poles in terrestrial ecoregions, whether this is so in aquatic ecosystems is still a hypothesis to be tested, especially in marine ecosystems where causes of this phenomenon are unclear.[11] In addition, particularly in marine ecosystems, there are several well stated cases where diversity in higher latitudes actually increases. Therefore, the lack of information on biodiversity of Tropics and Polar Regions prevents scientific conclusions on the distribution of the world's aquatic biodiversity.

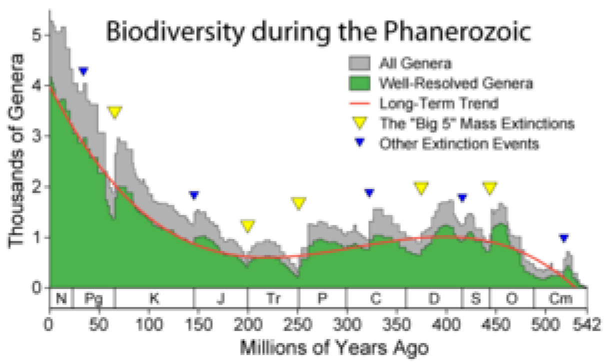
A biodiversity hotspot is a region with a high level of endemic species. These biodiversity hotspots were first identified by Dr. Norman Myers in two articles in the scientific journal *The Environmentalist*.[12][13] Dense human habitation tends to occur near hotspots. Most hotspots are located in the tropics and most of them are forests.

Brazil's Atlantic Forest is considered a hotspot of biodiversity and contains roughly 20,000 plant species, 1350 vertebrates, and millions of insects, about half of which occur nowhere else in the world. The island of Madagascar including the unique Madagascar dry deciduous forests and lowland rainforests possess a very high ratio of species endemism and biodiversity, since the island separated from mainland Africa 65 million years ago, most of the species and ecosystems have evolved independently producing unique species different from those in other parts of Africa.

Many regions of high biodiversity (as well as high endemism) arise from very specialized habitats which require unusual adaptation mechanisms. For example the peat bogs of Northern Europe.

[] Evolution

: Evolution



Apparent marine fossil diversity during the Phanerozoic Eon

Biodiversity found on Earth today is the result of 4 billion years of evolution. The origin of life has not been definitely established by science, however some evidence suggests that life may already have been well-established a few hundred million years after the formation of the Earth. Until approximately 600 million years ago, all life consisted of archaea, bacteria, protozoans and similar single-celled organisms.

The history of biodiversity during the Phanerozoic (the last 540 million years), starts with rapid growth during the Cambrian explosion—a period during which nearly every phylum of multicellular organisms first appeared. Over the next 400 million years or so, global diversity showed little overall trend, but was marked by periodic, massive losses of diversity classified as mass extinction events.

The apparent biodiversity shown in the fossil record suggests that the last few million years include the period of greatest biodiversity in the Earth's history. However, not all scientists support this view, since there is considerable uncertainty as to how strongly the fossil record is biased by the greater availability and preservation of recent geologic sections. Some (e.g. Alroy et al. 2001) argue that, corrected for sampling artifacts, modern biodiversity is not much different from biodiversity 300 million years ago.[14] Estimates of the present global macroscopic species diversity vary from 2 million to 100 million species, with a best estimate of somewhere near 13–14 million, the vast majority of them arthropods.[15]

Most biologists agree however that the period since the emergence of humans is part of a new mass extinction, the Holocene extinction event, caused primarily by the impact humans are having on the environment. It has been argued that the present rate of extinction is sufficient to eliminate most species on the planet Earth within 100 years.[16]

New species are regularly discovered (on average between 5–10,000 new species each year, most of them insects) and many, though discovered, are not yet classified (estimates are that nearly 90% of all arthropods are not yet classified).[15] Most of the terrestrial diversity is found in tropical forests.

[] Human benefits

Summer field in Belgium (Hamois).

Biodiversity also supports a number of natural ecosystem processes and services.[17] Some ecosystem services that benefit society are air quality,[18] climate (both global CO_2 sequestration and local), water purification, pollination, and prevention of erosion.[18]

Since the stone age, species loss has been accelerated above the geological rate by human activity. The rate of species extinction is difficult to estimate, but it has been estimated that species are now being lost at a rate approximately 100 times as fast as is typical in the geological record, or perhaps as high as 10 000 times as fast.[19] To feed such a large population, more land is being transformed from wilderness with wildlife into agricultural, mining, lumbering, and urban areas for humans.

Non-material benefits that are obtained from ecosystems include spiritual and aesthetic values, knowledge systems and the value of education.

[] Agriculture

Amazon Rainforest in Brazil.

The economic value of the reservoir of genetic traits present in wild varieties and traditionally grown landraces is extremely important in improving crop performance[citation needed]. Important crops, such as the potato and coffee, are often derived from only a few genetic strains[citation needed]. Improvements in crop plants over the last 250 years have been largely due to harnessing the genetic diversity present in wild and domestic crop plants[citation needed]. Interbreeding crops strains with different beneficial traits has resulted in more than doubling crop production in the last 50 years as a result of the Green Revolution[citation needed].

Crop diversity is also necessary to help the system recover when the dominant crop type is attacked by a disease:

- The Irish potato blight of 1846, which was a major factor in the deaths of a million people and migration of another million, was the result of planting only two potato varieties, both of which were vulnerable.
- When rice grassy stunt virus struck rice fields from Indonesia to India in the 1970s. 6273 varieties were tested for resistance.[20] One was found to be resistant, an Indian variety, known to science only since 1966.[20] This variety formed a hybrid with other varieties and is now widely grown.[20]
- Coffee rust attacked coffee plantations in Sri Lanka, Brazil, and Central America in 1970. A resistant variety was found in Ethiopia.[21] Although the diseases are themselves a form of biodiversity.

Monoculture, the lack of biodiversity, was a contributing factor to several agricultural disasters in history, the European wine industry collapse in the late 1800s, and the US Southern Corn Leaf Blight epidemic of 1970.[22] See also: Agricultural biodiversity

Higher biodiversity also controls the spread of certain diseases as pathogens will need to adapt to infect different species[citation needed].

Biodiversity provides food for humans[citation needed]. Although about 80 percent of our food supply comes from just 20 kinds of plants[citation needed], humans use at least 40,000 species of plants and animals a day[citation needed]. Many people around the world depend on these species for their food, shelter, and clothing[citation needed]. There is untapped potential for increasing the range of food products suitable for human consumption, provided that the high present extinction rate can be stopped.[16]

[] Human health

The diverse forest canopy on Barro Colorado Island, Panama, yielded this display of different fruit

The relevance of biodiversity to human health is becoming a major international political issue, as scientific evidence builds on the global health implications of biodiversity loss.[23][24][25] This issue is closely linked with the issue of climate change,[26] as many of the anticipated health risks of climate change are associated with changes in biodiversity (e.g. changes in populations and distribution of disease vectors, scarcity of fresh water, impacts on agricultural biodiversity and food resources etc). Some of the health issues influenced by biodiversity include dietary health and nutrition security, infectious diseases, medical science and medicinal resources, social and psychological health,[27] and spiritual well-being. Biodiversity is also known to have an important role in reducing disaster risk, and in post-disaster relief and recovery efforts.[28][29]

One of the key health issues associated with biodiversity is that of drug discovery and the availability of medicinal resources.[30] A significant proportion of drugs are derived, directly or indirectly, from biological sources; Chivian and Bernstein report that at least 50% of the pharmaceutical compounds on the market in the US are derived from natural compounds found in plants, animals, and microorganisms, while about 80% of the world population depends on medicines from nature (used in either modern or traditional medical practice) for primary healthcare.[24] Moreover, only a tiny proportion of the total diversity of wild species has been investigated for potential sources of new drugs. Through the field of bionics, considerable technological advancement has occurred which would not have without a rich biodiversity. It has been argued, based on evidence from market analysis and biodiversity science, that the decline in output from the pharmaceutical sector since the mid-1980s can be attributed to a move away from natural product exploration ("bioprospecting") in favour of R&D programmes based on genomics and synthetic chemistry, neither of which have yielded the expected product outputs; meanwhile, there is evidence that natural product chemistry can provide the basis for innovation which can yield significant economic and health benefits.[31][32] Marine ecosystems are of particular interest in this regard,[33] however unregulated and inappropriate bioprospecting can be considered a form of over-exploitation which has the potential to degrade ecosystems and increase biodiversity loss, as well as impacting on the rights of the communities and states from which the resources are taken.[34][35][36]

[] Business and Industry

Agriculture production, pictured is a Tractor and Chaser bin.

A wide range of industrial materials are derived directly from biological resources. These include building materials, fibers, dyes, resirubber and oil. There is enormous potential for further research into sustainably utilizing materials from a wider diversity of organisms. In addition, biodivesity and the ecosystem goods and services it provides are considered to be fundamental to healthy economic systems. The degree to which biodiversity supports business varies between regions and between economic sectors, however the importance of biodiversity to issues of resource security (water quantity and quality, timber, paper and fibre, food and medicinal resources etc) are increasingly recognized as universal.[37][38][39] As a result, the loss of biodiversity is increasingly recognized as a significant risk factor in business development and a threat to long term economic sustainability. A number of case studies recently compiled by the World Resources Institute demonstrate some of these risks as identified by specific industries.[40]

[] Other ecological services

See also: Ecological effects of biodiversity

Eagle Creek, Oregon hiking

Biodiversity provides many ecosystem services that are often not readily visible. It plays a part in regulating the chemistry of our atmosphere and water supply. Biodiversity is directly involved in water purification, recycling nutrients and providing fertile soils. Experiments with controlled environments have shown that humans cannot easily build ecosystems to support human needs; for example insect pollination cannot be mimicked by human-made construction, and that activity alone represents tens of billions of dollars in ecosystem services per annum to humankind.

The stability of ecosystems is also related to biodiversity, with higher biodiversity producing greater stability over time, reducing the chance that ecosystem services will be disrupted as a result of disturbances such as extreme weather events or human exploitation.

Polar bears on the sea ice of the Arctic Ocean, near the north pole.

[] Leisure, cultural and aesthetic value

Many people derive value from biodiversity through leisure activities such as hiking, birdwatching or natural history study. Biodiversity has inspired musicians, painters, sculptors, writers and other artists. Many cultural groups view themselves as an integral part of the natural world and show respect for other living organisms.

Popular activities such as gardening, caring for aquariums and collecting butterflies are all strongly dependent on biodiversity. The number of species involved in such pursuits is in the tens of thousands, though the great majority do not enter mainstream commercialism.

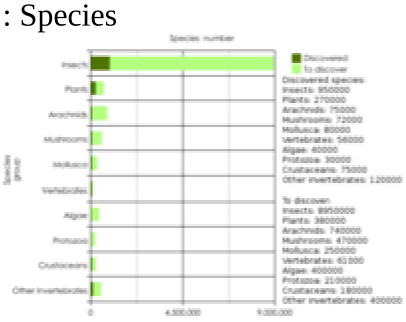
The relationships between the original natural areas of these often 'exotic' animals and plants and commercial collectors, suppliers, breeders, propagators and those who promote their understanding and enjoyment are complex and poorly understood. It seems clear, however, that the general public responds well to exposure to rare and unusual organisms—they recognize their inherent value at some level. A family outing to the botanical garden or zoo is as much an aesthetic or cultural experience as it is an educational one.

Philosophically it could be argued that biodiversity has intrinsic aesthetic and spiritual value to mankind *in and of itself*. This idea can be used as a counterweight to the notion that tropical forests and other ecological realms are only worthy of conservation because they may contain medicines or useful products.

An interesting point is that evolved DNA embodies knowledge,[41] and therefore destroying a species resembles burning a book, with the caveat that the book is of uncertain depth and importance and may in fact be best used as fuel.

[] Number of species

: Species



Undiscovered and discovered species

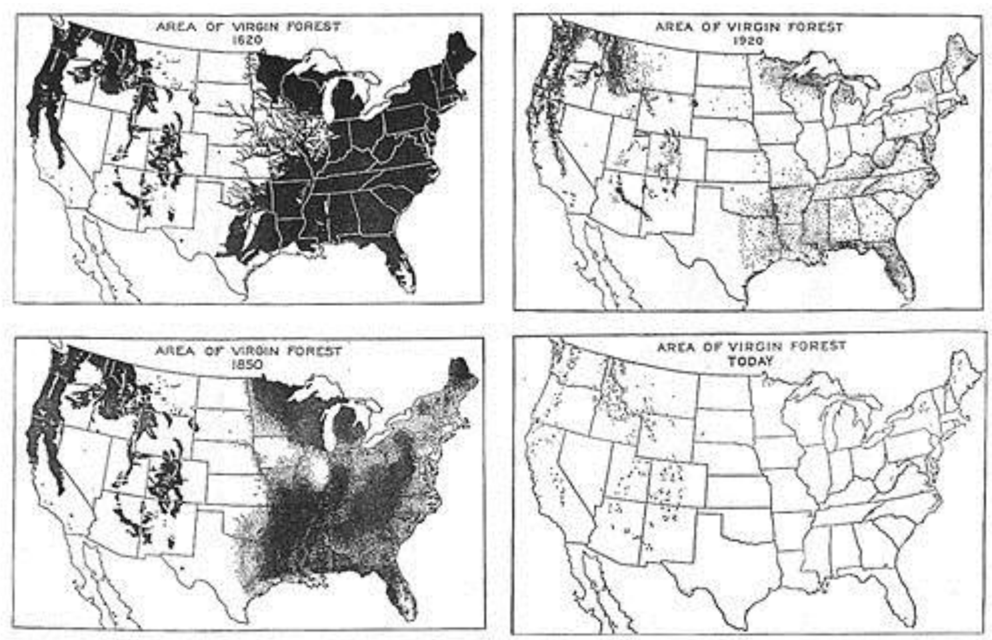
According to the Global Taxonomy Initiative[42] and the European Distributed Institute of Taxonomy, the *total* number of species for some phyla may be much higher as what we know currently:

- 10–30 million insects;[43] (of some 0,9 we know today [44])
- 5–10 million bacteria;[45]

- 1.5 million fungi;[46] (of some 0,4 million we know today [44])
- ~1 million mites[47]

Due to the fact that we know but a portion of the organisms in the biosphere, we do not have a complete understanding of the workings of our environment. To make matters worse, according to professor James Mallet, we are wiping out these species at an unprecedented rate.[48] This means that even before a species has had the chance of being discovered, studied and classified, it may already be extinct.

[] Threats



Loss of old growth forest in the United States; 1620, 1850, 1920, and 1992 maps: *From William B. Greeley's, The Relation of Geography to Timber Supply, Economic Geography, 1925, vol. 1, p. 1–11. Source of "Today" map: compiled by George Draffan from roadless area map in The Big Outside: A Descriptive Inventory of the Big Wilderness Areas of the United States, by Dave Foreman and Howie Wolke (Harmony Books, 1992).* These maps represent only virgin forest lost. Some regrowth has occurred but not to the age, size or extent of 1620 due to population increases and food cultivation.

During the last century, decreases in biodiversity have been increasingly observed. Studies[*by whom?*] show that 30% of all natural species will be extinct by 2050.[49] Of these, about one eighth of the known plant species are threatened with extinction.[50] Some estimates put the loss at up to 140,000 species per year (based on Species-area theory) and subject to discussion.[51] This figure indicates unsustainable ecological practices, because only a small number of species come into being each year. Almost all scientists acknowledge [50] that the rate of species loss is greater now than at any time in human history, with extinctions occurring at rates hundreds of times higher than background extinction rates.

The factors that threaten biodiversity have been variously categorized. Jared Diamond describes an "Evil Quartet" of habitat destruction, overkill, introduced species, and secondary extensions. Edward O. Wilson prefers the acronym **HIPPO**, standing for **H**abitat destruction, **I**nvasive species, **P**ollution, Human Over **P**opulation, and **O**verharvesting.[52][53] The most authoritative classification in use today is that of IUCN's Classification of Direct Threats[54] adopted by most major international conservation organizations such as the US Nature Conservancy, the World Wildlife Fund, Conservation International, and Birdlife International.

[] Destruction of habitat

Deforestation and increased road-building in the Amazon Rainforest are a significant concern because of increased human encroachment upon wild areas, increased resource extraction and further threats to **biodiversity**.
: Habitat destruction

Most of the species extinctions from 1000 AD to 2000 AD are due to human activities, in particular destruction of plant and animal habitats. Raised rates of extinction are being driven by human consumption of organic resources, especially related to tropical forest destruction.[55] While most of the species that are becoming extinct are not food species, their biomass is converted into human food when their habitat is transformed into pasture, cropland, and orchards. It is estimated that more than a third of the Earth's biomass[56] is tied up in only the few species that represent humans, livestock and crops. Because an ecosystem decreases in stability as its species are made extinct, these studies warn that the global ecosystem is destined for collapse if it is further reduced in complexity. Factors contributing to loss of biodiversity are: overpopulation, deforestation, pollution (air pollution, water pollution, soil contamination) and global warming or climate change, driven by human activity. These factors, while all stemming from overpopulation, produce a cumulative impact upon biodiversity.

There are systematic relationships between the area of a habitat and the number of species it can support, with greater sensitivity to reduction in habitat area for species of larger body size and for those living at lower latitudes or in forests or oceans.[57] Some characterize loss of biodiversity not as ecosystem degradation but by conversion to trivial standardized ecosystems (e.g., monoculture following deforestation). In some countries lack of property rights or access regulation to biotic resources necessarily leads to biodiversity loss (degradation costs having to be supported by the community).

A September 14, 2007 study conducted by the National Science Foundation found that biodiversity and genetic diversity are dependent upon each other—that diversity within a species is necessary to maintain diversity among species, and vice versa. According to the lead researcher in the study, Dr. Richard Lankau, "If any one type is removed from the system, the cycle can break down, and the community becomes dominated by a single species."[58]

At present, the most threathened ecosystems are those found in fresh water. The marking of fresh water ecosystems as the ecosystems most under threat was done by the Millennium Ecosystem Assessment 2005, and was confirmed again by the project "**Freshwater Animal Diversity Assessment**", organised by the biodiversity platform, and the French Institut de recherche pour le développement (MNHNP).[59]

[] Exotic species

Male *Lophura nycthemera* (Silver Pheasant), a native of East Asia that has been introduced into parts of Europe for ornamental reasons.

: Introduced species

Further information: Comparison of biodiversity health by nation

The rich diversity of unique species across many parts of the world exist only because they are separated by barriers, particularly large rivers, seas, oceans, mountains and deserts from other species of other land masses, particularly the highly fecund, ultra-competitive, generalist "super-species". These are barriers that couldn't have been easily crossed by natural processes, except through continental drift. However, humans have invented transportation with the ability to bring into contact species that they've never met in their evolutionary history; also, this is done on a time scale of days, unlike the centuries that historically have accompanied major animal migrations. As these species that never met before come in contact with each other, the rate at which species are extincting is increasing still. See below for an example.

The widespread introduction of exotic species by humans is a potent threat to biodiversity. When exotic species are introduced to ecosystems and establish self-sustaining populations, the endemic species in that ecosystem that have not evolved to cope with the exotic species may not survive. The exotic organisms may be either predators, parasites, or simply aggressive species that deprive indigenous species of nutrients, water and light. These invasive species often have features, due to their evolutionary background and new environment, that make them highly competitive; able to become well-established and spread quickly, reducing the effective habitat of endemic species.

Exotic species are introduced by human, either unwillingly or intentionally. Examples on unwilling introduction are fore example ladybugs, ... These were bred to help in combating pests in agriculture (for greenhouses). Other examples of unwilling introduction are species that are unknowingly brought in by vessel or automotive. These include certain bacteria, spiders, seeds of certain plants. Examples of intentional introduction are the planting of exotic plants in gardens. It is clear that with simple measures the preventing of the spread of exotic plants, yet as of present, trying to reduce the inflow of exotic species has remained low on the political agenda. Also, the intentional planting of species that are marked as "indiginous", yet are from a non-indigenous strain can be considered exotic and create problems in the ecosystem. For example in Belgium, Prunus spinosa (an indigenous species) that originates from Eastern Europe has been introduced. This has created problems, as the this tree species comes into leave much sooner than their West European counterparts, bringing the Thecla betulae butterfly (which feed on the leaves) into trouble.

As a consequence of the above, if humans continue to combine species from different ecoregions, there is the potential that the world's ecosystems will end up dominated by relatively a few, aggressive, cosmopolitan "super-species".

At present, several countries have already imported so much exotic species, that the own indigenous fauna/flora is greatly outnumbered. For example, in Belgium, only 5% of the indigenous trees remain.[60][61]

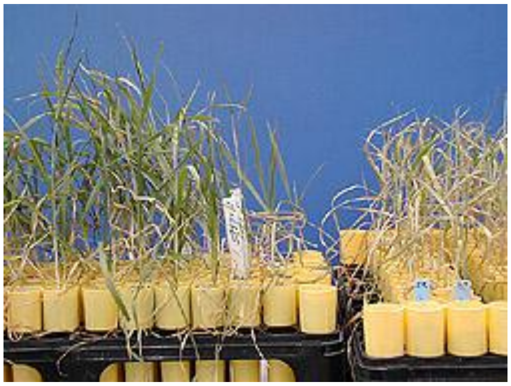
In 2004, an international team of scientists estimated that 10 percent of species would become extinct by 2050 because of global warming.[62] “We need to limit climate change or we wind up with a lot of species in trouble, possibly extinct,” said Dr. Lee Hannah, a co-author of the paper and chief climate change biologist at the Center for Applied Biodiversity Science at Conservation International.

[] Genetic pollution

: Genetic pollution

Purebred naturally evolved region specific wild species can be threatened with extinction[63] through the process of genetic pollution i.e. uncontrolled hybridization, introgression and genetic swamping which leads to homogenization or replacement of local genotypes as a result of either a numerical and/or fitness advantage of introduced plant or animal.[64] Nonnative species can bring about a form of extinction of native plants and animals by hybridization and introgression either through purposeful introduction by humans or through habitat modification, bringing previously isolated species into contact. These phenomena can be especially detrimental for rare species coming into contact with more abundant ones. The abundant species can interbreed with the rarer, swamping the entire gene pool and creating hybrids, thus driving the entire native stock to complete extinction. Attention has to be focused on the extent of this under appreciated problem that is not always apparent from morphological (outward appearance) observations alone. Some degree of gene flow may be a normal, evolutionarily constructive, process, and all constellations of genes and genotypes cannot be preserved. However, hybridization with or without introgression may, nevertheless, threaten a rare species' existence.[65][66]

[] Hybridization and genetics



The Yecoro wheat (right) cultivar is sensitive to salinity, plants resulting from a hybrid cross with cultivar W4910 (left) show greater tolerance to high salinity
See also: Food Security

In agriculture and animal husbandry, the green revolution popularized the use of conventional hybridization to increase yield by creating "high-yielding varieties". Often the handful of hybridized breeds originated in developed countries and were further hybridized with local varieties in the rest of the developing world to create high yield strains resistant to local climate and diseases. Local governments and industry have been pushing hybridization which has resulted in several of the indigenous breeds becoming extinct or threatened. Disuse because of unprofitability and uncontrolled intentional and unintentional cross-pollination and crossbreeding (genetic pollution), formerly huge gene pools of various wild and indigenous breeds have collapsed causing widespread genetic erosion and genetic pollution. This has resulted in loss of genetic diversity and biodiversity as a whole.[67]

A genetically modified organism (GMO) is an organism whose genetic material has been altered using the genetic engineering techniques generally known as recombinant DNA technology. Genetically Modified (GM) crops today have become a common source for genetic pollution, not only of wild varieties but also of other domesticated varieties derived from relatively natural hybridization.[68][69][70][71][72]

Genetic erosion coupled with genetic pollution may be destroying unique genotypes, thereby creating a hidden crisis which could result in a severe threat to our food security. Diverse genetic material could cease to exist which would impact our ability to further hybridize food crops and livestock against more resistant diseases and climatic changes.[67]

[] Climate Change

: Effect of Climate Change on Plant Biodiversity

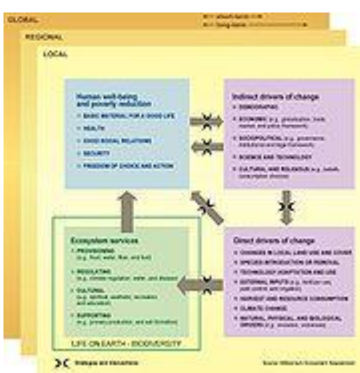
The recent phenomenon of global warming is also considered to be a major threat to global biodiversity.[*citation needed*] For example coral reefs -which are biodiversity hotspots- will be lost in 20 to 40 years if global warming continues at the current trend.[73]

[] Conserving biodiversity

: Conservation biology

The retreat of Aletsch Glacier in the Swiss Alps (situation in 1979, 1991 and 2002), due to global warming.

Conservation biology matured in the mid- 20th century as ecologists, naturalists, and other scientists began to collectively research and address issues pertaining to global declines in biodiversity.[74][75][76] The conservation ethic differs from the preservationist ethic, historically lead by John Muir, who advocate for protected areas devoid of human exploitation or interference for profit.[75] The conservation ethic advocates for wise stewardship and management of natural resource production for the purpose of protecting and sustaining biodiversity in species, ecosystems, the evolutionary process, and human culture and society.[74][76][77][78] Conservation biologists are concerned with the trends in biodiversity being reported in this era, which has been labeled by science as the Holocene extinction period, also known as the sixth mass extinction.[79] Rates of decline in biodiversity in this sixth mass extinction match or exceed rates of loss in the five previous mass extinction events recorded in the fossil record.[79][80][81][82][83] Loss of biodiversity results in the loss of natural capital that supplies ecosystem goods and services. The economic value of 17 ecosystem services for the entire biosphere (calculated in 1997) has an estimated average value of US$33trillion ($10^{12}$) per year![84]



A schematic image illustrating the relationship between biodiversity, ecosystem services, human well-being, and poverty.[85] The illustration shows where conservation action, strategies and plans can influence the drivers of the current biodiversity crisis at local, regional, to global scales.

In response to the extinction crisis, the research of conservation biologists is being organized into strategic plans that include principles, guidelines, and tools for the purpose of protecting biodiversity.[74][86][87] Conservation biology is a crisis orientated discipline and it is multi-disciplinary, including ecological, social, education, and other scientific disciplines outside of biology. Conservation biologists work in both the field and office, in government, universities, non-profit organizations and in industry.[74][76] The conservation of biological diversity is a global priority in strategic conservation plans that are designed to engage public policy and concerns affecting local, regional and global scales of communities, ecosystems, and cultures.[88] Conserving biodiversity and action plans identify ways of sustaining human well-being and global economics, including natural capital, market capital, and ecosystem services.[89][90]

[] Means

One of the strategies involves placing a monetary value on biodiversity through biodiversity banking, of which one example is the Australian Native Vegetation Management Framework. Other approaches are the creation of gene banks, as well as the creation of gene banks that have the intention of growing the indigenous species for reintroduction to the ecosystem (eg via tree nurseries, ...)[91] The eradication of exotic species is also an important method to preserve the local biodiversity. Exotic species that have become a pest can be identified using taxonomy (eg with DAISY, barcode of life[92], ...) and can then be eradicated. [93]This method however can only be used against a large group of a certain exotic organism due to the econimic cost. Other measures contributing to the preservation of biodiversity include: the reduction of pesticide use and/or a switching to organic pesticides, ... These measures however, are of less importance than the preserving of rural lands, reintroduction of indigenous species and the removal of exotic species. Finally, if the continued preservation of native organisms in an area can be guaranteed, efforts can be made in trying to reintroduce eliminated native species back into the environment. This can be done by first determining which species were indigenous to the area, and then reintroducing them. This determination can be done using databases as the Encyclopedia_of_life, Global Biodiversity Information Facility, ... Extermination is usually done with either (ecological) pesticides, or natural predators.

[] Strategies

As noted above (Distribution), biodiversity is not as rich everywhere on the planet. Regions as the tropics and subtropics are considerably much richer in biodiversity than regions in temperate climates. In addition, in temperate climates, a lot of countries are located which are already vastly urbanised, and require -in addition- great amounts of space for the growing of crops. As rehabilitating the biodiversity within these countries would again require the clearing and redeveloping of spaces, it has been proposed of some that efforts are best instead directed unto the tropics. Arguments include economics, it would be far less costly and more efficient to preserve the biodiversity in the tropics, especially as many countries in these areas are only now beginning to urbanise.[94]

However, only directing the efforts into these areas would not be enough, as many species still need to migrate at certain times of the year, requiring a connection to other regions/countries. In the more urbanised countries in temperate climates, this would mean that wildlife corridors need to be made. However, making wildlife corridors would still be considerably cheaper and easier than clearing/preserving entirely new areas.

[] Judicial status

Biodiversity is beginning to be evaluated and its evolution analysed (through observations, inventories, conservation...) as well as being taken into account in political and judicial decisions:

- The relationship between law and ecosystems is very ancient and has consequences for biodiversity. It is related to property rights, both private and public. It can define protection for threatened ecosystems, but also some rights and duties (for example, fishing rights, hunting rights).
- Law regarding species is a more recent issue. It defines species that must be protected because they may be threatened by extinction. The U.S. Endangered Species Act is an example of an attempt to address the "law and species" issue.
- Laws regarding gene pools are only about a century old[*citation needed*]. While the genetic approach is not new (domestication, plant traditional selection methods), progress made in the genetic field in the past 20 years have led to a tightening of laws in this field. With the new technologies of genetic analysis and genetic engineering, people are going through gene patenting, processes patenting, and a totally new concept of genetic resources.[95] A very hot debate today seeks to define whether the resource is the gene, the organism itself, or its DNA.

The 1972 UNESCO World Heritage convention established that biological resources, such as plants, were the common heritage of mankind. These rules probably inspired the creation of great public banks of genetic resources, located outside the source-countries.

New global agreements (e.g.Convention on Biological Diversity), now give **sovereign national rights over biological resources** (not property). The idea of static conservation of biodiversity is disappearing and being replaced by the idea of dynamic conservation, through the notion of resource and innovation.

The new agreements commit countries to **conserve biodiversity**, **develop resources for sustainability** and **share the benefits** resulting from their use. Under new rules, it is expected that bioprospecting or collection of natural products has to be allowed by the biodiversity-rich country, in exchange for a share of the benefits.

Sovereignty principles can rely upon what is better known as Access and Benefit Sharing Agreements (ABAs). The Convention on Biodiversity spirit implies a prior informed consent between the source country and the collector, to establish which resource will be used and for what, and to settle on a fair agreement on benefit sharing. Bioprospecting can become a type of biopiracy when those principles are not respected.

Uniform approval for use of biodiversity as a legal standard has not been achieved, however. At least one legal commentator has argued that biodiversity should not be used as a legal standard, arguing that the multiple layers of scientific uncertainty inherent in the concept of biodiversity will cause administrative waste and increase litigation without promoting preservation goals. See Fred Bosselman, A Dozen Biodiversity Puzzles, 12 N.Y.U. Environmental Law Journal 364 (2004)

[] Analytical limits

[] Taxonomic and size bias

Less than 1% of all species that have been described have been studied beyond simply noting their existence.[96] Biodiversity researcher Sean Nee points out that the vast majority of Earth's biodiversity is microbial, and that contemporary biodiversity physics is "firmly fixated on the visible world" (Nee uses "visible" as a synonym for macroscopic).[97] For example, microbial life is very much more metabolically and environmentally diverse than multicellular life (see extremophile). Nee has stated: "On the tree of life, based on analyses of small-subunit ribosomal RNA, visible life consists of barely noticeable twigs.

The size bias is not restricted to consideration of microbes. Entomologist Nigel Stork states that "to a first approximation, all multicellular species on Earth are insects".[98] Even in insects, however, the extinction rate is high and indicative of the general trend of the sixth greatest extinction period that human society is faced with.[99][100] Moreover, there are species co-extinctions, such as plants and beetles, where the extinction or decline in one is reciprocated in the other.[101]

[] Definition

1. Biodiversity is the variety of life: the different plants, animals and micro-organisms, their genes and the ecosystems of which they are a part. [102]
2. “Biodiversity” is often defined as the variety of all forms of life, from genes to species, through to the broad scale of ecosystems (for a list of variants on this simple definition see Gaston 1996). "

Ecological effects of biodiversity

Jump to: navigation, search

The diversity of species and genes in ecological communities affects the functioning of these communities. These **ecological effects of biodiversity** in turn affect both climate change through enhanced greenhouse gases, aerosols and loss of land cover, and biological diversity, causing a rapid loss of ecosystems and extinctions of species and local populations. The current rate of extinction is sometimes considered a mass extinction, with current species extinction rates on the order of 100 to 1000 times as high as in the past.[1]

The two main areas where the effect of biodiversity on ecosystem function have been studied are the relationship between diversity and productivity, and the relationship between diversity and community stability. More biologically diverse communities appear to be more productive (in terms of biomass production) than are less diverse communities, and they appear to be more stable in the face of perturbations.

Also animals that inhabit an area may alter the surviving conditions by factors assimilated by climate.

[] Definitions of diversity, productivity, and stability

In order to understand the effects that changes in biodiversity will have on ecosystem functioning, it is important to define some terms. Biodiversity is not easily defined, but may be thought of as the number and/or evenness of genes, species, and ecosystems in a region. This definition includes genetic diversity, or the diversity of genes within a species, species diversity, or the diversity of species within a habitat or region, and ecosystem diversity, or the diversity of habitats within a region.

Two things commonly measured in relation to changes in diversity are productivity and stability. Productivity is a measure of ecosystem function. It is generally measured by taking the total aboveground biomass of all plants in an area. Many assume that it can be used as a general indicator of ecosystem function and that total resource use and other indicators of ecosystem function are correlated with productivity.

Stability is much more difficult to define, but can be generally thought of in two ways. General stability of a population is a measure that assumes stability is higher if there is less of a chance of extinction. This kind of stability is generally measured by measuring the variability of aggregate community properties, like total biomass, over time [2] The other definition of stability is a measure of resilience and resistance, where an ecosystem that returns quickly to an equilibrium after a perturbation or resists invasion is thought of as more stable than one that doesn't.[3]

[] Productivity and stability as indicators of ecosystem health

The importance of stability in community ecology is clear. An unstable ecosystem will be more likely to lose species. Thus, if there is indeed a link between diversity and stability, it is likely that losses of diversity could feedback on themselves, causing even more losses of species. Productivity, on the other hand, has a less clear importance in community ecology. In managed areas like cropland, and in areas where animals are grown or caught, increasing productivity increases the economic success of the area and implies that the area has become more efficient, leading to possible long term resource sustainability.[4] It is more difficult to find the importance of productivity in natural ecosystems. This will be discussed in more detail later.

[] Does biodiversity have value?

Beyond the value biodiversity has in regulating and stabilizing ecosystem processes, there are direct economic consequences of losing diversity in certain ecosystems and in the world as a whole. Losing species means losing potential foods, medicines, industrial products, and tourism, all of which have a direct economic effect on peoples lives.[5] For more information, see the economic role of biodiversity.

[] Effects of diversity on community productivity

[] How species diversity may influence productivity

- **Complementarity** Plant species coexistence is thought to be the result of niche partitioning, or differences in resource requirements among species. By complementarity, a more diverse plant community should be able to use resources more completely, and thus be more productive.[4][6] Also called niche differentiation, this mechanism is a central principle in the functional group approach, which breaks species diversity down into functional components. [7][8]
- **Facilitation** Facilitation is a mechanism whereby certain species help or allow other species to grow by modifying the environment in a way that is favorable to a co-occurring species.[9] Plants can interact through an intermediary like nitrogen, water, temperature, space, or interactions with weeds or herbivores among others. Some examples of facilitation include large desert perennials acting as nurse plants, aiding the establishment of young neighbors of other species by alleviating water and temperature stress,[10] and nutrient enrichment by nitrogen-fixers such as legumes.
- **The Sampling Effect** The sampling effect of diversity can be thought of as having a greater chance of including a species of greatest inherent productivity in a plot that is more diverse. This provides for a composition effect on productivity, rather than diversity being a direct cause. However, the sampling effect may in fact be a compilation of different effects. The sampling effect can be separated into the greater likelihood of selecting a species that is 1) adapted well to particular site conditions, or 2) of a greater inherent productivity. Additionally, one can add to the sampling effect a greater likelihood of including 3) a pair of species that highly complement each other, or 4) a certain species with a large facilitative effect on other members of the community.

[] Review of data

Field experiments to test the degree to which diversity affects community productivity have found many things, but many long term studies in grassland ecosystems have found that diversity does indeed enhance the productivity of ecosystems. [11][12][13] Evidence of the relationship has also been found in grassland microcosms. However, these different studies have come to different conclusions as to whether the cause was due more to diversity or to species composition. Recent mathematical models have highlighted the importance of ecological context in unraveling this problem. Some models have indicated the importance of disturbance rates and spatial heterogeneity of the environment,[14] others have indicated that the time since disturbance and the habitat's carrying capacity can cause differing relationships.[15] Each ecological context should yield not only a different relationship, but a different contribution to the relationship due to diversity and to composition.

[] Implications for ecology/future research

In order to correctly identify the consequences of diversity on productivity and other ecosystem processes, many things must happen. First, it is imperative that scientists stop looking for a single relationship. It is obvious now from the models, the data, and the theory that there is no one overarching effect of diversity on productivity. Scientists must try to quantify the differences between composition effect and diversity effects, as many experiments never quantify the final realized species diversity (instead only counting numbers of species of seeds planted) and confound a sampling effect for facilitators (a compositional factor) with diversity effects.

Relative amounts of overyielding (or how much more a species grows when grown with other species than it does in monoculture) should be used rather than absolute amounts as relative overyielding can give clues as to the mechanism by which diversity is influencing productivity, however if experimental protocols are incomplete, one may be able to indicate the existence of a complementary or facilitative effect in the experiment, but not be able to recognize its cause. Experimenters should know what the goal of their experiment is, that is, whether it is meant to inform natural or managed ecosystems, as the sampling effect may only be a real effect of diversity in natural ecosystems (managed ecosystems are composed to maximize complementarity and facilitation regardless of species number). By knowing this, they should be able to choose spatial and temporal scales that are appropriate for their experiment. Lastly, to resolve the diversity-function debate, it is advisable that experiments be done with large amounts of spatial and resource heterogeneity and environmental fluctuation over time, as these types of experiments should be able to demonstrate the diversity-function relationship more easily.[4]

[] Effects of diversity on community stability

[] How species diversity may influence community stability

- **Averaging Effect** If all species have differential responses to changes in the ecosystem over time, then the averaging of these responses will cause a more temporally stable ecosystem if more species are in the ecosystem.[2]. This effect is a statistical effect due to summing random variables.
- **Negative Covariance Effect** If some species do better when other species are not doing well, then when there are more species in the ecosystem, their overall variance will be lower than if there were fewer species in the system. This lower variance indicates higher stability. [16] This effect is a consequence of competition as highly competitive species will negatively covary.
- **Insurance Effect** If an ecosystem contains more species then it will have a greater likelihood of having redundant stabilizing species, and it will have a greater number of species that respond differently to perturbations. This will enhance an ecosystem's ability to buffer perturbations.[17]

- **Resistance to Invasion** Diverse communities may use resources more completely than simple communities because of a diversity effect for complementarity. Thus invaders may have reduced success in diverse ecosystems, or there may be a reduced likelihood that an invading species will introduce a new property or process to a diverse ecosystem.[8][18][19]
- **Resistance to Disease** A decreased number of competing plant species may allow the abundances of other species to increase, facilitating the spread of diseases of those species. [18][19][20]

[] Review of temporal stability data

Models have predicted that empirical relationships between temporal variation of community productivity and species diversity are indeed real, and that they almost have to be. Some temporal stability data can be almost completely explained by the averaging effect by constructing null models to test the data against.[2][11] Competition, which causes negative covariances, only serves to strengthen these relationships.

[] Review of resistance/resilience stability data

This area is more contentious than the area of temporal stability, mostly because some have tried generalizing the findings of the temporal stability models and theory to stability in general. While the relationship between temporal variations in productivity and diversity has a mathematical cause, which will allow the relationship to be seen much more often than not, it is not the case with resistance/resilience stability. Some experimenters have seen a correlation between diversity and reduced invasibility, though many have also seen the opposite. [21] The correlation between diversity and disease is also tenuous, though theory and data do seem to support it.[20]

[] Implications for ecology/future research

In order to more fully understand the effects of diversity on the temporal stability of ecosystems it is necessary to recognize that they are bound to occur. By constructing null models to test the data against (as in Doak et al. 1998[2]) it becomes possible to find situations and ecological contexts where ecosystems become more or less stable than they should be. Finding these contexts would allow for mechanistic studies into why these ecosystems are more stable, which may allow for applications in conservation management.

More importantly more complete experiments into whether diverse ecosystems actually resist invasion and disease better than their less diverse equivalents as invasion and disease are two important factors that lead to species extinctions in the present day.

[] Theory and preliminary effects from examining food webs

One major problem with both the diversity-productivity and diversity-stability debates discussed up to this point is that both focus on interactions at just a single trophic level. That is, they are concerned with only one level of the food web, namely plants. Other research, unconcerned with the effects of diversity, has demonstrated strong top-down forcing of ecosystems (see keystone species). There is very little actual data available regarding the effects of different food webs, but theory helps us in this area. First, if a food web in an ecosystem has a lot of weak interactions between different species, then it should have more stable populations and the community as a whole should be more stable.[3] If upper levels of the web are more diverse, then there will be less biomass in the lower levels and if lower levels are more diverse they will better be able to resist consumption and be more stable in the face of consumption. Also, top-down forcing should be reduced in less diverse ecosystems because of the bias for species in higher trophic levels to go extinct first.[22] Lastly, it has recently been shown that consumers can dramatically change the biodiversity-productivity-stability relationships that are implied by plants alone.[23] Thus, it will be important in the future to incorporate food web theory into the future study of the effects of biodiversity. In addition this complexity will need to be addressed when designing biodiversity management plans.

[] Conclusions

It is imperative that we come to a realization that there is no single overarching effect of diversity on either productivity or stability. The realized effects will depend heavily on environmental context and the time scale over which the effects are studied. However, it has become obvious that biodiversity is indeed important for both managed and natural ecosystems, though the relative contributions of diversity and composition remain unclear. It is therefore necessary for legislators to understand the basic science in order to maintain diversity at its current levels. If current human growth and resource management patterns do not change, it is likely that we will lose many important species, and the ecosystems of the world may never recover.

Introduced species

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"Alien species" redirects here. For life on planets other than Earth, see extraterrestrial life.

For a list of extraterrestrials in fiction, see List of alien species.

Sweet clover (*Melilotus sp.*), introduced and naturalized to the U.S. from Eurasia as a forage and cover crop.

An **introduced**, **alien**, **exotic**, **non-indigenous**, or **non-native species**, or simply an **introduction**, is a species living outside its native distributional range, which has arrived there by human activity, either deliberate or accidental. Some introduced species are damaging to the ecosystem they are introduced into, others negatively affect agriculture and other human uses of natural resources, or impact on the health of animals and humans. A list of introduced species is given in a separate article. Introduced species and their effects on natural environments is a controversial subject and one that has gained much scrutiny by scientists, governments, farmers and others.

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[] Terminology

The terminology associated with introduced species is presently in flux for a variety of reasons. Other terms that are used sometimes interchangeably (having the same or similar meanings) with *introduced* are *acclimatized*, *adventive*, *naturalized*, *immigrant*, and *xenobiotic*. Nonetheless, distinctions can and should be made between some of these terms.

In the broadest and most widely used sense, an introduced species is synonymous with *non-native* and therefore applies as well to most garden and farm organisms; these adequately fit the basic definition given above. However, some sources add to that basic definition: "...and are now reproducing in the wild",[1] which removes from consideration as *introduced* all of those species raised or grown in gardens or farms that do not survive without tending by people. With respect to plants, these latter are in this case defined as either *ornamental* or *cultivated* plants.

The following definition from the United States Environmental Protection Agency, although perhaps lacking ecological sophistication, is more typical: *introduced species* are .."[s]pecies that have become able to survive and reproduce outside the habitats where they evolved or spread naturally".[2] However, introduction of a species outside its native range is often all that is required to be qualified as an "introduced species" such that one can distinguish between introduced species that may only occur in cultivation, under domestication or captivity whereas other become established outside their native range and reproduce without human assistance. Such species might be termed "naturalized", "established", "wild non-native species", or "invasive". The transition from introduction, to establishment and invasion has been described by in the context of plants.[3] Introduced species are essentially "non-native" species. Invasive species are those introduced species that spread-widely or quickly, and cause harm, be that to the environment,[4] human health, other valued resources or the economy. There have been calls from scientists to consider a species "invasive" only in terms of their spread and reproduction rather than the harm they may cause.[5].

An invasive species is one that has been introduced and become a pest in its new location, spreading (invading) by natural means. The term is used to imply both a sense of urgency and actual or potential harm. For example, U.S. Executive Order 13112 (1999) defines "invasive species" as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health".[6]

Although some argue that "invasive" is a loaded word and harm is difficult to define,[1] the fact of the matter is that organisms have and continue to be introduced to areas where they are not native, sometimes with, usually without, much regard to the harm that could result.

From a regulatory perspective, it is neither desirable nor practical to simply list as undesirable or outright ban all non-native species (although the State of Hawaii has adopted an approach that comes close to this). Regulations require a definitional distinction between non-natives that are deemed especially onerous and all others. Introduced *pest species* that are *officially listed* as invasive, best fit the definition of an *invasive species*.

In Great Britain the Wildlife and Countryside Act 1981 prevents the introduction of any animal not naturally occurring in the wild, and also any of a list of both animals or plants which have been introduced previously and have proved to be invasive.

<table>
<caption>Table of terms related to "Introduced Species"</caption>
<tr><td>NATIVE</td><td colspan="3">NON-NATIVE
INTRODUCED (broad definition)</td></tr>
<tr><td rowspan="2">INDIGENOUS
or ENDEMIC</td><td rowspan="2">CULTIVATED
and
LIVESTOCK</td><td colspan="2">Established in the wild
INTRODUCED
(narrow definition)</td></tr>
<tr><td>INVASIVE
(pest)</td><td>All others
not listed*</td></tr>
</table>

*Not listed in any "official" source as a pest species

[] Nature of introductions

By definition, a species is considered “introduced” when its transport into an area outside of its native range is human mediated. Introductions by humans can be described as either intentional or accidental. Intentional introductions have been motivated by individuals or groups who believe that the newly introduced species will be in some way beneficial to humans in its new location. Unintentional or accidental introductions are most often a byproduct of human movements, and are thus unbound to human motivations. Subsequent range expansion of introduced species may or may not involve human activity.

[] Intentional introductions

Species that humans intentionally transport to new regions can subsequently become successfully established in two ways. In the first case, organisms are purposely released for establishment in the wild. It is sometimes difficult to predict whether a species will become established upon release, and if not initially successful, humans have made repeated introductions to improve the probability that the species will survive and eventually reproduce in the wild. In these cases it is clear that the introduction is directly facilitated by human desires.

In the second case, species intentionally transported into a new region may escape from captive or cultivated populations and subsequently establish independent breeding populations. Escaped organisms are included in this category because their initial transport to a new region is human motivated.

Perhaps the most common motivation for introducing a species into a new place is that of economic gain. Examples of species introduced for the purposes of benefiting agriculture, aquaculture or other economic activities are widespread.[7] Eurasian carp was first introduced to the United States as a potential food source. The apple snail was released in Southeast Asia with the intent that it be used as a protein source, and subsequently to places like Hawaiʻi to establish a food industry. In Alaska, foxes were introduced to many islands to create new populations for the fur trade. The timber industry promoted the introduction of Monterey Pine (*Pinus radiata*) from California to Australia and New Zealand as a commercial timber crop. These examples represent only a small subsample of species that have been moved by humans for economic interests.

Introductions have also been important in supporting recreation activities or otherwise increasing human enjoyment. Numerous fish and game animals have been introduced for the purposes of sport fishing and hunting. The introduced amphibian (*Ambystoma tigrinum*) that threatens the endemic California salamander (*Ambystoma californiense*) was introduced to California as a source of bait for fishermen.[8] Pet animals have also been frequently transported into new areas by humans, and their escapes have resulted in several successful introductions, such as those of feral cats and parrots.

Many plants have been introduced with the intent of aesthetically improving public recreation areas or private properties. The introduced Norway Maple for example occupies a prominent status in many of Canada's parks.[9] The transport of ornamental plants for landscaping use has and continues to be a source of many introductions. Some of these species have escaped horticultural control and become invasive. Notable examples include water hyacinth, salt cedar, and purple loosestrife.

In other cases, species have been translocated for reasons of “cultural nostalgia,” which refers to instances in which humans who have migrated to new regions have intentionally brought with them familiar organisms. Famous examples include the introduction of starlings to North America by Englishman Eugene Schieffelin, a lover of the works of Shakespeare, who, it is rumoured, wanted to introduce all of the birds mentioned in Shakespeare's plays into the United States. He deliberately released eighty starlings into Central Park in New York City in 1890, and another forty in 1891. Yet another prominent example is the introduction of the European rabbit to Australia by one Thomas Austin, a British landowner who had the rabbits released on his estate in Victoria because he missed hunting them. A more recent example is the introduction of the wall lizard to North America by a Cincinnati boy, George Rau, in the 1950s after a family vacation to Italy.[10]

Intentional introductions have also been undertaken with the aim of ameliorating environmental problems. A number of fast spreading plants such as Garlic Mustard and kudzu have been introduced as a means of erosion control. Other species have been introduced as biological control agents to control invasive species and involves the purposeful introduction of a natural enemy of the target species with the intention of reducing its numbers or controlling its spread.

A special case of introduction is the reintroduction of a species that has become locally endangered or extinct, done in the interests of conservation. Examples of successful reintroductions include wolves to Yellowstone National Park in the U.S., and the Red kite to parts of England and Scotland. Introductions or translocations of species have also been proposed in the interest of genetic conservation, which advocates the introduction of new individuals into genetically depauperate populations of endangered or threatened species.[11]

The above examples highlight the intent of humans to introduce species as a means of incurring some benefit. While these benefits have in some cases been realized, introductions have also resulted in unforeseen costs, particularly when introduced species take on characteristics of invasive species.

Non-native species can become such a common part of an environment, culture, and even diet that little thought is given to their geographic origin. For example, soybeans, kiwi fruit, wheat and all livestock except the llama and the turkey are non-native species to North America. Collectively, non-native crops and livestock comprise 98% of US food.[12] These and other benefits from non-natives are so vast that, according to the Congressional Research Service, they probably exceed the costs.[13]

[] Accidental introductions

Unintentional introductions occur when species are transported by human vectors. For example, three species of rat (the Black, Norway and Polynesian) have spread to most of the world as hitchhikers on ships. There are also numerous examples of marine organisms being transported in ballast water, one being the zebra mussel. Over 200 species have been introduced to the San Francisco Bay in this manner making it the most heavily invaded estuary in the world.[14] Increasing rates of human travel are providing accelerating opportunities for species to be accidentally transported into areas in which they are not considered native. There is also the accidental release of the Africanized honey bees (AHB), known colloquially as "killer bees" or Africanized_bee to Brazil in 1957. The Asian_carps to the United States.

[] Introduced plants and algae

Many non-native plants have been introduced into new territories, initially as either ornamental plants or for erosion control, stock feed, or forestry. Whether an exotic will become invasive is seldom understood in the beginning, and many non-native ornamentals languish in the trade for years before suddenly naturalizing and becoming invasive.

Peaches, for example, originated in Persia, and have been carried to much of the populated world. Tomatoes are native to the Andes. Squash (pumpkins), maize, and tobacco are native to the Americas, but were introduced to the Old World. Many introduced species require continued human intervention to survive in the new environment. Others may become feral, but do not seriously compete with natives, but simply increase the biodiversity of the area.

Dandelions are also introduced species to North America.

A very troublesome marine species in southern Europe is the seaweed *Caulerpa taxifolia*. *Caulerpa* was first observed in the Merranean Sea in 1984, off the coast of Monaco. By 1997, it had covered some 50 km². It has a strong potential to overgrow natural biotopes, and represents a major risk for sublittoral ecosystems. The origin of the alga in the Merranean was thought to be either as a migration through the Suez Canal from the Red Sea, or as an accidental introduction from an aquarium.

Japanese knotweed grows profusely in many nations. Human beings introduced it into many places in the 19th century. It is a source of resveratrol, a dietary supplement.

[] Introduced animals

Male *Lophura nycthemera* (Silver Pheasant), a native of East Asia that has been introduced into parts of Europe for ornamental reasons.

One example of introducing an exotic animal was carried out by a lover of the works of Shakespeare, who wanted to introduce all of the birds mentioned in Shakespeare's plays into the United States. He deliberately released eighty starlings into Central Park in New York City in 1890, and another forty in 1891. The starling had been introduced previously into Ohio and had failed to survive.

Other examples of introduced animals include the gypsy moth in eastern North America, the zebra mussel and alewife in the Great Lakes, the Canada Goose and Gray Squirrel in Europe, the Muskrat in Europe and Asia, the Cane Toad and Red fox in Australia, Nutria in North America, Eurasia, and Africa, and the Common Brushtail Possum in New Zealand.

[] Invasive exotic diseases

History is rife with the spread of exotic diseases, such as the introduction of smallpox into the Americas, where it obliterated entire Native American civilizations before they were ever even seen by Europeans.

Problematic exotic disease introductions in the past century or so include the chestnut blight which has virtually extinguished the American chestnut, and Dutch elm disease, which has severely damaged the American elm. The most common diseases to find here are gotasloy which can make you have very severe mental and phyiscal problems

[] Most commonly introduced species

Some species, such as the Brown Rat, House Sparrow, Ring-necked Pheasant and European Starling, have been introduced very widely. In addition there are some agricultural and pet species that frequently become feral; these include rabbits, dogs, goats, fish, pigs and cats.

[] Introduced species on islands

Perhaps the best place to study problems associated with introduced species is on islands. Depending upon the isolation (how far an island is located from continental biotas), native island biological communities may be poorly adapted to the threat posed by exotic introductions. Often this can mean that no natural predator of an introduced species is present, and the non-native spreads uncontrollably into open or occupied niche.

An additional problem is that birds native to small islands may have become flightless because of the absence of predators prior to introductions, and cannot readily escape danger. The tendency of rails in particular to evolve flightless forms on islands has led to the disproportionate number of extinctions in that family.

The field of island restoration has developed as a field of conservation biology and ecological restoration, a great deal of which deals with the eradication of introduced species.

[] New Zealand

: Introduced species in New Zealand

In New Zealand the largest commercial crop is *Pinus radiata*, the Monterey Pine from California, which grows better in New Zealand than in California. However, the pine forests are also occupied by deer from North America and Europe and by possums from Australia. All are exotic species and all have thrived in the New Zealand environment. The pines are seen as beneficial while the deer and possums are regarded as serious pests.

Common gorse, originally a hedge plant in Scotland, was introduced to New Zealand for the same purpose. Like the radiata pine, it has shown a favour to its new climate and is regarded as a noxious plant which threatens to obliterate native plants in much of the country and is hence routinely eradicated, though it can also provide a nursery environment for native plants to reestablish themselves.

Rabbits, introduced as a food source by sailors in the 1800s, have become a severe nuisance to farmers, notably in South Island. The myxomatosis virus was illegally imported and illegally released but it had little lasting effect upon the rabbit population other than to make it more resistant to the virus.

Rats, brought either by the first humans to arrive in New Zealand (the Māori) or by Europeans have had a devastating effect upon native birdlife, particularly as many New Zealand birds are flightless. Feral cats and dogs which were originally brought as pets are also known to kill large numbers of birds. A recent (2006) study in South Island has shown that even domestic cats with a ready supply of food from their owners may kill hundreds of birds in a year, including natives.

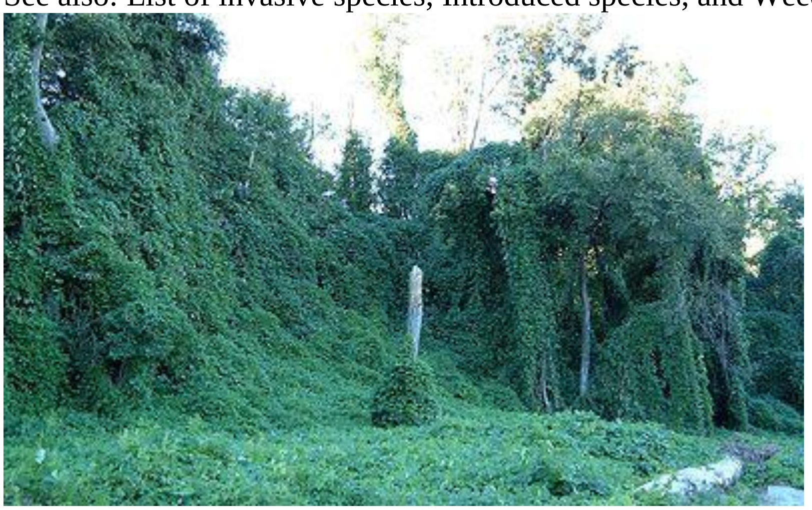
Sparrows, which were brought to control insects upon the introduced grain crops, have displaced native birds as have Rainbow Lorikeets and cockatoos (both from Australia) which fly free around areas west of Auckland City such as the Waitakere Ranges.

In much of the New Zealand the Australian black swan has effectively eliminated the existence of the previously introduced mute swan.

Two notable varieties of spiders have also been introduced: the white tail spider and the black widow spider. Both may have arrived inside shipments of fruit. Prior to this the only spider (and the only poisonous animal) dangerous to humans was the native katipo which is very similar to the black widow and which is known to successfully interbreed with the more aggressive North American variety.

Invasive species

Jump to: navigation, search
See also: List of invasive species, Introduced species, and Weed



Kudzu, a Japanese vine species invasive in the southeast United States, growing in Atlanta, Georgia

"Invasive species" is a phrase with several definitions. The first definition expresses the phrase in terms of non-indigenous species (e.g. plants or animals) that adversely affect the habitats they invade economically, environmentally or ecologically. It has been used in this sense by government organizations[1][2] as well as conservation groups such as the IUCN (International Union for Conservation of Nature).[3]

The second definition broadens the boundaries to include both *native* and *non-native* species that heavily colonize a particular habitat.

The third definition is an expansion of the first and defines an invasive species as a *widespread non-indigenous species*.[3] This last definition is arguably too broad as not all *non-indigenous* species necessarily have an adverse effect on their adopted environment. An example of this broader use would include the claim that the common goldfish (*Carassius auratus*) is invasive. Although it is common outside its range globally, it almost never appears in harmful densities.[3]

Because of the ambiguity of its definition, the phrase *invasive species* is often criticized as an imprecise term within the field of ecology.[3] This article concerns the first two definitions; for the third, see introduced species.

[] Conditions that lead to invasion

Scientists propose several mechanisms to explain invasive species, including species-based mechanisms and ecosystem-based mechanisms. It is most likely a combination of several mechanisms that cause an invasive situation to occur, since most introduced plants and animals do not become invasive.

[] Species-based mechanisms

Species-based characteristics focus on competition. While all species compete to survive, invasive species appear to have specific traits or combinations of specific traits that allow them to outcompete native species. Sometimes they just have the ability to grow and reproduce more rapidly than native species; other times it's more complex, involving a multiplex of traits and interactions.

Studies seem to indicate that certain traits mark a species as potentially invasive. One study found that of a list of invasive and noninvasive species, 86% of the invasive species could be identified from the traits alone.[4] Another study found that invasive species tended only to have a small subset of the invasive traits and that many of these invasive traits were found in non-invasive species as well indicating that invasiveness involves complex interaction not easily categorized.[4][5][6] Common invasive species traits include:

- The ability to reproduce both asexually as well as sexually
- Fast growth
- Rapid reproduction
- High dispersal ability
- Phenotypic plasticity (the ability to alter one’s growth form to suit current conditions)
- Tolerance of a wide range of environmental conditions (generalist)
- Ability to live off of a wide range of food types (generalist)
- Association with humans[7]
- Other successful invasions[8]

Typically an introduced species must survive at low population densities before it becomes invasive in a new location.[9] At low population densities, it can be difficult for the introduced species to reproduce and maintain itself in a new location, so a species might be transported to a location a number of times before it become established. Repeated patterns of human movement from one location to another, such as ships sailing to and from ports or cars driving up and down highways, allow for species to have multiple opportunities for establishment (also known as a high *propagule pressure*).[10]

An introduced species might become invasive if it can out-compete native species for resources such as nutrients, light, physical space, water or food. If these species evolved under great competition or predation, the new environment may allow them to proliferate quickly. Ecosystems in which all available resources are being used to their fullest capacity by native species can be modeled as zero-sum systems, where any gain for the invader is a loss for the native. However, such unilateral competitive superiority (and extinction of native species with increased populations of the invader) is not the rule.[11][12] Invasive species often coexist with native species for an extended time, and gradually the superior competitive ability of an invasive species becomes apparent as its population grows larger and denser and it adapts to its new location.

Lantana growing in abandoned citrus plantation; Moshav Sdei Hemed, Israel

An invasive species might be able to use resources previously unavailable to native species, such as deep water sources accessed by a long taproot, or an ability to live on previously uninhabited soil types. For example, Barbed Goatgrass (*Aegilops triuncialis*) was introduced to California on serpentine soils, which have low water-retention, low nutrient levels, a high Mg/Ca ratio, and possible heavy metal toxicity. Plant populations on these soils tend to show low density, but goatgrass can form dense stands on these soils crowding out native species that have not adapted well to growing on serpentine soils.[13]

Facilitation is the mechanism by which some species can alter their environment using chemicals or manipulating abiotic factors, allowing the species to thrive while making the environment less favorable to other species with which it competes.[*citation needed*] One such facilitative mechanism is *allelopathy*, also known as *chemical competition* or *interference competition*. In allelopathy a plant will secrete chemicals which make the surrounding soil uninhabitable, or at least inhibitory, to competing species.

One example of this is the knapweed *Centaurea diffusa*. This Eastern European weed has spread its way through the western United States. Experiments show that 8-Hydroxyquinoline, a chemical produced at the root of *C. diffusa*, has a negative effect only on plants that have not co-evolved with *C. diffusa*. Such co-evolved native plants have also evolved defenses, and *C. diffusa* does not appear in its native habitat to be an overwhelmingly successful competitor. This shows how difficult it can be to predict if a species will be invasive just from looking at its behavior in its native habitat, and demonstrates the potential for novel weapons to aid in invasiveness.[14][15]

Changes in fire regimes are another form of facilitation. *Bromus tectorum*, originally from Eurasia, is highly fire-adapted. It not only spreads rapidly after burning, but actually increases the frequency and intensity (heat) of fires, by providing large amounts of dry detritus during the dry fire season in western North America. In areas where it is widespread, it has altered the local fire regime so much that native plants cannot survive the frequent fires, allowing *B. tectorum* to further extend and maintain dominance in its introduced range.[16]

Facilitation also occurs when one species physically modifies a habitat and that modification is advantageous to other species. For example, zebra mussels increase habitat complexity on lake floors providing crevases in which invertebrates live. This increase in complexity, together with the nutrition provided by the waste products of mussel filter-feeding increases the density and diversity of benthic invertebrate communities.[17]

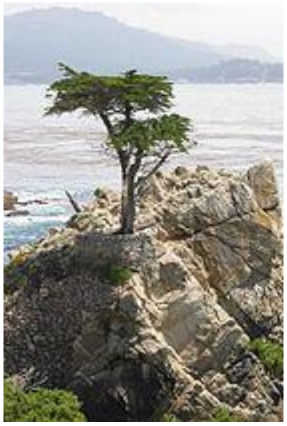
[] Ecosystem-based mechanisms

In ecosystems, the amount of available resources and the extent to which those resources are utilized by organisms determines the effects of additional species on the ecosystem. In stable ecosystems, equilibrium exists in the utilization of available resources. These mechanisms describe a situation in which the ecosystem has suffered a disturbance which changes the fundamental nature of the ecosystem.[18] When changes occur in an ecosystem, like forest fires in an area, normal succession would favor certain native grasses and forbs. With the introduction of a species that can multiply and spread faster than the native species, the balance is changed and the resources that would have been used by the native species are now utilized by an invader. This impacts the ecosystem and changes its composition of organisms and their use of available resources. Nitrogen and phosphorus are often the limiting factors in these situations.[19]

Every species has a role to play in its native ecosystem; some species fill large and varied roles while others are highly specialized. These roles are known as *niches*. Some invading species are able to fill niches that are not utilized by native species, and they also can create niches that did not exist.

When changes occur to ecosystems, conditions change that impact the dynamics of species interaction and niche development. This can cause once rare species to replace other species, because they now can utilize greater available resources that did not exist before, an example would be the edge effect. The changes can favor the expansion of a species that would not have been able to colonize areas and niches that did not exist before.

[] Ecology



Monterey Cypress

Although an invasive species is often defined as an introduced species that has spread widely and causes harm, some species native to a particular area can, under the influence of natural events such as long-term rainfall changes or human modifications to the habitat, increase in numbers and become invasive.

All species go through changes in population numbers, in many cases accompanied by expansion or contraction of range. Human landscape alterations are especially significant. This anthropogenic alteration of an environment may enable the expansion of a species into a geographical area where it had not been seen before and thus that species could be described as invasive. In essence, one must define "native" with care, as it refers to some natural geographic range of a species, and is not coincident with human political boundaries. Whether noticed increases in population numbers and expanding geographical ranges is sufficient reason to regard a native species as "invasive" requires a broad definition of the term but some native species in disrupted ecosystems can spread widely and cause harm and in that sense become invasive. For example, the Monterey Cypress is an endangered endemic[20] naturally occurring only in two small stands in California. They are being exterminated as exotic invasive species less than 50 miles (80 km) from their native home.

[] Traits of invaded ecosystems

In 1958, Charles S. Elton[21] argued that ecosystems with higher species diversity were less subject to invasive species because of fewer available niches. Since then, other ecologists have pointed to highly diverse, but heavily invaded ecosystems and have argued that ecosystems with high species diversity seem to be more susceptible to invasion.[11] This debate seems largely to hinge on the spatial scale at which invasion studies are performed, and the issue of how diversity affects community susceptibility to invasion remains unresolved. Small-scale studies tend to show a negative relationship between diversity and invasion, while large-scale studies tend to show a positive relationship. The latter result may be an artifact of invasive or non-native species capitalizing on increased resource availability and weaker overall species interactions that are more common when larger samples are considered.[22][23]

The brown tree snake (*Boiga irregularis*)

Invasion is more likely if an ecosystem is similar to the one in which the potential invader evolved.[7] Island ecosystems may be prone to invasion because their species are “naïve” and have faced few strong competitors and predators throughout their existence, or because their distance from colonizing species populations makes them more likely to have “open” niches.[24] An example of this phenomenon is the decimation of the native bird populations on Guam by the invasive brown tree snake.[25] Alternately, invaded ecosystems may lack the natural competitors and predators that keep introduced species in check in their native ecosystems, a point that is also seen in the Guam example. Lastly, invaded ecosystems have often experienced disturbance, usually human-induced.[7] This disturbance may give invasive species, which are not otherwise co-evolved with the ecosystem, a chance to establish themselves with less competition from more adapted species.[9]

[] Vectors

Non-native species have many *vectors*, including many biogenic ones, but most species considered "invasive" are associated with human activity. Natural range extensions are common in many species, but the rate and magnitude of human-mediated extensions in these species tend to be much larger than natural extensions, and the distances that species can travel to colonize are also often much greater with human agency.[26]

Chinese mitten crab (*Eriocheir sinensis*)

One of the earliest human influenced introductions involves prehistoric humans introducing the Pacific rat (*Rattus exulans*) to Polynesia.[27] Today, non-native species come from horticultural plants either in the form of the plants themselves or animals and seeds carried with them, and from animals and plants released through the pet trade. Invasive species also come from organisms stowed away on every type of transport vehicle. For example, ballast water taken up at sea and released in port is a major source of exotic marine life. The invasive freshwater zebra mussels, native to the Black, Caspian and Azov seas, were probably transported to the Great Lakes via ballast water from a transoceanic vessel.[28] The arrival of invasive propagules to a new site is a function of the site's invasibility.[29]

Species have also been introduced intentionally. For example, to feel more "at home", American colonists formed "Acclimation Societies" that repeatedly released birds that were native to Europe until they finally established along the east coast of North America.

Economics play a major role in exotic species introduction. The scarcity and demand for the valuable Chinese mitten crab is one explanation for the possible intentional release of the species in foreign waters.

[] Impact

[] Ecological impacts

Land clearing and human habitation put significant pressure on local species. This disturbed habitat is prone to invasions that can have adverse effects on local ecosystems, changing ecosystem functions. A species of wetland plant known as ʻaeʻae in Hawaiʻi (the indigenous *Bacopa monnieri*) is regarded as a pest species in artificially manipulated water bird refuges because it quickly covers shallow mudflats established for endangered Hawaiian stilt (*Himantopus mexicanus knudseni*), making these undesirable feeding areas for the birds.

Multiple successive introductions of different nonnative species can have interactive effects; the introduction of a second non-native species can enable the first invasive species to flourish. Examples of this are the introductions of the amethyst gem clam (*Gemma gemma*) and the European green crab (*Carcinus maenas*). The gem clam was introduced into California's Bodega Harbor from the East Coast of the United States a century ago. It had been found in small quantities in the harbor but had never displaced the native clam species (*Nutricola* spp.). In the mid 1990s, the introduction of the European green crab, found to prey preferentially on the native clams, resulted in a decline of the native clams and an increase of the introduced clam populations.[30]

In the Waterberg region of South Africa, cattle grazing over the past six centuries has allowed invasive scrub and small trees to displace much of the original grassland, resulting in a massive reduction in forage for native bovids and other grazers. Since the 1970s large scale efforts have been underway to reduce invasive species; partial success has led to re-establishment of many species that had dwindled or left the region. Examples of these species are giraffe, Blue Wildebeest, impala, kudu and White Rhino.

Invasive species can change the functions of ecosystems. For example invasive plants can alter the fire regime (cheatgrass, *Bromus tectorum*), nutrient cycling (smooth cordgrass *Spartina alterniflora*), and hydrology (*Tamarix*) in native ecosystems.[31] Invasive species that are closely related with rare native species have the potential to hybridize with the native species. Harmful effects of hybridization have led to a decline and even extinction of native species.[32][33] For example, hybridization with introduced cordgrass, *Spartina alterniflora*, threatens the existence of California cordgrass (*Spartina foliosa*) in San Francisco Bay.[34]

[] Genetic pollution

: Genetic pollution

Natural, wild species can be threatened with extinction[35] through the process of *genetic pollution*. Genetic pollution is uncontrolled hybridization and introgression which leads to homogenization or replacement of local genotypes as a result of either a numerical or fitness advantage of the introduced species.[36] Genetic pollution can bring about a form of extinction either through purposeful introduction or through habitat modification, bringing previously isolated species into contact. These phenomena can be especially detrimental for rare species coming into contact with more abundant ones where the abundant ones can interbreed with them, creating hybrids and swamping the entire rarer gene pool, thus driving the native species to extinction. Attention has to be focused on the extent of this problem, it is not always apparent from morphological observations alone. Some degree of gene flow may be a normal, evolutionarily constructive process, and all constellations of genes and genotypes cannot be preserved. However, hybridization with or without introgression may, nevertheless, threaten a rare species' existence.[37][38]

[] Economic impacts

[] Benefits

Often overlooked, economic benefits from "invasive" species should also be accounted. The wide range of benefits from many "invasive species" is both well-documented and under-reported. (In most cases invasive species have benefits, but the negative effects almost always outweigh the positive.) Asian oysters, for example, are better at filtering out water pollutants than native oysters. They also grow faster and withstand disease better than natives. Biologists are currently considering releasing the mollusk in the Chesapeake Bay to help restore oyster stocks and clean up the bay's pollution. A recent study by the Johns Hopkins School of Public Health found the Asian oyster could significantly benefit the bay's deteriorating water quality.[39]

[] Costs

Economic costs from invasive species can be separated into direct costs through production loss in agriculture and forestry, and management costs of invasive species. Estimated damage and control cost of invasive species in the U.S. alone amount to more than $138 billion annually.[40] In addition to these costs, economic losses can occur through loss of recreational and tourism revenues.[41] Economic costs of invasions, when calculated as production loss and management costs, are low because they do not usually consider environmental damages. If monetary values could be assigned to the extinction of species, loss in biodiversity, and loss of ecosystem services, costs from impacts of invasive species would drastically increase.[40] The following examples from different sectors of the economy demonstrate the impact of biological invasions.

[] Economic Opportunities

For many invasive species there are commercial benefits, either existent or capable of being developed. For instance, Silver Carp and Common Carp where heavy metals are not excessive in their flesh can be harvested for human food and exported to markets already familiar with the product, or into pet foods, or mink food. Numerous vegetative 'invasives' like Water Hyacinth can, when in sufficient quantities to be harvestable, be turned into methane digesters if no other better use can be determined. The depletion or exploitation of any unwanted species is dependent on officials who recognize the need for a solution. Commercial enterprises need assurances that the exploitation can continue long enough for a reasonable profit to be generated and that taxation of the 'resource' is given a sufficiently long period of grace that an enterprise is attracted to the proposition.

[] Agriculture

Weeds cause an overall reduction in yield, though they often provide essential nutrients for sustenance farmers. Weeds can have other useful purposes: some deep-rooted weeds can "mine" nutrients from the subsoil and bring them to the topsoil, while others provide habitat for beneficial insects and/or provide alternative foods for pest species. Many weed species are accidental introductions with crop seeds and imported plant material. Many introduced weeds in pastures compete with native forage plants, are toxic (e.g., Leafy Spurge, *Euphorbia esula*) to young cattle (older animals will avoid them) or non-palatable because of thorns and spines (e.g., Yellow Starthistle, *Centaurea solstitialis*). Forage loss from invasive weeds on pastures amounts to nearly $1 billion in the U.S. alone.[40] A decline in pollinator services and loss of fruit production has been observed to cause the infection of honey bees (*Apis mellifera* another invasive species to the Americas) by the invasive varroa mite. Introduced rodents (rats, *Rattus rattus* and *R. norvegicus*) have become serious pests on farms destroying stored grains.[40]

In many cases, one could consider the over-abundant invasive plant species as a ready source of biomass in the perspective of biogas production. See Eichhornia crassipes.

[] Forestry

The unintentional introduction of forest pest species and plant pathogens can change forest ecology and negatively impact timber industry. The Asian long-horned beetle (*Anoplophora glabripennis*) was first introduced into the U.S. in 1996 and is expected to infect and damage millions of acres of hardwood trees. Thirty million dollars have already been spent in attempts to eradicate this pest and protect millions of trees in the affected regions.[40]

The woolly adelgid inflicts damage on old growth spruce fir forests and negatively impacts the Christmas tree industry.[42] The chestnut blight fungus (*Cryphonectria parasitica*) and Dutch elm disease (*Ophiostoma novo-ulmi*) are two plant pathogens with serious impacts on forest health.

[] Tourism and recreation

Invasive species can have impacts on recreational activities such as fishing,[43] hunting, hiking, wildlife viewing, and water-based recreation. They negatively affect a wide array of environmental attributes that are important to support recreation, including but not limited to water quality and quantity, plant and animal diversity, and species abundance.[44] Eiswerth goes on to say that "very little research has been performed to estimate the corresponding economic losses at spatial scales such as regions, states, and watersheds." Eurasian Watermilfoil (*Myriophyllum spicatum*) in parts of the US, fill lakes with plants making fishing and boating difficult.[45]

[] Health impacts

An increasing threat of exotic diseases exists because of increased transportation and encroachment of humans into previously remote ecosystems. This can lead to new associations between a disease and a human host (e.g., AIDS virus[40]). Introduced birds (e.g. pigeons), rodents and insects (e.g. mosquitoes, fleas, lice and tsetse fly) can serve as vectors and reservoirs of human diseases. The introduced Chinese mitten crabs are carriers of the Asian lung fluke.[46] Throughout recorded history epidemics of human diseases such as malaria, yellow fever, typhus, and bubonic plague have been associated with these vectors.[21] A recent example of an introduced disease is the spread of the West Nile virus across North America resulting in the deaths of humans, birds, mammals, and reptiles.[47] Waterborne disease agents, such as Cholera bacteria (*Vibrio cholerae*), and causative agents of harmful algal blooms are often transported via ballast water.[48] The full range of impacts of invasive species and their control goes beyond immediate effects and can have long term public health implications. For instance, pesticides applied to treat a particular pest species could pollute soil and surface water.[40]

[] Threat to global biodiversity

: Biodiversity

Biotic invasion is one of the five top drivers for global biodiversity loss and is increasing because of tourism and globalization.[*citation needed*] It poses a particular risk to inadequately regulated fresh water systems, though quarantines and ballast water rules have improved the situation.[49]

[] Scientific definition

Stage	Characteristic
0	Propagules residing in a donor region
I	Traveling
II	Introduced
III	Localized and numerically rare
IVa	Widespread but rare
IVb	Localized but dominant
V	Widespread and dominant

In an attempt to avoid the ambiguous, subjective, and pejorative vocabulary that so often accompanies discussion of invasive species even in scientific papers, Colautti and MacIsaac[3] have proposed a new nomenclature system based on biogeography rather than on taxa.

By removing taxonomy, human health, and economic factors from consideration, this model focuses only on ecological factors. The model evaluates individual populations, and not entire species. This model does not attribute detrimentality to invasive species and beneficiality to native species. It merely classifies a species in a particular location based on its growth patterns in that particular microenvironment. This model could be applied equally to indigenous and to non-native species.