

University of California, Riverside
College of Natural and Agricultural Sciences

STUDY GUIDE for the video

EARTH 101: TOO MANY PEOPLE?

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In March through May 2012, the College of Natural and Agricultural Sciences (CNAS) and the community support group Science Circle presented the fifth in their annual series of science lectures. The four lectures in the series, named “Earth 101: What You Need to Know about Life on Our Planet,” were delivered to standing-room-only audiences in the University of California, Riverside, Extension Center. The lectures were delivered a second time, and videotaped, in the campus’s television studio to small audiences of middle- and high school students. The teachers of these students had partnered with the faculty lecturers during development of the lectures, and subsequently the pairs wrote these study guides to be used in conjunction with the videos, to help educate young people about important issues facing our planet.

For more information about the Science Lecture Series, email sciencedean@ucr.edu or visit cnas.ucr.edu/sciencelectures/.

The other three lecture videos are:

Earth 101: What Hollywood Can Teach Us about Our Planet

Earth 101: What’s Your Carbon Footprint?

Earth 101: Where Does Your Water Come From?

These 58-minute videos and their study guides are available for download at <http://cnas.ucr.edu/sciencelectures/slsvideos.html>.

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Background Information

Human Population Growth on Earth

- Data on human populations have been collected for the past two thousand years.
- Humans have been remarkably successful in increasing their population from less than 1 billion people to over 7 billion people over this time period.
- The majority of population growth has occurred over the past 100 years with more people living on the planet today than the total number of people that have lived (and died) in all of human history.
- The curve that documents the growth of human populations over time is known as the J-curve. The human population on earth is currently adding 1 billion people approximately every 13 years. The planet’s human population will reach 9 billion people by 2030.
- Over the past century, humans have populated areas that were previously unoccupied. Many of these areas are away from major waterways and substantial food sources.
- Deaths caused by disease, famine, and war have had only a minor impact on human population growth.
- The most important factor to consider is the fertility rate which is defined as the average number of children born to a woman over a lifetime.
- Fertility rates vary depending on geographical region. Fertility rates are highest in Africa and portions of Asia and lowest in Australia, Europe, and North America.
- In general, countries that have high fertility rates also have low life expectancies. As an example, many countries in Africa have fertility rates approaching 7 births per female but those same countries have life expectancies less than 50 years.

Estimating the Carrying Capacity of the Planet

- The carrying capacity of the planet is defined as the number of people, or any organism, that can be supported without harming the environment. It is often meant to mean the environment's maximal load.
- As a result of increasing population the amount of land available per human has been reduced by a factor of approximately four in just one century.
- For nearly five hundred years, various individuals have estimated the human carrying capacity for earth.
- Robert Malthus in 1798 wrote an essay stating that the human population will increase faster than the food supply unless checked by disease, famine, and war.
- Estimates of carrying capacity are based on a number of factors including the availability of resources (water, food, breathable air) and impacts on the environment.
- Most scientists place the carrying capacity between 2 billion people and 40 billion people.
- Paul and Anne Erlich proposed that environmental impact of human population is due to three factors: population size, quality of life (affluence), and technology that harms the environment.
- In order for the United States to maintain its current level of affluence, it has been estimated that the U.S. population needs to be reduced to 100 million people (it has currently at approximately 313 million people). To achieve this, the birth rate would need to be reduced from 2.0 to 1.5 in the next 100 years.

Ecological Consequences of Overpopulation

- Left unchecked, high numbers of humans on the planet will impact not only the availability of resources for humans but other organisms as well.
- Availability of safe drinking water is a concern and many areas with high population densities do not have access to safe water.
- There are many examples of resources that are used by humans that are being used at rates that are unsustainable.
- Helium is an example of an element that is used widely by humans in technology and medicine. It is being mined at a rate that will deplete the worldwide supply in less than a century.

The Biology of Reproduction

CELLULAR REPRODUCTION: MITOSIS VS. MEIOSIS

- All cells are capable of reproduction.
- Most cells in our body reproduce through the process of mitosis that yields identical copies (clones). All of these cells contain 23 pairs of chromosomes. Each pair of chromosomes, which encode the same genetic traits, consists of one chromosome from the mother and the other from the father.

- Germ cells, either sperm or eggs, result from a halving of their total chromosome number through the process of meiosis. As a result of meiosis, each germ cell contains 23 chromosomes.
- Eggs are produced in the ovaries and their development and release is primarily controlled by hormones (estrogen and progesterone).
- Sperm are produced in the testes of males and their production is controlled by the hormone testosterone.

FERTILIZATION

- Fertilization results from the union of one sperm with one egg which occurs in the female reproductive tract.
- Successful fertilization requires a number of complex physiological and molecular events to occur.
- The sperm first must penetrate a cellular layer that surrounds the egg known as the cumulus layer. The cells in the cumulus layer are stuck together by a molecule known as hyaluronic acid. (Hyaluronic acid is also found between joints, where it acts as a lubricant, and in the eye, where it binds large amounts of water.) Sperm carry an enzyme known as hyaluronidase that digests that hyaluronic acid, allowing the sperm to penetrate the cumulus layer.
- Once through the cumulus layer, sperm interact with a matrix known as the zona pellucida. Specific molecules on the sperm surface, known as receptors, bind to the molecules in the zona pellucida similar to a lock and key. This binding is necessary for successful penetration through the zona pellucida.
- Finally, the sperm fuses with the egg. Specific molecules on the sperm and the egg are needed for successful fusion to occur.
- After fusion, the fertilized egg (also known as a zygote) has 23 chromosomes from the egg and 23 chromosomes from the sperm. These 23 pairs (46 total chromosomes) is the beginning of a new individual.
- Together, the processes of meiosis and fertilization lead to great biological diversity in the population.

TARGETING MOLECULES TO CONTROL CELLULAR REPRODUCTION

- Modern approaches for controlling fertilization target particular cells or molecules involved in the production of gametes or the interaction between sperm and egg. By interfering with these molecules, fertilization can be prevented in a specific but reproducible way.
- Traditionally, fertility was controlled by interfering with hormones, especially female hormones. However, since hormones have effects on other cells, interfering with them is not ideal.
- Modern cancer therapies use an approach that targets defective cells (or molecules) that are unique to cancer cells. The same idea is being used to design agents that are involved in fertility.
- Specific targets involved in fertilization include the hyaluronidase on sperm, the molecules that make up the zona pellucida, or the molecules that are involved in sperm-egg fusion.
- A region in China that uses cotton oil showed a markedly decreased fertility rate. Scientists isolated a compound known as gossypol that decreased sperm motility. Although gossypol showed early promise, it has been found to have other side effects that make it undesirable as a birth control agent.

- Birth control research is not limited to humans. Scientists are actively involved in developing agents that control fertility in organisms that are harmful to humans (e.g., insects, rodents, etc.) or that have demonstrated exploding populations (rabbits, deer, weeds, etc.).

Ethical considerations

- At the present high rate of population growth we are faced with some important problems. Currently, areas that have the highest fertility rates and the lowest life expectancies also have the lowest standards of living. As the populations in those countries increase, how will the global population respond?
- Developed countries such as the United States have a high standard of living and consume resources at higher levels than most of the world. Although their rate of population is lower than most of the world, the impact on the environment per person is substantially higher than less developed countries. How will we respond?

References

BOOKS

Cohen, Joel E. *How many people can the earth support?* W.H. Norton and Co., New York City, 1995.

Ehrlich, Paul R. *The population bomb*. Buccaneer Books, Cutchogue, New York, 1968.

Ehrlich, Paul R., and Ehrlich, Anne H. *The population explosion*. Simon and Schuster, New York City, 1990.

INTERNET RESOURCES

Current world clock: <http://www.worldometers.info/world-population/>

United Nations Population Information Network: <http://www.un.org/popin/>

Relevant Vocabulary

- Biological diversity
- Carrying capacity
- Chromosome
- Cumulus layer
- Diploid
- Egg
- Fertility rate
- Fertilization
- Fertilized egg
- Gamete
- Haploid
- Hormone
- J-curve
- Life expectancy
- Meiosis
- Mitosis
- Sperm
- Thomas Malthus
- Zona Pellucida
- Zygote

Free Response Questions for Students

- Identify some examples of human impacts on the planet – which of these could be considered the “biggest transformation”?
- What attributes of humankind make it such a successful species?
- How has the amount of time required for the human species to add another billion people changed?
- Discuss the world distribution of the human population. Where is it most dense? Least dense?
- At what point in time did the world population reach 7 billion inhabitants?
- Based on current predictions, how large will the human population be in 2030?
- Explain why fertility rates as opposed to death rates are useful in predicting future population changes.
- Identify at least three consequences of accelerated population growth.
- Evaluate the statement: “The earth is getting smaller.”
- Discuss some of the challenges facing the continent of Africa.
- When seen from space at night, Africa has the fewest lighted areas. Describe possible reasons for this.
- Helium consumption is an example of human population impacts. Why? Besides helium, what are some other examples you can think of?
- Define carrying capacity. Can it be modified?
- Identify some of the options that have been explored to slow or reduce population growth.
- Discuss the role of technology in lowering the impacts of a growing population.

Relevant Science Content Standards (Grades 7 – 12)

Grade 7 — Focus on Life Science

CELL BIOLOGY

1. All living organisms are composed of cells, from just one to many trillions, whose details usually are visible only through a microscope. As a basis for understanding this concept:
 - c. Students know the nucleus is the repository for genetic information in plant and animal cells.
 - e. Students know cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.
 - f. Students know that as multicellular organisms develop, their cells differentiate.

GENETICS

2. A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences. As a basis for understanding this concept:
 - a. Students know the differences between the life cycles and reproduction methods of sexual and asexual organisms.
 - b. Students know sexual reproduction produces offspring that inherit half their genes from each parent.
 - e. Students know DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.

STRUCTURE AND FUNCTION IN LIVING SYSTEMS

5. The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. As a basis for understanding this concept:
 - d. Students know how the reproductive organs of the human female and male generate eggs and sperm and how sexual activity may lead to fertilization and pregnancy.
 - e. Students know the function of the umbilicus and placenta during pregnancy.

INVESTIGATION AND EXPERIMENTATION

7. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
 - b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.
 - c. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.
 - d. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).

Biology/Life Sciences — Grades 9 – 12

Standards that all students are expected to achieve in the course of their studies are unmarked. Standards that all students should have the opportunity to learn are marked with an asterisk (*).

GENETICS

2. Mutation and sexual reproduction lead to genetic variation in a population. As a basis for understanding this concept:
 - a. Students know meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.
 - b. Students know only certain cells in a multicellular organism undergo meiosis.
 - c. Students know how random chromosome segregation explains the probability that a particular allele will be in a gamete.
 - d. Students know new combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization).
 - e. Students know why approximately half of an individual's DNA sequence comes from each parent.
 - f. Students know the role of chromosomes in determining an individual's sex.
 - g. Students know how to predict possible combinations of alleles in a zygote from the genetic makeup of the parents.

ECOLOGY

6. Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept:
 - a. Students know biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.
 - b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.
 - c. Students know how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.
 - g. * Students know how to distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.

PHYSIOLOGY

9. As a result of the coordinated structures and functions of organ systems, the internal environment of the human body remains relatively stable (homeostatic) despite changes in the outside environment. As a basis for understanding this concept:
 - c. Students know how feedback loops in the nervous and endocrine systems regulate conditions in the body.
 - i. * Students know how hormones (including digestive, reproductive, osmoregulatory) provide internal feedback mechanisms for homeostasis at the cellular level and in whole organisms.