Outline and chapter notes to accompany chapter 1

BIOLOGY: SCIENCE AND ETHICS
Dec., 2003

A. SCIENCE DEVELOPS THEORIES BY TESTING HYPOTHESES

BIOLOGY is the scientific study of living things.

HYPOTHESES are central to science
Scientific statements must be TESTABLE against real-world observations.
Ideas that are tested in this way are called HYPOTHESES.
Statements that could possibly be confirmed (proved true) are called VERIFIABLE.
Statements that could possibly be disconfirmed (proved false) are FALSIFIABLE.
Statements that are both verifiable and falsifiable tend to be so specific that they are only of limited interest (to few people, and only for a short time).
The most interesting statements in science are general statements that:
* pertain to "all" instances of some phenomenon
* are therefore not verifiable
* are still falsifiable

METHODS OF REASONING:
DEDUCTION = reasoning from the general to the specific
Deduction is used in the testing of hypotheses
INDUCTION = reasoning from the specific to the general
Induction never guarantees the truth of any conclusions

WAYS OF DEVISING HYPOTHESES:
Induction
Intuition and imagination (see Fig. 1.1)
Esthetic preferences
Religious or philosophical ideas
Analogy with other processes
Serendipity (discovering something not sought for)

HYPOTHESES ARE NOT CONCLUSIONS. Since none of the above methods guarantee truthful results, all hypotheses must be tested against events and conditions in the observable world. Observations collected in the testing of hypotheses are called DATA.

SCIENCE is defined as a method of investigation that relies on the testing of falsifiable hypotheses

THEORIES
A THEORY is an interrelated set of hypotheses that:
a) explain many observed phenomena in terms of unseen ("theoretical") entities like genes or atoms, and
b) have been tested many times and in many different ways without being falsified.
A PRODUCTIVE theory is one that suggests many new hypotheses to test.
A theory may be communicated in terms of a MODEL (a simplified

mathematical or visual form).

A THEORY TO DESCRIBE LIVING SYSTEMS
Living systems, including organisms (but also cells and ecosystems) are distinguished by the following suite of characteristics:
Metabolism: Materials are taken in and chemically altered; materials brought in have, on average, higher energy levels that materials released; some of the energy released during metabolism is used to carry out life functions.
Motion: Some metabolic energy is usually used to produce motion.
Selective response: Living systems respond to certain stimuli and not others, often distinguishing danger from nondanger and food from nonfood.
Homeostasis: Living systems often maintain favorable conditions (and thus avoid extremes) by activities that undo or reverse deviations from those favorable conditions.
Growth and biosynthesis: Living systems add to themselves by synthesizing new materials.
Genetic material: All living systems have genetic material in the form of nucleic acids, carrying hereditary information derived from previously existing living systems.
Reproduction: Living organisms can make other organisms like themselves, a process that involves copying the genetic material.
Population structure: All living organisms belong to populations of similar organisms related by common descent.

HYPOTHESIS TESTING IN EXPERIMENTAL SCIENCE
Hypotheses can be tested by setting up artificial situations called EXPERIMENTS.
Well-designed experiments always compare the experimental set of conditions with another similar set of conditions called a CONTROL. The control conditions must differ from the experimental conditions in only the one variable being tested.
Example: Lederberg & Lederberg's replica-plating experiment.

HYPOTHESIS TESTING IN NATURALISTIC SCIENCE
Many branches of science deal with phenomena restricted to the past or too large, too complex, or too long-lasting to allow experimental manipulation.
Naturalistic scientists are restricted to those observations that nature permits. Naturalistic comparisons are thus like experiments that nature has performed, and the scientists must search for situations where the experimental conditions naturally differ (e.g., differences from place to place in natural temperature or lighting). Since other conditions (those not being tested) are not controlled, natural scientists often collect large samples and use statistical methods to eliminate or minimize the effects of these other variables.

B. SCIENTISTS WORK IN PARADIGMS, WHICH CAN HELP DEFINE SCIENTIFIC REVOLUTIONS

A PARADIGM is a set of interconnected theories, hypotheses, value judgements, assumptions, concepts, and terminology within which scientific activity takes place.

NORMAL SCIENCE takes place within the context of a paradigm.
   Normal science proceeds piecemeal by testing one hypothesis at a time.

SCIENTIFIC REVOLUTIONS occur when one paradigm replaces another.
   The newer paradigm, in order to replace the older, must explain everything that the old one did and more.
   Scientific revolutions proceed by recruiting new adherents to the new paradigm. Often, these new adherents represent a new generation of younger scientists.

MOLECULAR GENETICS AS A PARADIGM IN BIOLOGY

Molecular genetics since the 1950s was a paradigm that introduced an entire terminology and a way of describing how genes work.

The "central dogma" of molecular genetics was that information from DNA was used to make RNA, which in turn was used to make a protein sequence.

Terminology associated with this paradigm includes: code, codon, transcription, translation.

THE SCIENTIFIC COMMUNITY

Science occurs in a cultural context.

Science occurs in many cultures and societies.

Scientists publish their results and make these results accessible to other scientists.

At least since seventeenth century England, scientists have formed a SCIENTIFIC COMMUNITY.

"Turf wars" and other forms of competition in science demonstrate both the existence of a social context and the kinds of problems that may result from the fact that scientists are human.

C. SCIENTISTS OFTEN CONSIDER ETHICAL ISSUES

ETHICS

MORALS are beliefs about what is right and what is wrong. These beliefs serve as guidelines for conduct. MORAL CODES are sets of such guidelines. The study of moral codes is called ETHICS.

Moral codes help people to make specific judgements about the rightness or wrongness of particular acts by applying general rules.

RESOLVING MORAL CONFLICTS

Moral conflicts exist WITHIN a moral code when its rules suggest two or more incompatible actions.

Within a moral code, moral conflicts may be resolved by ranking moral guidelines so that one guideline gives way to another rule of higher rank when the two conflict.

Moral conflicts also arise when people follow different moral codes.

DEONTOLOGICAL ETHICS

A moral code is DEONTOLOGICAL if acts are judged without regard to their consequences.

Some deontological systems are based on religious texts or religious principles; some are not.

Immanuel Kant's deontological system was based on one principle, called the "categorical imperative": act only according to rules that you would want all others to follow.

Most deontological systems recognize certain RIGHTS that we should not violate.

UTILITARIAN ETHICS

Utilitarian moral codes are those in which acts are judged according to their consequences.

Utilitarian systems always strive to maximize the greatest good for the greatest number of people, or the greatest excess of pleasures over pains.

OTHER ETHICAL SYSTEMS include:

EGOISM, a system which judges acts according to whether they benefit one individual or group.

NATURE-BASED ETHICS, a system which judges acts according to whether or not they are "natural". However, examples can be found in nature for many incompatible acts.

ETHICAL RELATIVISM, the position that ethics do differ and should differ from one society to the next and that no universal standard can be applied.

HOW SOCIETIES MAKE ETHICAL DECISIONS

In pluralistic societies, different people bring different ethical systems to the public forums in which collective decisions are made.

Most pluralistic societies make collective decisions by some form of voting.

John Rawls argues that pluralistic decision-making rules (such as voting) are justified if they embody some principle of FAIRNESS to all.

SOCIAL POLICY DECISIONS ON ISSUES INVOLVING SCIENCE & TECHNOLOGY

Decisions on issues involving science and technology can be subdivided into three phases:

1. SCIENTIFIC ISSUES: "purely scientific" issues on which scientists will generally agree if sufficient data are known. Issues are resolved by reviewing many scientific tests based on data; political or ethical opinions are expected to be irrelevant at this stage. EXAMPLE: is chemical X poisonous to fish?
2. SCIENCE POLICY ISSUES: issues involving the possible consequences of one or another proposed course of action. Like the scientific issues, these issues are judged on the basis of data, but different methods of estimating RISKS and uncertainties may lead to differences of opinion regarding future consequences. (A RISK is the probability of a particular outcome.) EXAMPLE: what level of chemical X will exist in the river if certain measures are adopted?
3. POLICY ISSUES: issues of choice among various alternatives,

based largely on value judgements in the light of the findings on the science policy issues.

EXAMPLE: is it worth investing 15 million dollars to build a treatment plant if it is estimated to reduce the level of chemical X by 30% and the fish mortality by 40%?

All stages of decision-making should include procedures for exposing misinformation.

D. ETHICAL QUESTIONS ARISE IN DECISIONS ABOUT EXPERIMENTAL SUBJECTS

USES OF ANIMALS

Animals are used for many purposes by human societies:

- As a source of food for humans (by far the most animals are used for food).
- As a source of clothing
- As companion animals (pets)
- As work animals
- In recreational hunting, fishing, and trapping
- In research

Animal use is justified in various ways:

- Providing food for people
- Serving as status symbols
- Serving recreational needs
- Improving human health by testing medicines, surgical procedures, and hypotheses about the causes of a disease
- As stand-ins for people in dangerous situations
- Providing other information (including educational uses)

Animals are used as test subjects to verify that new drugs, food additives, and the like are safe before they are tested on humans. If this type of use were abolished, more tests would need to be performed on humans without benefit of prior testing on animals.

THE ANIMAL RIGHTS MOVEMENT consists of people with varying beliefs.

Rational dialogue may be impeded if animal rights advocates demonize all scientists as sadists and psychopaths, or if science researchers demonize all animal rights advocates as terrorists.

DO ANIMALS HAVE RIGHTS?

Some animal advocates recognize that animals have "rights" from a deontological perspective, including the right to go on living and the right to live their life as they wish.

Other animal advocates use utilitarian principles to say that animals' interests must be considered side by side with human interests.

In evaluating the rights of animals versus those of people (or the amount of harm done to animals versus harm done to people), one can either treat animals as less important than people or one can treat them as equally important. Some animal rights advocates have said that anyone who does not afford animals equal standing with people in such decisions is guilty of SPECIESISM.

People who argue against animal rights point out that animals

cannot make moral decisions or enter into voluntary agreements.
If we do not prosecute predators for killing their prey, then
we really don't recognize that the prey have any rights.
Nearly all people recognize that humans have a moral obligation to
minimize pain and suffering to animals in their care.

PARTICULAR ISSUES CONCERNING ANIMAL RIGHTS
Fur clothing: Should animal furs be used as clothing?
The rights of the animals to continue living must be balanced
with the desire of some people to wear furs. Because many
alternative forms of clothing exist, many people would
place a low value on any human demand to wear fur clothing.
Toxicology testing:
Animals are used to help determine LD50 values. Is knowledge
of these quantities sufficiently important to justify the
pain and suffering of the animals, and the death of many of
them, in the testing process?
Testing of pharmaceuticals:
The use of animals in testing drugs is often justified on the
basis of human lives saved. This kind of justification
judges the pain and suffering of animals to be of less
importance than the pain and suffering of humans.
Cosmetic testing:
The Draize test has been widely criticized because it causes
pain and suffering to animals in order to test new
cosmetics or new batches or colors of cosmetics that have
previously been tested. It has also been argued that
information of equal usefulness could just as easily be
obtained by other means (e.g., from external tests on the
skins of human volunteers).

IMPROVING THE TREATMENT OF ANIMALS
Both animal rights advocates and scientists have urged that we
practice three R's:
REDUCTION in the number of animals used;
REFINEMENT in the amount of information obtained from each
animal, including efforts to minimize repetition of
experiments already performed by others;
REPLACEMENT of live animals by bacteria or tissue cultures
whenever possible.
Government guidelines specify that animals be humanely treated and
housed and that pain-killing medication be given wherever
possible.
Most research institutions now have committees to review all
proposed experiments in which animal are to be used as test
subjects.

HUMANS AS EXPERIMENTAL SUBJECTS
Humans as subjects can give certain types of results that animals
cannot easily give:
they can be asked how they feel;
they can be given psychological tests, tests of perceptual
ability, etc.
Results based on human test subjects can more readily be applied to

other humans than tests based on animals.
Ethical guidelines require voluntary informed consent from all human subjects.
Most research institutions have committees to evaluate all proposals in which people are used as test subjects.
If results will be extrapolated to both sexes, testing should include test subjects of both sexes.

---------------------------------- Dec., 2003

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Outline and Chapter notes to accompany chapter 2

GENES, CHROMOSOMES, AND DNA
Dec., 2003

A. MENDEL OBSERVED PHENOTYPES AND FORMED HYPOTHESES

INHERITANCE FOLLOWS THE SAME LAWS IN MOST ORGANISMS.

THE BASIC LAWS OF GENETICS were first established by Gregor Mendel in 1865.
Mendel used peas which could either be crossed or self-fertilized
Earlier observers looked at many traits at once--
Mendel focused on one at a time.
Earlier observers used parents of unknown hereditary background.
Mendel bred PURE LINES first until they bred true.
Earlier observers only observed a single generation at a time--
Mendel extended his observations over several generations.
Earlier observers failed to quantify their results--
Mendel counted offspring and established ratios.

TERMINOLOGY:
PHENOTYPE = appearance ("pheno-"=visible, as in "phenomenon");
GENOTYPE = genetic make-up, not always visible, but detectable by performing crosses
ALLELES = variants of a gene.
HOMOZYGOUS = having two alleles that are alike;
HETEROZYGOUS = having two unlike alleles
DOMINANT = showing a phenotypic effect in heterozygous form
RECESSIVE = showing a phenotypic effect only when homozygous

MENDEL'S FINDINGS:
Crosses between PURE LINES produce offspring of one (dominant) phenotype only
Crossing of first generation plants produces 3:1 ratio of dominants

to recessives in the second generation (F2).
Explanation of 3:1 ratio in terms of PARTICULATE INHERITANCE.
"LAW OF SEGREGATION" = dominant and recessive alleles of heterozygote separate from one another during meiosis
"LAW OF INDEPENDENT ASSORTMENT" for 2 genes at a time: genes at different locations are chosen (sampled) independently of one another during gamete formation.

B. THE CHROMOSOMAL BASIS OF INHERITANCE EXPLAINS MENDEL'S HYPOTHESES:

Genes are located on chromosomes within the nucleus of each cell. Behavior of genes follows behavior of chromosomes. (This includes an exception to independent assortment in the case of "linked" genes on the same chromosome.)

MITOSIS:
Normal cell division is called MITOSIS; chromosome number doubles and is then halved, so the resulting chromosome number remains unchanged in the two daughter cells.
MEIOSIS:
Most animal and plant cells are DIPLOID (their chromosomes occur in pairs); the major exceptions are the egg and sperm cells, called GAMETES; gametes are always HAPLOID (their chromosomes occur as singletons).
The cell division that produces haploid cells (such as gametes) is called MEIOSIS. During meiosis, the chromosomes double once and divide twice, resulting in four haploid cells that each have half of the original chromosome number, including one chromosome from each pair.
The separation of chromosome pairs during meiosis is responsible for segregation.
GENE LINKAGE:
The independent separation of different pairs of chromosomes is responsible for independent assortment.
Genes on the same chromosome segregate together (LINKAGE), unless a chromosomal cross-over brings about their recombination.
CONFIRMATION OF THE CHROMOSOMAL THEORY:
Experiments have shown that the inheritance of genes parallels the inheritance of visible chromosomes.
When chromosomes have visible markers at opposite ends, recombination of genes (as observed in crosses) is always accompanied by the rearrangement (recombination) of the visible chromosome markers.

C. GENES CARRIED ON SEX CHROMOSOMES DETERMINE SEX AND SEX-LINKED TRAITS.

SEX DETERMINATION:
Humans and most other species have an XX / XY form of sex determination:
XX usually produces female (with two copies genes on the X-chromosome);
XY usually produces male (only one copy of most sex-linked genes)
Occasional anomalies resulted in discovery of the sry gene carried on the Y chromosome; this gene determines maleness, presumably

by regulating production of the hormone TESTOSTERONE.
Two other forms of sex determination are WW (male) versus WZ (female) in birds and haplodiploidy (males are haploid and females are diploid) in the insect order Hymenoptera.

SEX-LINKED TRAITS are those carried on the X chromosome.
Because males only have one X chromosome, they only have one copy of any sex-linked gene, and thus only a single allele. The product of this allele is always displayed phenotypically.
Females have two copies of each sex-linked genes. If a sex-linked allele is recessive, females will not exhibit the phenotype unless they have two copies of that allele.
Females heterozygous for a recessive sex-linked trait are called carriers. They do not exhibit the trait phenotypically, but they can pass it on to their descendents.
Recessive sex-linked alleles for uncommon conditions show up much more often in males and only rarely in females. Males with such traits may have affected grandfathers or great-grandfathers, and the connecting individuals in the intervening generations are carrier females.
Red-green colorblindness and hemophilia are examples of sex-linked traits in humans.

CHROMOSOMAL VARIATION:
The pattern of chromosomes visible under a light microscope is called a KARYOTYPE.
Most people have 23 pairs of chromosomes. These include the sex chromosomes and 22 pairs of other chromosomes, called autosomes.
Trisomy is an uncommon condition in which an extra chromosome is present, making a triple instead of the usual pair.
The most frequent form of trisomy is trisomy of chromosome 21, resulting in one form of Down's syndrome.
Other examples of trisomy include Patau's syndrome (trisomy #13)
Trisomy of the sex chromosomes can result in:
XXY (sterile males with Klinefelter's syndrome),
XYY (males with an extra Y), or
XXX (sterile females with an extra X).
Chromosome numbers may also be lower than 46. Females with only one X chromosome (XO) have Turner's syndrome and are sterile.
Both Turner's and Klinefelter's syndomes result from a type of abnormal cell division called nondisjunction.
Chromosomal translocations occur when a piece of one chromosome is attached to another.

SOCIAL AND ETHICAL ISSUES:
Rare individuals can be XX but not female, or XY but not male.
Rare individuals show ambiguous indications of sex.
Some people say it is unfair to forcibly assign an individual to one sex or another because many variations naturally exist.

D. THE MOLECULAR BASIS OF INHERITANCE FURTHER EXPLAINS MENDEL'S HYPOTHESES.

DNA AND GENETIC TRANSFORMATION:

Griffith's experiment established the phenomenon of BACTERIAL
TRANSFORMATION: dead bacteria of a virulent strain called IIIS
were able to transform the nonvirulent strain IIR into IIIS.
Avery, MacLeod & McCarty established that bacterial transformation
required DNA.
Hershey & Chase demonstrated that BACTERIOPHAGE viruses
reproduced by using genetic material made of DNA. The viruses
injected this DNA, but not their protein, into host bacteria
during viral reproduction.

THE CHEMICAL COMPOSITION OF DNA:

DNA is composed of phosphate groups, deoxyribose sugar, and nitrogenous
bases of four types (abbreviated A, G, C, and T).
Chargaff discovered that the amount of adenine and thymine were
equal (A=T) in DNA from a given species, as were the amounts of
guanine and cytosine (G=C).

THE THREE-DIMENSIONAL STRUCTURE OF DNA:

Rosalind Franklin used X-RAY DIFFRACTION to study the 3-D structure
of DNA
Watson & Crick described double-helix model of DNA structure:
- Building blocks: phosphate groups, deoxyribose sugar, and
nitrogen-containing bases (A = adenine, G = guanine, C =
cytosine, and T = thymine)
- One phosphate + one deoxyribose sugar + one base = a
NUCLEOTIDE.
- Nucleotides are connected by alternating chain of phosphates &
sugars.
- There are two strands of nucleotides, arranged in opposite
directions.
- Base-pairing of (A with T) and (C with G) holds the two strands
together.
- The two strands are twisted to form a DOUBLE HELIX.

A gene is a sequence of bases in DNA. The location of the gene on
the DNA is called its LOCUS.

DNA REPLICATION: DNA is made from DNA, using one strand as a TEMPLATE
(pattern) to synthesize the missing strand one base at a time.

---------------------------------- Dec., 2003

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Outline and Chapter notes to accompany chapter 3

HUMAN GENETICS

Dec., 2003

A. WHAT DO GENES DO?

GENE EXPRESSION consists of two steps:

TRANSCRIPTION to RNA: DNA unwinds in one area, then part of one DNA strand can be used as a template to synthesize a complementary strand of RNA, still keeping the message in the language of a series of nucleotides.

TRANSLATION into protein (i.e., changing nucleotide language into a sequence of amino acids, the language of proteins):
Within a ribosome, MESSENGER RNA comes together with a TRANSFER RNA molecule linked to an amino acid. A three-base sequence (CODON) on the messenger RNA matches a complementary sequence (ANTICODON) on the transfer RNA. The codon thus determines which transfer RNA molecule is used, and thus which amino acid is the next one to be inserted in a growing polypeptide strand.

MUTATIONS:
Mutations are heritable changes in genes or chromosomes.
Most mutations are SINGLE-GENE MUTATIONS that arise from errors in replication or from unrepaired damage to DNA molecules.
NOTE: Some geneticists restrict the term "mutation" to single-gene mutations only.
Single-gene mutations include:
base-pair substitutions
frame-shift mutations (additions & deletions)
CHROMOSOMAL ABERRATIONS, which arise from errors in meiosis, include:
changes in chromosome number (including polyploidy in plants)
duplications: a piece of a chromosome appears twice
inversions: a piece of a chromosome turns 180 degrees
deletions: a piece of a chromosome is missing
translocations: a piece of a chromosome attaches to another chromosome

B. SOME DISEASES AND DISEASE PREDISPOSITIONS ARE INHERITED

IDENTIFYING GENETIC CAUSES FOR TRAITS.
PEDIGREES of large families (or of many families) can help identifiy whether a genetic trait is caused by a dominant or a recessive allele, and whether the trait is sex-linked or autosomal.
Many human traits are affected by single genes. Examples include:
Brown eyes (dominant to blue eyes)
Ability to curl or roll up tongue (dominant to inability)
Ability to taste the chemical PTC (dominant to nontasting)

SOME HEREDITARY DISEASES ARE ASSOCIATED WITH KNOWN GENES:
Huntington's disease (dominant to absence of the disease)
NOTE: phenotypic effects develop late in life
Metabolic diseases controlled by recessive alleles are called "INBORN ERRORS OF METABOLISM"
Albinism (inability to make melanin pigment)
Phenylketonuria (PKU) (inability to break down the amino acid

phenylalanine)
Alkaptonuria (inability to break down homogentisic acid)
Porphyria (inability to break down certain purines)

C. GENETIC INFORMATION CAN BE USED OR MISUSED IN VARIOUS WAYS.

GENETIC TESTING AND COUNSELING:
Pedigree analysis helps identify dominant and recessive traits; it also distinguishes sex-linked traits from other (autosomal) traits.
Identifying a gene (or its gene product): DNA probes for specific genes; enzyme tests for many gene products. Some of these tests are preceded by PCR (polymerase chain reaction) to get enough identical copies of DNA to run the tests.
Identifying chromosome abnormalities
Newer sampling methods include: AMNIOCENTESIS, CHORIONIC VILLUS SAMPLING
Some tests allow us to detect heterozygous carriers of recessive traits; others do not.
We can advise testees of future risks for themselves or their children.
Most testing requires obtaining INFORMED CONSENT first
Genetic testing raises many new ethical issues in medical decision-making

ALTERING INDIVIDUAL GENOTYPES:
Currently possible only through genetic engineering (RECOMBINANT DNA THERAPY)

ALTERING THE GENE POOL OF POPULATIONS:
POSITIVE EUGENICS = encouraging certain genotypes to breed in greater numbers
NEGATIVE EUGENICS = preventing certain genotypes from breeding (by sterilizing or killing them)-- has led to genocide in the past
CLONING (not currently possible with humans) = asexually produced (therefore genetically identical) organisms or cells
An ethical question: who decides what is considered a defect?

CHANGING THE BALANCE BETWEEN GENETIC AND ENVIRONMENTAL FACTORS:
Euphenics: modification of individual phenotypes (producing PHENOCOPIES)
Euthenics: providing external assistive devices (like wheelchairs & eyeglasses)
Eupsychics: changing other peoples' social attitudes, customs, and laws, or providing special education for handicapped individuals

---------------------------------- Dec., 2003 may likewise use and modify these notes as study aids.

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Outline and Chapter notes to accompany chapter 4

GENETIC ENGINEERING AND GENOMICS
Dec., 2003

A. GENETIC ENGINEERING CHANGES THE WAY THAT GENES ARE TRANSFERRED.

METHODS OF GENETIC ENGINEERING
Requires restriction endonucleases, also called RESTRICTION ENZYMES
Cutting several pieces of DNA with the same enzyme results in
MATCHING "STICKY ENDS"

GENETICALLY ENGINEERED INSULIN (same technique can be used to
produce other useful gene products):
1. Take cells that make a useful product from a human or
animal.
2. Cut the DNA with a restriction enzyme into RESTRICTION
FRAGMENTS.
3. Isolate the DNA fragment containing the gene.
4. Also isolaste a bacterial PLASMID and cut it with the same
restriction enzyme;
the plasmid must also have a gene that can be used to
select bacteria that have incorporated the plasmid, such as
ability to survive on a medium deficient in a particular
amino acid or other nutrient.
5. Mix the human DNA fragments with the plasmid; some plasmids
will recombine with the human DNA fragments.
6. Allow bacteria to take up the new plasmid, and select for
those bacteria that have done so.
7. Test the bacteria for the presence of the human gene;
isolate any bacteria possessing the gene.
8. Grow the bacteria in large numbers (called CLONING); allow
the bacteria to produce the (medically or commercially
useful) protein product of the introduced gene.

RELATED SPIN-OFF TECHNOLOGIES:
Making other human gene products in other species
Growing other species with human genetic traits, in the hope that
their tissues, if transplanted into human patients, will not
be rejected
Making spider silk proteins in goats' milk

GENE THERAPY (genetic engineering used to fix a human gene defect):
1. Isolate human cells containing the normal version of the
gene.
2. Grow these cells in tissue culture; isolate DNA from them.
3. Use a restriction enzyme to cut the DNA into fragments with
sticky ends.

4. Isolate DNA from a virus (such as LASN) and cut this DNA with the same restriction enzyme.
5. Mix the DNA fragments and allow new viruses to take up the recombinant DNA.
6. Obtain cells from a patient who is incapable of making an important enzyme because their DNA lacks the normal gene.
7. Combine these cells with the virus containing the recombinant DNA. (The virus thus acts as a VECTOR for inserting the recombinant DNA into human cells.)
8. Grow the human cells in tissue culture and isolate those which make the proper enzyme.
9. Inject the genetically engineered cells back into the patient who donated the cells; hopefully, the cells will proliferate in sufficient numbers to produce adequate amounts of the previously missing enzyme in the patient.

B. MOLECULAR TECHNIQUES HAVE LED TO NEW USES FOR GENETIC INFORMATION.

THE FIRST DNA MARKER: RESTRICTION-FRAGMENT LENGTH POLYMORPHISMS
The fragments cut by restriction enzymes differ in length among different individuals, and these differences are inherited.
The RFLP technique (available since 1980) has allowed rapid advances in gene mapping:
Cut DNA with restriction enzymes.
Use electrophoresis to separate RESTRICTION FRAGMENTS differing in length; variation in the lengths of particular fragments is a RESTRICTION FRAGMENT LENGTH POLYMORPHISM (RFLP).
Try to find a family with a genetic condition and a RFLP that accompanies the condition; the responsible gene and the RFLP will therefore be nearby on the same chromosome.

USING DNA MARKERS TO IDENTIFY INDIVIDUALS (forensic uses):
Matching DNA samples between suspects and evidence from a crime scene
Identifying the father in paternity disputes
Using DNA from relatives to identify dead bodies from crime scenes, wars, etc.

USING DNA TESTING IN HISTORICAL CONTROVERSIES
Using DNA to confirm relationships (as in the Thomas Jefferson case)

C. THE HUMAN GENOME PROJECT HAS CHANGED BIOLOGY

SEQUENCING THE HUMAN GENOME
A GENOME is the complete hereditary material of an organism.
One goal of the Human Genome Project was to map the human DNA sequence.
A common method of sequencing is the dideoxy method, using fluorescent dyes to identify the last base in each of many fragments.
Another goal was to map the location of all functional genes. Many DNA sequences have not yet been matched to any known genetic function.

THE HUMAN GENOTYPE DRAFT SEQUENCE was published in 2001.
Less than 5% of the sequences seems to code for functional genes.

The remaining 95% consists of repetetive sequences. Very little is known with any certainty about the function of this 95%.
The total number of human genes is just over 30,000, much fewer than had previously been estimated.
Over 99.9% of the sequence is the same in humans tested from all over the world. Less than 1/10 of 1% of the genome is responsible for all known genetic variation among human beings.
Many genes and their products have not yet had their functions identified.
Most human genes are closely similar in sequence to the genes of other organisms as distant as yeasts and bacteria.

MAPPING THE HUMAN GENOME requires:
sequencing of long fragments, commonly by the dideoxy method;
assembling the fragment sequences into an overall sequence.

ETHICAL ISSUES RAISED by the Human Genome Project include:
privacy;
misuse of medical information;
knowing one's fate (actually one's predispositions) early in life;
doctors and insurers "playing God".

D. GENOMICS IS A NEW FIELD OF BIOLOGY DEVELOPED AS A RESULT OF THE HUMAN GENOME PROJECT

BIOINFORMATICS is the use of computer methods to search genome sequences and find matches and near-matches:
among different fragments (for assembly into a complete sequence);
among different genes, to study gene duplication and its consequences;
among different organisms, to discover evolutionary history.

COMPARATIVE GENOMICS is the comparison of the genomes of different species. It is used to study their evolution.

FUNCTIONAL GENOMICS is the study of how genes and their products lead to important phenotypic conditions such as those of medical interest. Scientists hope that revealing these causative pathways will help us to better understand diseases and their possible treatments.

PROTEOMICS is the study of protein sequences, including comparative and functional aspects.

---------------------------------- Dec., 2003

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Outline and Chapter notes to accompany chapter 5

EVOLUTION

Dec., 2003

A. THE DARWINIAN PARADIGM REORGANIZED BIOLOGICAL THOUGHT

PRE-DARWINIAN THOUGHT:
THE SCALE OF BEING (Scala Naturae):
Originally a non-evolutionary hierarchy of static, unchanging perfection, with people on top, animals below them, plants below animals; theological versions had angels above people.
Among people, racist, sexist, and class-based ideologies put Europeans above other races, men above women, masters above slaves (as in Aristotle), and upper castes or classes above lower ones. People who were listed at lower levels were taught to accept their position as "natural" and unchangeable.
Continuity of the scale was stressed, e.g., by Alexander Pope.
Discoveries of the Renaissance and later centuries seemed to confirm the continuum because all newly discovered species could be made to fit into it somewhere. Gaps were explained by saying that new discoveries would fill them in.
LAMARCK:
Made the chain of being into a moving escalator which he called Nature's Parade (La Marche de la Nature). The lowest forms of life, such as bacteria, formed by spontaneous generation from lifeless matter, and each species would slowly change (i.e., evolve) into the next higher species on the scale.
In order to account for local adaptation to the environment, Lamarck added as a secondary mechanism the Use and Disuse hypothesis: use would strengthen and enlarge any organ, while disuse would weaken an organ and allow it to atrophy. Lamarck did not realize that such ACQUIRED CHARACTERISTICS would not be inherited (it was commonly assumed in his day that they would be; non-inheritance of acquired characteristics was demonstrated in the 1870s by Weismann). Whenever ADAPTATION was discovered, Lamarck attributed it to the effects of use and disuse under each individual's voluntary control.
Other French writers (Geoffroy, de Maupertius, Buffon) also stressed local adaptation to the environment, though sometimes by different mechanisms.
WILLIAM PALEY AND NATURAL THEOLOGY:
A British clergyman, Rev. William Paley, attributed all ADAPTATIONS to divine benevolence. He used the intricacy of adaptations as evidence that they had been consciously designed by a mind more powerful than our own: "design must have a designer, that designer must [be] ... God." Paley's ideas were the dominant theory in England during the early nineteenth century.

THE DEVELOPMENT OF DARWIN'S IDEAS

Darwin's ideas were formulated principally during the voyage of H.M.S. Beagle.

Darwin saw many tropical habitats much richer in species than those he knew.

He noticed that the same habitat often produced different species on different continents: the savannahs (grasslands) of East Africa and the pampas (grasslands) of Argentina have almost no species in common. This is contrary to Lamarck's and similar theories of environmental determinism.

He also noticed that the closest relatives of animals were often found elsewhere on the same continent but in different habitats: the same group of South American rodents (the Caviomorpha, or guinea pig group) inhabited South American forests (but not African forests), South American plains, South American mountain regions, and so on. In other words, geography was more important than habitat in determining relationships (Fig. 5.2).

He noticed that islands (like the Galapagos) always had inhabitants whose nearest relatives were on the nearest continent. For example, the Galapagos Islands had birds and plants related to those of South America, while the Cape Verde Islands (volcanic, geologically similar to the Galapagos) had species related to those of Africa and unlike those of the Galapagos. Also, nearby islands often had distinct but related species, as if they were descendants of a few original colonists.

He noticed the absence of frogs and other amphibians on oceanic islands. In a few places, where humans had introduced them, amphibians flourished, meaning that the habitat was quite suited to them. Neither Lamarck's theory nor Paley's could explain why the environment (Lamarck) or God (Paley) had not produced amphibians on these islands, but Darwin said that they could never arrive as colonists across salt water.

BRANCHING DESCENT WITH MODIFICATION

Darwin's was not the first evolutionary theory, but it was the first that emphasized BRANCHING descent (in treelike patterns), which Darwin called "descent with modification".

Descent with modification explained why classifications should have "groups within groups": families of related species, orders and classes made of related families, etc. (see also Ch. 6).

The Darwinian paradigm was very productive of other research.

NATURAL SELECTION:

Upon return to England, Darwin began studying the methods of animal breeders who had changed many domesticated species in the preceding 100 years or so. They had done so by always selecting the best of their flocks or breeds, a practice called ARTIFICIAL SELECTION.

Darwin also read the works of the economist Malthus, who convinced Darwin that populations tend to overreproduce and overreach the available resources, only to be held in check by starvation, predation, and similar forces. From these ideas, he concluded that a continual "struggle for existence" (metaphorical) always exists in nature, not usually including actual combat, but, "what is more important, success in leaving progeny".

Darwin concluded that the struggle for existence brings about NATURAL SELECTION by a process similar to artificial selection among domestic species. Variations that lessen the ability to survive and reproduce will not be passed on to future generations; variations that increase the ability to survive and reproduce will be passed on; this difference in the contributions to future generations is called NATURAL SELECTION.

NATURAL SELECTION DEFINED: Consistent differences in the relative contribution of different genotypes to future generations.

Agents of selection can include predators, diseases, environmental extremes, ability to obtain food, and potential mates (of the opposite sex). Selection by potential mates is called SEXUAL SELECTION.

FITNESS DEFINED: The relative number of viable offspring left by each genotype.

B. A GREAT DEAL OF EVIDENCE SUPPORTS DARWIN'S IDEAS

Darwin's theory became accepted because it explained the available evidence better than any previous theory.

Natural selection can explain MIMICRY while earlier theories could not: many species survive because they resemble other, unrelated species that predators avoid. Selection by predators perpetuates the best mimics and eliminates the less effective ones.

Industrial melanism among moths demonstrates natural selection:

- The frequency of dark-colored moths varies geographically with levels of soot pollution.
- Experiments with bird predators confirms that predators eat the non-camouflaged moths much more often than those which resemble their background.

Branching descent with modification explained the facts of geographic distribution much better than any previous theory. The theory also explained HOMOLOGIES (Fig. 5.6), structures which resembled one another in their construction among related species, despite differences in adaptive use in many cases; earlier theories could not explain homologies so well. Some homologies include embryonic characters; others include functionless VESTIGIAL organs. Darwin's theory also explained CONVERGENT resemblances reflecting similar adaptations (ANALOGIES).

The fossil record was poorly known in Darwin's time, but fossils discovered since then have in most cases fit well into branching patterns of descent with modification. The ages of fossils are determined by both relative and absolute dating methods.

As an example: mollusks of the class Cephalopoda (squids, octopus, extinct ammonites, etc.) all fit into a pattern of branching descent, and their shared adaptations and anatomical features are all consistent with this pattern of descent.

Other evidence supporting branching descent includes the patterns of resemblance among embryos (comparative embryology) and among gene sequences (comparative genomics).

Post-Darwinian evolutionary thought has added various details and secondary theories to Darwin's paradigm. For example, theories of species formation, mutualism, genetic drift, and puctuated equilibria have all become included in the paradigm.

C. CREATIONISTS CHALLENGE EVOLUTIONARY THOUGHT

Most scientists before Darwin were devout. Many were clergymen, and most believed that living species had been created by God.

BIBLE-BASED CREATIONISM

This type of creationist belief centers around the literal reading of the bible, and is often hostile to scientific ideas that appear to contradict scripture.

Starting around 1890 in the United States, certain Protestants who called themselves Fundamentalists sought to outlaw the teaching of evolution because they feared that the teaching of evolution was eroding people's faith in divine creation and in religious faith more generally. In 1925, John Scopes was convicted in a Tennessee court for teaching evolution in violation of a state law. The law remained on the books until many decades later.

Since about 1960, creationists have changed tactics by insisting only that creationism be taught side by side with evolution and be given "equal time". Religious concepts and quotations from the Bible pervade their writings. Leading creationist writers have proclaimed the Bible to be an infallible guide that is not subject to falsification. Arkansas public law 590, providing "Balanced Treatment" for "Evolution Science" and "Creation Science", was declared unconstitutional in 1981, as was a similar Louisiana law a few years later.

INTELLIGENT DESIGN

The many scientific allies of Rev. William Paley believed in the theory of SPECIAL CREATION, under which each species was the result of a separate ("special") divine act of creation.

Rev. Paley and his supporters all used scientific methods, not biblical quotations, to support their claims. Foremost among their claims were adaptations so perfect in every detail that they said only God could have made them.

Darwin and his supporters argued against Paley's theory by showing:

* Adaptations seemingly limited by inherited patterns; such patterns would not constrain an omnipotent God.
* Geographic distributions limited by opportunity to migrate; an omnipotent God would not be subject to such limitations.
* Mimicry, a form of deceptive resemblance that always imitated a species living in the same area but never far away.

Michael Behe has recently revived Paley's arguments and used cell biology and biochemistry to build new examples of "irreducible complexity" that he says must have been intelligently designed. All of his examples could, however, have evolved step by step by natural selection, especially when changes in function during evolution are considered.

RECONCILING SCIENCE AND RELIGION

Many scientists and theologians have sought and found ways to

reconcile science and religious beliefs. Possibilities include:
1. declaring that science and religion exist in separate spheres (body versus soul), or that religion is the realm of the "ultimately unknowable".
2. accepting science as only a series of operational descriptions.
3. accepting that the laws of science are the way that God operates.

Theistic evolution (evolution following God's laws or God's design) is an example of the third approach.

D. SPECIES ARE CENTRAL TO THE MODERN EVOLUTIONARY PARADIGM

POPULATIONS AND SPECIES

A POPULATION consists of all members of a species inhabiting a given location. A population can also be defined as all individuals that freely interbreed with one another in nature.

SPECIES are defined as reproductively isolated groups of naturally interbreeding populations.

REPRODUCTIVE ISOLATION consists of all biological mechanisms (not mere geographical separation) that prevent the interbreeding of natural populations.

REPRODUCTIVE ISOLATING MECHANISMS can act either before or after mating. These mechanisms include isolation by differences in ecology, differences in mating seasons, differences in behavior, differences which prevent sexual parts from fitting together, or incompatibilities that make gametes, fertilized eggs, embryos, larvae, or adult hybrids inviable or sterile.

HOW NEW SPECIES ORIGINATE

Most new species originate after a period of geographic separation by an extrinsic barrier. If the barrier lasts long enough for the populations on either side to diverge, then one or more reproductive isolating mechanisms will result.

Evidence to support this theory comes from many cases where intermediate stages in the process can be observed. Especially revealing are cases of incomplete speciation in which populations disconnected for a time were brought back together before reproductive isolation between them had been completed.

E. LIFE ON EARTH ORIGINATED BY NATURAL PROCESSES AND CONTINUES TO EVOLVE

THE ORIGIN OF LIFE and its early evolution is covered in chapter 19.

CONTINUING EVOLUTION WITHIN SPECIES

There is good evidence that evolution continues to take place.

Natural selection brings about seasonal fluctuations in the characteristics of fruit flies and Galapagos finches.

Agricultural and industrial societies have greatly changed the selective forces operating on human populations.

Evolution continues to take place wherever natural selection occurs, meaning whenever mortality differs according to genotype or phenotype. Examples include:

* higher mortality among low birth weight babies (even

with good hospitals),
* higher susceptibility of certain blood groups to epidemic diseases,
* higher incidence of certain cancers in people with certain genotypes
* people with certain genetic conditions dying before reproduction
* people with certain genetic conditions leaving fewer children

---------------------------------- Dec., 2003

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Outline and Chapter notes to accompany chapter 6

CLASSIFYING NATURE
Dec., 2003

A. WHY CLASSIFICATION IS IMPORTANT

"ALL THOSE NAMES"

All societies give names to groups of similar species such as birds, insects, oaks, ferns, and orchids. Scientists need formal names for these groups in order to be able to discuss them and form hypotheses about them.

Related species are grouped into GENERA (singular: genus), related genera into FAMILIES, related families into ORDERS, related orders into CLASSES, related classes into PHYLA, and related phyla into KINGDOMS. Any one of these groups is called a TAXON (plural, TAXA). Taxa above the species level are called HIGHER TAXA.

Formal scientific names of taxa are usually based on Latin and Greek.

TAXONOMIC THEORY

A grouping of taxa within larger taxa is called a CLASSIFICATION.

The study of classifcations and the principles of their construction is called TAXONOMY.

Levels among higher taxa are based on interpretations of data and are thus somewhat arbitrary: what one expert calls a class may be only a subclass to another expert.

Traditional classifications were based on grouping species together on the basis of shared resemblances. Unfortunately, groupings based on different traits (e.g., mouthpart characters instead of wing characters) may give different classifications.

A modern theory of classification, called CLADISTICS, is based on drawing up a treelike diagram (cladogram) based on a large number of consistent characters. The classification is then based on the cladogram.

B. MODERN CLASSIFICATIONS RECOGNIZE A GREAT DIFFERENCE BETWEEN PROCARYOTIC AND EUCARYOTIC CELLS

PROCARYOTIC CELLS

The earliest cells were PROCARYOTIC, resembling those of present-day simple bacteria. Bacterial and other procaryotic cells have only a single unpaired chromosome (containing DNA but no protein) and no internal membrane-limited ORGANELLES. The DNA of procaryotic cells is not enclosed in a well-defined nucleus.

EUCARYOTIC CELLS contain protein in their chromosomes, which are usually multiple in number and diploid during at least some portion of the life cycle. They also contain large numbers of membrane-limited ORGANELLES: mitochondria, endoplasmic reticulum, golgi apparatus, vacuoles, lysosomes, and (in plants) chloroplasts. The chromosomes of eucaryotic cells are contained in a well-defined nucleus which is enclosed in a nuclear envelope.

ENDOSYMBIOSIS AND THE ORIGIN OF EUCARYOTES

In 1970, Lynn Margulis proposed a theory of the origin of eucaryotic cells by ENDOSYMBIOSIS: large procaryotic cells became eucaryotic by engulfing smaller procaryotic cells and maintaining them inside without digesting them. The smaller procaryotes became organelles, and their plasma membranes became the membranes around the organelles. Evidence for this theory includes the fact that both chloroplasts and mitochondria contain their own DNA that resembles procaryotic DNA and differs from the DNA in the nuclei of eucaryotic cells.

C. SIX KINGDOMS OF ORGANISMS ARE INCLUDED IN THREE DOMAINS

KINGDOMS OF ORGANISMS (See also Classification on the Web site)

Since 1970, most biologists have recognized five kingdoms of organisms:

- EUBACTERIA: Bacteria and blue-green Cyanobacteria (procaryotic)
- PROTISTA: Simple eucaryotic organisms such as Protozoa (eucaryotic)
- MYCOTA: Fungi, characterized by absorptive nutrition (eucaryotic)
- PLANTAE: Plants, containing plastids (eucaryotic)
- ANIMALIA: Animals, usually containing motile, multicellular life stages (eucaryotic).

The discovery of ARCHAEBACTERIA, a very primitive group of procaryotic organisms, has added a sixth kingdom.

Boundaries between these kingdoms, especially between plants and protists, are drawn differently by different experts, depending on their different interpretations of the available data.

Nucleic acid sequences have revealed that these kingdoms are arranged in three domains: one for the Archaea, one for the Eubacteria, and a third domain for all eucaryotic organisms.

DOMAIN AND KINGDOM ARCHAEA

Includes certain simple procaryotes with unusual metabolic abilities.

DOMAIN AND KINGDOM EUBACTERIA

Includes the true bacteria and the blue-green bacteria.

KINGDOM PROTISTA

Includes single-celled eucaryotic organisms that lack the specializations of other eucaryotic kingdoms.

Different Protista are distinguished by their means of locomotion and in some cases by their means of reproduction.

Some experts include algae among the Protista.

KINGDOM PLANTAE

Includes photosynthetic organisms possessing chloroplasts.

Subkingdom Thallophyta includes simple plants (algae) lacking differentiated organs and having eggs not protected by nonreproductive cells. Most algae are aquatic.

Subkingdom Embryophyta includes plants whose eggs are surrounded by nonreproductive cells, forming an embryo. Most live on land.

Bryophyta includes mosses and liverworts, which lack vascular tissues capable of efficiently transporting materials.

Tracheophyta or vascular plants are those possessing vascular tissues capable of efficiently transporting materials from one part of the plant to another, thus allowing different parts of the plant to specialize into different organs.

The simplest vascular plants do not possess seeds.

Seeds are reproductive structures in which the plant embryo and some food reserves are enclosed in several protective layers.

The most advanced vascular plants are he flowering plants or angiosperms (division Anthophyta).

KINGDOM MYCOTA

Includes fungi, characterized by absorptive nutrition.

Most fungi have threadlike filaments called hyphae, and most reproduce using spores.

KINGDOM ANIMALIA

Includes multicellular organisms that develop from a hollow ball of cells called a blastula.

Most animals are motile at some life stage.

Sponges (phylum Porifera) are simple animals without tissues.

Most animals are differentiated into tissues, consisting in the simplest cases of an outer layer (ectoderm) and an inner layer (endoderm). Many animals also have a middle layer (mesoderm).

Phylum Cnidaria contains jellyfish and other animals with just two tissue layers (ectoderm and endoderm).

Phylum Platyhelminthes (flatworms) contains animals with three tissue layers (ectoderm, mesoderm, and endoderm) but no body cavities.

Animals more complex than the Platyhelminthes all possess body cavities.

A body cavity surrounded entirely by mesoderm is called a coelom.

A body cavity containing other tissue layers in its lining is called a pseudocoel.

Most animals with body cavities also have a digestive system with an entrance (mouth) at one end and an exit (anus) at the other end.

Annelid worms (phylum Annelida) and arthropods (phylum Arthropoda) have bodies divided into a series of segments.

The Arthropoda, including the shrimp, lobsters, spiders, mites, and insects, are the largest phylum by far, including over three fourths of the whole animal kingdom.

The phylum Chordata, to which we belong, is characterized by a stiff notochord, gill slits, and a dorsal, hollow nerve cord at some stage of development. Most Chordata also have a backbone and are called vertebrates. Vertebrates include fishes, amphibians, reptiles, birds, and mammals.

D. HUMANS ARE PRODUCTS OF EVOLUTION

OUR PRIMATE HERITAGE

Humans all belong to the kingdom Animalia, the phylum Chordata, and the class Mammalia. Mammals maintain a steady internal body temperatures (usually above that of their surroundings) with the help of insulation (usually hair or fur). All mammals provide parental care and nurse their young with milk.

Among the mammals, humans, apes, monkeys, and lemurs belong to the order Primates. Primates show many anatomical and behavioral adaptations to life in trees, such as grasping hands and feet, good depth perception, and a prolonged period of spatial learning associated with high intelligence and extensive parental care.

Among primates, humans are distinguisted from apes by upright locomotion (bipedal walking).

EARLY HOMINIDS

The earliest known hominds lived about 6 million years ago and are placed in the genus Sahelanthropus. Other early hominids include Ororrin and Ardipithecus.

The best known early hominids belong to the genus Australopithecus. Most fossils of Australopithecus come from South or East Africa.

Both large and small Australopithecus are known. Small, early species include A. anamensis and A. afarensis. The best-known small species is the late-appearing A. africanus of South Africa. Larger ("robust") species include A. robustus in South Africa and A. boisei in East Africa.

Anatomical study of the feet, pelvis, and lower vertebral column shows that Australopithecus walked erect and bipedally. Footprints at Laetoli, Kenya confirm this.

Stone tools and tools made of bones and teeth were made by hand. Many tools were used as weapons. Hunting seems to have been cooperative, which implies some language or communication.

THE GENUS HOMO

Homo habilis was a contemporary of later Australopithecus. It was small, but it brain was proportionately larger than that of a comparably sized Australopithecus would have been.

Homo erectus was widespread across Africa, Asia, and much of Europe. Its brain size was larger than that of Australopithecus. There is evidence of the use of fire.

Homo sapiens came after (and evolved from) Homo erectus. Homo sapiens had larger brains than Homo erectus, especially in the vertical dimension. Stone tools were mounted on shafts to make spears, and larger animals were hunted. Cave paintings show

artistic sophistication and religious rituals.
Cultural changes took place throughout human evolution.
Agriculture presented humans with new selection forces: new foods, new needs, new diseases (and an increase in many old ones).
Many infectious diseases (like malaria and tuberculosis) were able to spread more rapidly in larger, settled populations than they did when populations were sparse.
Industrial society presents new hazards and thus new forces of natural selection, including motor vehicle accidents, industrial accidents, more alcohol and drugs, pollution, etc.

---------------------------------- Dec., 2003

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Outline and Chapter notes to accompany chapter 7

HUMAN VARIATION
Dec., 2003

A. THERE IS BIOLOGICAL VARIATION BOTH WITHIN AND BETWEEN HUMAN POPULATIONS

In modern evolutionary theory, populations are defined in terms of their interbreeding, not in terms of any physical features. In most cases, people belonging to a population live in the same geographic area, but migrations make these situations more complex.

CONTINUOUS AND DISCONTINUOUS VARIATION
Most human variation occurs within populations.
Variation occurs in continuously measured traits like height or pigmentation. Such variation is often shown as a frequency distribution or normal curve.
Variation also occurs discontinuously in many genetically controlled traits. Examples include eye color, blood types, and many genetically controlled diseases. For such discontinuous traits, we can either show the population frequency of a trait (the percent of individuals in a population having the trait) or the frequency of an allele for that trait.

VARIATION BETWEEN POPULATIONS
Continuous traits vary geographically in their average (mean) values.
Differences between populations are usually differences in their mean values, nearly always with considerable overlap.
Discontinuous traits vary geographically in the frequencies of various blood groups, disease conditions, or genotypes.

CONCEPTS OF RACE (in historical order):

1. SOCIALLY CONSTRUCTED RACES are recognized by a group of people in control as part of an effort to deny equal status to other people. Language, customs, and physical features are all used to distinguish "us" from "them" (racism), often resulting in groups that do not make sense biologically. Characteristics assigned to oppressed groups are viewed as marks of inferiority and are asserted to be inherited (hereditarian bias).
2. MORPHOLOGICALLY DEFINED RACES are distinguished by physical features only, not languages or customs. The extremes of variation are distinct biologically, but geographically distinct populations are often connected by a graded series of intermediate populations that make boundaries hard to draw. Historically, each morphologically defined race was thought to conform to a different Platonic type or to have originated in a different center of origin, concepts which biologists no longer accept.
3. GENETICALLY DEFINED RACES are based on the frequencies of alleles and blood groups. These frequencies are used to describe different groups of populations, while admitting that the boundaries between them are gradual.
4. THE NO-RACES CONCEPT uses the gradualness of boundaries, the imprecision of identifying membership in human populations, and the evils resulting from past and current racial conflicts as arguments against recognizing any racial groupings at all. Advocates of this position say that no racial groupings make sense biologically.

THE STUDY OF HUMAN VARIATION

The study of human variation is important in such fields as engineering, design, and architecture. Buildings, furniture, instrument panels, space capsules, fire fighting equipment, and safety equipment must all be designed with human dimensions, abilities, and limitations in mind. This is sometimes called "human factors engineering".

B. POPULATION GENETICS CAN HELP US UNDERSTAND HUMAN VARIATION

HUMAN BLOOD GROUPS AND GEOGRAPHY

Many genetically determined traits (such as blood groups) vary geographically. Gradual geographic variations in allele frequencies are called CLINES.

ABO blood groups: A and B are codominant alleles; o is recessive.

- Genotypes AA and Ao are both blood type A; they have type A molecules on the surface of their red blood cells.
- Genotypes BB and Bo are both blood type B; they have type B molecules on the surface of their red blood cells.
- Genotype AB is blood type AB, which has both type A and type B molecules on the surface of their red blood cells.
- Genotype oo is blood type O, which has neither type A nor type B molecules on the surface of their red blood cells.

The frequencies of alleles A, B, and o vary geographically:

- A is more frequent in Western Europe than elsewhere, but is less frequent than o in nearly all populations.
- B shows its highest frequencies in East Asia and is absent among Native Americans.

o shows its highest frequencies (close to 100%) among Native Americans.

Rh blood groups (a combination of 3 closely linked genes) also vary geographically:

Rh blood groups are important because Rh-negative women, when pregnant, make antibodies against any Rh-positive fetuses they may be carrying. These antibodies are a threat to any subsequent Rh-positive fetus carried by the same mother.

Rh-negative (cde) has its highest frequencies in northern Spain (among Basques). It is the second most frequent combination of alleles in most of Europe and Africa, but is very rare or absent in all other populations.

CDe is the most frequent allele combination in most populations, except in Africa, where cDe is most frequent.

MN blood groups also vary geographically:

Native American populations have high frequencies of M and almost no N;

Australian Aborigines and some Pacific Island populations have high frequencies of N and almost no M;

All other populations have both M and N alleles frequent.

ISOLATED POPULATIONS AND GENETIC DRIFT:

Genetic drift consists of random changes in genotype frequencies due to chance, especially in small populations.

Populations that become isolated (for any reason) may undergo genetic drift, especially if the population is small.
Populations descended from small numbers of individuals will reflect the allele frequencies of these founders (the founder effect). Examples that have been studied include the Dunkers of Pennsylvania (and neighboring states) and the Hutterites of the northern prairies.

RECONSTRUCTING THE HISTORY OF HUMAN POPULATIONS

Genotypes and RFLPs can now be used to measure the degree of relatedness of modern populations and to reconstruct their past histories. Results of such studies are consistent with population histories based on linguistic or other evidence.

C. MALARIA AND OTHER DISEASES ARE AGENTS OF NATURAL SELECTION

MALARIA

Malaria causes more deaths world-wide than any other single infectious disease.

Malaria is a parasitic disease caused by a protozoan called Plasmodium. Plasmodium is transmitted by mosquitoes when they bite. Many stages of the parasite's life cycle are carried out inside human red blood cells.

The parasites can reproduce either sexually or asexually.
Asexual reproduction can go on repeatedly within a human host.
Parasites can be picked up by a female mosquito when she bites a human host. Sexual reproduction takes place inside the mosquito, where the early larval stages mature. Larval parasites later migrate to the mosquito's salivary glands and are injected into

the next human.

SICKLE-CELL ANEMIA AND RESISTANCE TO MALARIA:

Originally described in the United States, then in Jamaica, sickle-cell anemia affects mostly people of African descent. It results from a change in one amino acid in the beta chain of the hemoglobin protein, a molecule in red blood cells which helps carry oxygen through blood.

People homozygous for hemoglobin S develop sickle-cell anemia. Their red blood cells assume deformed and often sickle-like shapes, causing these cells to be destroyed. Other symptoms include an increase in bone marrow activity, enlargement of the spleen, "towering" of the skull, blockage of many small blood vessels, painful swelling of joints, rheumatism, and heart failure. The disease is fatal if untreated.

People heterozygous for hemoglobin S are healthy under most conditions, but they could develop sick cell symptoms if they over-exert themselves. They are protected against malaria. We can now test for heterozygotes.

People homozygous for hemoglobin A are more often bitten by Anopheles mosquitoes and more often die from malaria.

Sickle-cell anemia persists in many African populations because hemoglobin S confers resistance to malaria, even in heterozygous form. Mosquitoes are less likely to bite, and, if they do bite, the parasite's life cycle is interrupted in the sickle cells and any illness is mild and brief.

THALASSEMIA (Mediterranean anemia):

Occurs all around the Mediterranean (including North Africa, Italy, Greece, Middle East), and eastward across Pakistan to populations in Cambodia and Thailand.

The heterozygous form (thalassemia minor) is mild; the homozygous form (thalassemia major) can be fatal. Both can now be controlled with drugs if funds are available.

All forms of thalassemia protect against malaria.

Many forms of thalassemia are known; all are defects in one of the protein chains of hemoglobin.

OTHER GENETIC TRAITS THAT PROTECT AGAINST MALARIA:

Favism, or G6PD deficiency, occurs in many populations around the Eastern Mediterranean. Both homozygous and heterozygous individuals are more resistant to malaria.

Adult persistence of fetal hemoglobin (APFE) occurs mostly in African populations and appears to protect against malaria.

Ovalocytosis, a condition in which red blood cells are oval instead of circular, occurs in Southeast Asia and New Guinea, and is believed to offer resistance to malaria.

POPULATION GENETICS OF MALARIA RESISTANCE:

Hardy-Weinberg principle: allele frequencies tend to remain unchanged in large random-mating populations that do not experience selection, migration or unbalanced mutation.

Frequencies of many alleles (including harmful ones) can always be maintained in a population (a balanced polymorphism) if the

heterozygous genotypes show the highest fitness.
The incidence of malaria varies geographically, in part because some habitats offer more opportunities for mosquitoes to breed. Geographic variations in the natural selection caused by malaria can explain variations in the gene frequencies for sickle-cell anemia, thalassemia, and the other traits listed above.

OTHER DISEASES AS AGENTS OF SELECTION:
Cystic fibrosis is a genetic disease whose highest frequencies are in Western Europe (especially Ireland); it is the most common genetic disease in the United States. It has been hypothesized that the gene for this condition persists because the heterozygotes are resistant to tuberculosis, a disease which caused high mortality in Europe prior to 1900.

D. NATURAL SELECTION BY PHYSICAL FACTORS CAUSES MORE POPULATION VARIATION

HUMAN VARIATIONS IN PHYSIOLOGY AND PHYSIQUE

Bergmann's rule: Within a geographically variable species, larger body sizes are favored in colder climates because of their greater efficiency in conserving heat. (Larger bodies generally have smaller surface-to-volume ratios because surface area is proportional to the square of length dimensions, while volume is proportional to the cube of length.) Conversely, smaller body sizes are favored in warm climates.
Allen's rule: Within a geographically variable species, protruding parts such as arms, legs, ears, and tails will be shorter and thicker in cold climates, and longer and thinner in warm climates, again because of differences in heat loss.
In accordance with the above two rules, tropical people tend in most cases to be small and thin-legged, while Arctic people have thicker-set bodies and thicker limbs.
During the Korean War (1950-1953), a disproportionate number of African-Americans (compared to Euro-Americans) lost toes and fingers to frostbite. Subsequent tests by the U.S. Army confirmed racial variation in resistance to environmental extremes. When temperatures drop, blood flow to limbs is reduced in all people. When temperature drops further or persists long enough to raise risks of frostbite, the blood vessels often dilate and send warm blood into the extremities, but not usually in people of African or African-American descent.
"Thrifty genes" may account for the higher incidence of diabetes in certain Pacific Island and Native American populations; diet and exercise may also play a role.

NATURAL SELECTION, SKIN COLOR, AND DISEASE RESISTANCE

Gloger's rule: Within a geographically variable species, populations living in warm humid regions tend to be dark in color, those living in warm arid places tend toward tan and reddish hues, and those in cold places tend to be pale or white.
Skin color variation in human populations generally follows Gloger's rule among continents and also more gradually within continents. (This comparison is based on places where populations lived prior

to 1500, when long-distance migrations became more frequent.)
Sunlight is most abundant in the tropics and decreases with latitude, especially in the UV portion of the spectrum. Europe receives the least sunlight of any populous region.
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---------------------------------- Dec., 2003

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Outline and Chapter notes to accompany chapter 7

HUMAN VARIATION
Dec., 2003

A. THERE IS BIOLOGICAL VARIATION BOTH WITHIN AND BETWEEN HUMAN POPULATIONS

In modern evolutionary theory, populations are defined in terms of their interbreeding, not in terms of any physical features. In most cases, people belonging to a population live in the same geographic area, but migrations make these situations more complex.

CONTINUOUS AND DISCONTINUOUS VARIATION
Most human variation occurs within populations.
Variation occurs in continuously measured traits like height or pigmentation. Such variation is often shown as a frequency distribution or normal curve.
Variation also occurs discontinuously in many genetically controlled traits. Examples include eye color, blood types, and many genetically controlled diseases. For such discontinuous traits, we can either show the population frequency of a trait (the percent of individuals in a population having the trait) or the frequency of an allele for that trait.

VARIATION BETWEEN POPULATIONS

Continuous traits vary geographically in their average (mean) values.
Differences between populations are usually differences in their mean values, nearly always with considerable overlap.
Discontinuous traits vary geographically in the frequencies of various blood groups, disease conditions, or genotypes.

CONCEPTS OF RACE (in historical order):

1. SOCIALLY CONSTRUCTED RACES are recognized by a group of people in control as part of an effort to deny equal status to other people. Language, customs, and physical features are all used to distinguish "us" from "them" (racism), often resulting in groups that do not make sense biologically. Characteristics assigned to oppressed groups are viewed as marks of inferiority and are asserted to be inherited (hereditarian bias).
2. MORPHOLOGICALLY DEFINED RACES are distinguished by physical features only, not languages or customs. The extremes of variation are distinct biologically, but geographically distinct populations are often connected by a graded series of intermediate populations that make boundaries hard to draw. Historically, each morphologically defined race was thought to conform to a different Platonic type or to have originated in a different center of origin, concepts which biologists no longer accept.
3. GENETICALLY DEFINED RACES are based on the frequencies of alleles and blood groups. These frequencies are used to describe different groups of populations, while admitting that the boundaries between them are gradual.
4. THE NO-RACES CONCEPT uses the gradualness of boundaries, the imprecision of identifying membership in human populations, and the evils resulting from past and current racial conflicts as arguments against recognizing any racial groupings at all. Advocates of this position say that no racial groupings make sense biologically.

THE STUDY OF HUMAN VARIATION

The study of human variation is important in such fields as engineering, design, and architecture. Buildings, furniture, instrument panels, space capsules, fire fighting equipment, and safety equipment must all be designed with human dimensions, abilities, and limitations in mind. This is sometimes called "human factors engineering".

B. POPULATION GENETICS CAN HELP US UNDERSTAND HUMAN VARIATION

HUMAN BLOOD GROUPS AND GEOGRAPHY

Many genetically determined traits (such as blood groups) vary geographically. Gradual geographic variations in allele frequencies are called CLINES.

ABO blood groups: A and B are codominant alleles; o is recessive.
- Genotypes AA and Ao are both blood type A; they have type A molecules on the surface of their red blood cells.
- Genotypes BB and Bo are both blood type B; they have type B molecules on the surface of their red blood cells.
- Genotype AB is blood type AB, which has both type A and type B molecules on the surface of their red blood cells.

Genotype oo is blood type O, which has neither type A nor type B molecules on the surface of their red blood cells.

The frequencies of alleles A, B, and o vary geographically:

A is more frequent in Western Europe than elsewhere, but is less frequent than o in nearly all populations.

B shows its highest frequencies in East Asia and is absent among Native Americans.

o shows its highest frequencies (close to 100%) among Native Americans.

Rh blood groups (a combination of 3 closely linked genes) also vary geographically:

Rh blood groups are important because Rh-negative women, when pregnant, make antibodies against any Rh-positive fetuses they may be carrying. These antibodies are a threat to any subsequent Rh-positive fetus carried by the same mother.

Rh-negative (cde) has its highest frequencies in northern Spain (among Basques). It is the second most frequent combination of alleles in most of Europe and Africa, but is very rare or absent in all other populations.

CDe is the most frequent allele combination in most populations, except in Africa, where cDe is most frequent.

MN blood groups also vary geographically:

Native American populations have high frequencies of M and almost no N;

Australian Aborigines and some Pacific Island populations have high frequencies of N and almost no M;

All other populations have both M and N alleles frequent.

ISOLATED POPULATIONS AND GENETIC DRIFT:

Genetic drift consists of random changes in genotype frequencies due to chance, especially in small populations.

Populations that become isolated (for any reason) may undergo genetic drift, especially if the population is small.
Populations descended from small numbers of individuals will reflect the allele frequencies of these founders (the founder effect). Examples that have been studied include the Dunkers of Pennsylvania (and neighboring states) and the Hutterites of the northern prairies.

RECONSTRUCTING THE HISTORY OF HUMAN POPULATIONS

Genotypes and RFLPs can now be used to measure the degree of relatedness of modern populations and to reconstruct their past histories. Results of such studies are consistent with population histories based on linguistic or other evidence.

C. MALARIA AND OTHER DISEASES ARE AGENTS OF NATURAL SELECTION

MALARIA

Malaria causes more deaths world-wide than any other single infectious disease.

Malaria is a parasitic disease caused by a protozoan called Plasmodium. Plasmodium is transmitted by mosquitoes when they bite. Many stages of the parasite's life cycle are

carried out inside human red blood cells.
The parasites can reproduce either sexually or asexually.
Asexual reproduction can go on repeatedly within a human host. Parasites can be picked up by a female mosquito when she bites a human host. Sexual reproduction takes place inside the mosquito, where the early larval stages mature. Larval parasites later migrate to the mosquito's salivary glands and are injected into the next human.

SICKLE-CELL ANEMIA AND RESISTANCE TO MALARIA:
Originally described in the United States, then in Jamaica, sickle-cell anemia affects mostly people of African descent. It results from a change in one amino acid in the beta chain of the hemoglobin protein, a molecule in red blood cells which helps carry oxygen through blood.
People homozygous for hemoglobin S develop sickle-cell anemia. Their red blood cells assume deformed and often sickle-like shapes, causing these cells to be destroyed. Other symptoms include an increase in bone marrow activity, enlargement of the spleen, "towering" of the skull, blockage of many small blood vessels, painful swelling of joints, rheumatism, and heart failure. The disease is fatal if untreated.
People heterozygous for hemoglobin S are healthy under most conditions, but they could develop sick cell symptoms if they over-exert themselves. They are protected against malaria. We can now test for heterozygotes.
People homozygous for hemoglobin A are more often bitten by Anopheles mosquitoes and more often die from malaria.
Sickle-cell anemia persists in many African populations because hemoglobin S confers resistance to malaria, even in heterozygous form. Mosquitoes are less likely to bite, and, if they do bite, the parasite's life cycle is interrupted in the sickle cells and any illness is mild and brief.

THALASSEMIA (Mediterranean anemia):
Occurs all around the Mediterranean (including North Africa, Italy, Greece, Middle East), and eastward across Pakistan to populations in Cambodia and Thailand.
The heterozygous form (thalassemia minor) is mild; the homozygous form (thalassemia major) can be fatal. Both can now be controlled with drugs if funds are available.
All forms of thalassemia protect against malaria.
Many forms of thalassemia are known; all are defects in one of the protein chains of hemoglobin.

OTHER GENETIC TRAITS THAT PROTECT AGAINST MALARIA:
Favism, or G6PD deficiency, occurs in many populations around the Eastern Mediterranean. Both homozygous and heterozygous individuals are more resistant to malaria.
Adult persistence of fetal hemoglobin (APFE) occurs mostly in African populations and appears to protect against malaria.
Ovalocytosis, a condition in which red blood cells are oval instead of circular, occurs in Southeast Asia and New Guinea, and is believed to offer resistance to malaria.

POPULATION GENETICS OF MALARIA RESISTANCE:

Hardy-Weinberg principle: allele frequencies tend to remain unchanged in large random-mating populations that do not experience selection, migration or unbalanced mutation.

Frequencies of many alleles (including harmful ones) can always be maintained in a population (a balanced polymorphism) if the heterozygous genotypes show the highest fitness.

The incidence of malaria varies geographically, in part because some habitats offer more opportunities for mosquitoes to breed. Geographic variations in the natural selection caused by malaria can explain variations in the gene frequencies for sickle-cell anemia, thalassemia, and the other traits listed above.

OTHER DISEASES AS AGENTS OF SELECTION:

Cystic fibrosis is a genetic disease whose highest frequencies are in Western Europe (especially Ireland); it is the most common genetic disease in the United States. It has been hypothesized that the gene for this condition persists because the heterozygotes are resistant to tuberculosis, a disease which caused high mortality in Europe prior to 1900.

D. NATURAL SELECTION BY PHYSICAL FACTORS CAUSES MORE POPULATION VARIATION

HUMAN VARIATIONS IN PHYSIOLOGY AND PHYSIQUE

Bergmann's rule: Within a geographically variable species, larger body sizes are favored in colder climates because of their greater efficiency in conserving heat. (Larger bodies generally have smaller surface-to-volume ratios because surface area is proportional to the square of length dimensions, while volume is proportional to the cube of length.) Conversely, smaller body sizes are favored in warm climates.

Allen's rule: Within a geographically variable species, protruding parts such as arms, legs, ears, and tails will be shorter and thicker in cold climates, and longer and thinner in warm climates, again because of differences in heat loss.

In accordance with the above two rules, tropical people tend in most cases to be small and thin-legged, while Arctic people have thicker-set bodies and thicker limbs.

During the Korean War (1950-1953), a disproportionate number of African-Americans (compared to Euro-Americans) lost toes and fingers to frostbite. Subsequent tests by the U.S. Army confirmed racial variation in resistance to environmental extremes. When temperatures drop, blood flow to limbs is reduced in all people. When temperature drops further or persists long enough to raise risks of frostbite, the blood vessels often dilate and send warm blood into the extremities, but not usually in people of African or African-American descent.

"Thrifty genes" may account for the higher incidence of diabetes in certain Pacific Island and Native American populations; diet and exercise may also play a role.

NATURAL SELECTION, SKIN COLOR, AND DISEASE RESISTANCE

Gloger's rule: Within a geographically variable species, populations living in warm humid regions tend to be dark in color, those living in warm arid places tend toward tan and reddish hues, and those in cold places tend to be pale or white.

Skin color variation in human populations generally follows Gloger's rule among continents and also more gradually within continents. (This comparison is based on places where populations lived prior to 1500, when long-distance migrations became more frequent.)

Sunlight is most abundant in the tropics and decreases with latitude, especially in the UV portion of the spectrum. Europe receives the least sunlight of any populous region.

People living far from the equator, especially in Europe, receive the least sunlight and are therefore at risk for vitamin D deficiency because the final step of vitamin D synthesis takes place under the skin with the aid of ultraviolet light. Deficiency of vitamin D can lead to rickets in children. Selection by vitamin D deficiency has resulted in pale skin colors over most of northern Europe.

People living in the tropics receive the most sunlight and are therefore at risk for skin cancer. This risk is reduced if the skin is darkly pigmented, so most tropical people on all continents have darker skin colors.

Inuit people (Eskimos) get their vitamin D in fully synthesized form from fish livers, so they do not need to expose their skin to the sun to get adequate amounts of vitamin D.

---------------------------------- Dec., 2003

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Outline and chapter notes to accompany chapter 8

SOCIOBIOLOGY

Dec., 2003

A. SOCIOBIOLOGY DEALS WITH SOCIAL BEHAVIOR

Social behavior is defined as behavior which influences the behavior of other individuals of the same species.

Sociobiology is the study of social behavior and its evolution.

LEARNED AND INHERITED BEHAVIOR

Inherited behaviors that are complex are called instincts.

Most behavior can be modified by learning, i.e., experience in dealing with the environment.

Natural selection can work only on the inherited components of any behavior.

Nearly every behavior pattern is at least partly learned and at least partly innate.

THE PARADIGM OF SOCIOBIOLOGY

The sociobiology paradigm dates from Wilson's book Sociobiology (1975).

Shared beliefs within the sociobiology paradigm (Box 8.1) include:

1-2. Behavior is interesting, and much of behavior is social.

3-4. Social behavior evolves, largely by natural selection.

5. Behavior is modified by learning, but only within biological limits, at least some of which are inherited.
6. Learned modifications of behavior are not inherited; only the innate predispositions are inherited, and only these can evolve by natural selection.
7. It is therefore important to distinguish learned from innate components of behavior.

8-9. Methods to be used include lengthy observation and description of behavior, comparisons among populations or species, and measuring reproductive fitness.

Critics have charged:

1. that most behavior is learned (especially in mammals),
2. that sociobiology devalues learning by emphasizing inherited traits, and
3. that extrapolations from other species to humans are risky at best.

Many of the critics of sociobiology fear genetic determinism or hereditarian bias.

RESEARCH METHODS IN SOCIOBIOLOGY

Observational field studies usually come first, beginning at a descriptive level.

Research questions (hypotheses) are usually posed on the basis of initial field studies or previous research.

Most field studies are designed to answer a research question.

There are many ways of demonstrating learned or innate components of behavior:

1. Behavior performed by an animal reared in isolation is largely innate.
2. If animals are reared under different conditions or if humans grow up in strikingly different cultures, behaviors which do not vary are largely innate, while learned behavior patterns are expected to vary.
3. If different breeds or strains of a species show consistent differences in behavior, these differences are largely inherited.
4. If two populations differ in behavior, we may examine individuals from one group adopted early in life and raised by the other group. Behavior consistently resembling the population of birth shows an inherited influence; behavior resembling the population of rearing shows a learned influence. In many cases, both influences are present.
5. If a trait is under strong genetic control, then identical twins should show similarities in the trait even if they are reared under different conditions, and should resemble one another more often or more strongly than fraternal twins.

INSTINCTS

Complex behaviors under strong genetic control are called instincts.
Most instincts are stereotyped (they show little variation).
Advantages of instinctive control include:

1. no mistakes are made during any learning process;
2. complex behavior can be performed with fewer neurons;
3. variation is minimal, so behavior can be used in species recognition.

Instincts typically occur in situations where uniformity and automatic response are adaptive, and where variety and innovation are likely to be inadaptive.
Courtship and mating behaviors are instinctive in most species.
Other instinctive behaviors include escape responses, nesting and nest-building behavior, territorial behavior, and gestures of threat or submission.

B. SOCIAL ORGANIZATION IS ADAPTIVE

ADVANTAGES AND DISADVANTAGES OF SOCIAL GROUPS

The many biological advantages of social groupings include: ease in finding a mate, increased food-finding ability (in many species), and increased opportunities for defense.
Disadvantages include: increased competition for some resources (food, nesting sites), easier spread of infections diseases, and easier spotting by some predators

SIMPLE FORMS OF SOCIAL ORGANIZATION

Many invertebrate species form simple aggregates without any dominant individuals.
Fish schools also appear to be simple aggregates without any dominant individuals.
Captive or domesticated animals often form linear dominance hierarchies, or "pecking orders".

ALTRUISM: AN EVOLUTIONARY PUZZLE

Altruism is defined as behavior that benefits others but lowers the performer's fitness. It is an evolutionary puzzle to explain how natural selection does not eliminate altruism.
Mathematical models to explain the evolution of altruism or to test hypotheses about it are often expressed in terms of game theory. Game theory is a type of mathematical model in which individuals or species are compared to players in a game and their characteristics are compared to game-playing strategies.
Under simple models of individual fitness, selfish "cheaters" would have a higher fitness than altruists (in populations containing both), and natural selection would therefore favor cheaters.
The group selection model, favored by Wynne-Edwards, is that social groups containing altruists are favored over groups containing selfish individuals only.
The kin selection model, favored by most researchers, uses the concept of inclusive fitness, which includes the total fitness of all individuals sharing a certain genotype. If I perform an act which lowers my own fitness as an individual, but which raises the fitness

of other individuals sharing parts of my genotype, my inclusive fitness may increase. My inclusive fitness increases whenever more copies of my genotype occur in future generations. Altruistic behavior can therefore be selectively favored if it raises the fitness of related individuals sufficiently.

Reciprocal altruism is another possible explanation: altruistic acts are favored if individuals who benefit are likely to reciprocate, indirectly benefitting the altruist or the altruist's kin. Several evolutionary models explain reciprocal altruism as an evolutionarily stable strategy (ESS) that favors altruists over selfish individuals.

THE EVOLUTION OF EUSOCIALITY

Eusocial species share three characteristics:

1. strictly defined castes or subgroups;
2. cooperative brood care; and
3. overlap between generations.

Full eusociality has evolved only in two orders, both of them insects: Isoptera (termites), and Hymenoptera (bees, wasps, & ants).

Among termites, eusociality is associated with the need to pass on symbiotic microorganisms that help to digest wood. The passing of these symbiotic organisms to other colony members also allows the passing of food and of pheromones (external chemical communication signals).

Among Hymenoptera, eusociality is favored by haplodiploidy, a peculiar type of sex determination in which males are haploid and females are diploid. Females under this system are more closely related to their sisters than to their own children; they therefore increase their inclusive fitness more if they help raise their mother's children (their sisters) than if they raise their own.

C. REPRODUCTIVE STRATEGIES CAN ALTER FITNESS

Reproductive strategies are patterns of behavior, physiology, and other traits related to reproduction.

ASEXUAL VERSUS SEXUAL REPRODUCTION

Asexual reproduction is reproduction without genetic recombination. It is favored whenever genetic uniformity and rapid reproduction at a small body size are advantageous.

Sexual reproduction is reproduction which includes genetic recombination. The most common form of sexual reproduction produces haploid sex cells (gametes) which recombine randomly, resulting in many new genetic combinations. Sexually reproduced offspring vary greatly in nearly all genetically controlled traits, and sexual reproduction is therefore favored whenever future conditions are uncertain.

DIFFERENCES BETWEEN THE SEXES

Isogamy is a condition in which gametes are all equal in size.

Anisogamy is a condition in which gametes are different: larger, nonmotile eggs, and smaller, motile sperm. Egg producers are called female; sperm producers are called males.

Parental investment in their offspring is generally higher for females-- each offspring represents a greater investment of reproductive effort, including stored food, gestational effort, and parental care. Females tend to become more discriminating in mate selection, while males mate more indiscriminately and more often.

MATING SYSTEMS

Monogamy-- mating between one male and one female, often resulting in cooperative parental care and permanent pair-bonding.

Polygyny-- mating between one male and several females.

Polyandry-- an uncommon form of mating between one female and several males.

Promiscuity-- both sexes mate with multiple partners and avoid permanent partnerships.

D. PRIMATE SOCIOBIOLOGY PRESENTS ADDED COMPLEXITIES

Primates are an order of mammals that includes monkeys, apes, lemurs, and humans.

All primate species are social, and most are highly social.

PRIMATE SOCIAL BEHAVIOR AND ITS DEVELOPMENT

Primate behavior develops in a social context.

Young primates need to cling to soft, cuddly surfaces in order to develop normal behavior.

Young primates also need opportunities for social play (especially rough-and-tumble play with body contact) in order to develop normal sexual behavior as adults.

Grooming is a pleasurable body-contact activity for primates of all ages, and is most important to the social development of young primates.

Savanna baboons have a complex social organization, described on our Web site under Resources: Baboons.

REPRODUCTIVE STRATEGIES IN PRIMATES

Sexual dimorphism (anatomical differences or size differences between the sexes) is greater when males and females have very different social roles.

Male primates typically maximize their fitness by forming alliances with other males and by mating as often as they can.

Female primates typically maximize their fitness by caring for their young and also by more subtle strategies. For example, females may secure the protection of high-ranking males by copulating with them; even if no offspring are produced, the male knows that he has mated with that female and he therefore protects both the female and her offspring.

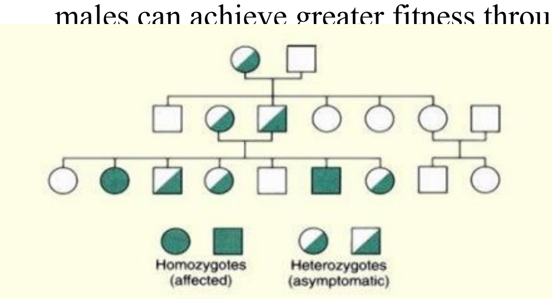
In pre-agricultural human societies, men were primarily hunters and women gathered plant foods. Adrienne Zihlmann studied early human fossils and found them to show very little sexual dimorphism. From this, she reasoned that gathering (an activity that produces little dimorphism) evolved early and that hunting (an activity which produces increased dimorphism) came later.

SOME EXAMPLES OF HUMAN BEHAVIOR

Alcoholism has components which vary according to culture and social standing. One type of male-limited, early-onset alcoholism shows strong hereditary components: sons born to fathers with this type of alcoholism show a much higher rate of this type of alcoholism, even if adopted into nonalcoholic families. Other types of alcoholism show stronger environmental influences.

Sexual orientation: much less evidence exists on this. Among homosexual men who have twin brothers, the rate of homosexual orientation is higher among identical twin brothers than among fraternal twin brothers. This suggests some genetic influence, but there are methodological problems with such studies and many other influences are probably also present.

Rape is theorized by some researchers to persist because it increases the fitness of rapists. However, the majority of males can achieve greater fitness through faithful sexual



n are not rapists.

Dec., 2003

instructors who have adopted the book
download, modify, and use these notes
Students of such instructors may likewise use and modify these notes as study aids.

Table 1: Punnett square for Hardy–Weinberg equilibrium

		Females	
		A (p)	a (q)
Males	A (p)	AA (p^2)	Aa (pq)
	a (q)	Aa (pq)	aa (q^2)

		Father's Blood Type A	B	AB	O	
Mother's Blood Type	A	A or O	A, B, AB, or O	A, B, or AB	A or O	Child's Blood type Must Be
	B	A, B, AB or O	B or O	A, B, or AB	B or O	
	AB	A, B, or AB	A, B, or AB	A, B, or AB	A or B	
	O	A or O	B or O	A or B	O	