

gesi and *T. splendens* Ewing. Also called jiggers and redbugs. Chiggers cause skin irritation in humans and dermatitis in animals.

chigoe flea A flea (*Tunga penetrans*) that attacks bare feet and causes nodular swellings and ulcers around toenails, as well as between the toes and the sole.

chirality A term describing the geometric property of a rigid object (or spatial arrangement of points or atoms) that is nonsuperimposable on its mirror image; such an object has no symmetry elements of the second kind (a mirror plane, a center of inversion, a rotation reflection axis). If the object is superimposable on its mirror image, the object is described as being achiral.

chi-square test A statistical exercise that compares the frequencies of various kinds or categories of items in a random sample with the frequencies that are expected if the population frequencies are as hypothesized by the researcher.

chitin The long-chained structural polysaccharide found in the exoskeleton of invertebrates such as crustaceans, insects, and spiders and in some cell walls of fungi. A beta-1,4-linked homopolymer of N-acetyl-D-glucosamine.

chlamydospore A thick-walled asexual resting spore of certain fungi assuming a role for survival in soil or in decaying crop debris from year to year.

chlorin In organic chemistry, it is an unsubstituted, reduced PORPHYRIN with two nonfused saturated carbon atoms (C-2, C-3) in one of the pyrrole rings.

chlorophyll Part of the photosynthetic systems in green plants. Generally speaking, it can be considered as a magnesium complex of a PORPHYRIN in which a double bond in one of the pyrrole rings (17-18) has been reduced. A fused cyclopentanone ring is also pre-

sent (positions 13-14-15). In the case of chlorophyll *a*, the substituted porphyrin ligand further contains four methyl groups in positions 2, 7, 12, and 18, a vinyl group in position 3, an ethyl group in position 8, and a $-(CH_2)_2CO_2R$ group ($R=$ phytyl, (2*E*)-(7*R*, 11*R*)-3,7,11,15-tetramethylhexadec-2-en-1-yl) in position 17. In chlorophyll *b*, the group in position 7 is a $-CHO$ group. In bacteriochlorophyll *a*, the porphyrin ring is further reduced (7-8), and the group in position 3 is now a $-COCH_3$ group. In addition, in bacteriochlorophyll *b*, the group in position 8 is a $=CHCH_3$ group.

See also PHOTOSYNTHESIS.

chloroplast The double membrane organelle of eukaryotic photosynthesis; contains enzymes and pigments that perform photosynthesis.

See also EUKARYOTES; PHOTOSYNTHESIS.

cholera An acute infection of the small intestines by *Vibrio cholerae* that is transmitted by ingesting fecal-contaminated water or food, or raw or undercooked seafood. Symptoms include diarrhea, abdominal cramps, nausea, vomiting, and severe dehydration. Endemic to India, Africa, the Mediterranean, South and Central America, Mexico, and the United States. Highly infectious disease that can be fatal, but there is a vaccine against it.

cholesterol A soft, waxy, fat-soluble steroid formed by the liver and a natural component of fats in the bloodstream (as lipoproteins); most common steroid in the human body and used by all cells in permeability of their membranes. It is used in the formation of many products such as bile acids, vitamin D, progesterone, estrogens, and androgens. In relation to human health, there is the high-density "good" cholesterol (HDL), which protects the heart, and the low-density "bad" cholesterol (LDL), which causes heart disease and other problems.

chondrichthyes Cartilaginous fishes; internal skeletons are made of cartilage and reinforced by small bony plates, while the external body is covered with hooklike scales. There are over 900 species in two sub-

classes, Elasmobranchii (sharks, skates, and rays) and Holocephali (chimaeras).

chondrin A substance that forms the matrix of cartilage, along with collagen; formed by chondrocytes.

chordate One of the most diverse and successful animal groups. The phylum Chordata includes fish, amphibians, reptiles, birds, mammals, and two invertebrates (tunicates and lancelets). Characterized by having at various times of their life a notochord (primitive spine, skeletal rod), pharyngeal slits, and hollow nerve cord ending in the brain area; usually have a head, a tail, and a digestive system, with an opening at both ends of the body. Their bodies are elongate and bilaterally symmetrical. Includes the hemichordates (vertebrates), cephalochordates (e.g., amphioxus), and urochordates (e.g., sea squirts).

chorion One of the four extraembryonic membranes, along with AMNION, YOLK SAC, and ALLANTOIS. It contributes to the formation of the PLACENTA in mammals; outermost membrane.

chorionic villus sampling A prenatal diagnosis technique that takes a small sample of tissue from the placenta and tests for certain birth defects. This is an early detection test, as it can be performed 10 to 12 weeks after a woman's last menstrual cycle.

chromatin The combination of DNA and proteins that make up the chromosomes of eukaryotes. Exists as long, thin fibers when cells are not dividing; not visible until cell division takes place.

chromatography A method of chemical analysis where a compound is separated by allowing it to migrate over an absorbent material, revealing each of the constituent chemicals as separate layers.

Chromista Brown algae, diatoms, and golden algae, placed together under a new proposed kingdom name.

chromophore That part of a molecular entity consisting of an atom or group of atoms in which the electronic transition responsible for a given spectral band is approximately localized.

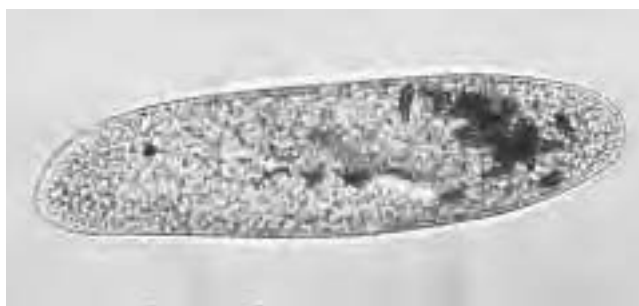
chromosome The self-replicating gene-carrying member found in the cell nucleus and composed of a DNA molecule and proteins (chromatin). Prokaryote organisms contain only one chromosome (circular DNA), while eukaryotes contain numerous chromosomes that comprise a genome. Chromosomes are divided into functional units called genes, each of which contains the genetic code (instructions) for making a specific protein.

See also GENE.

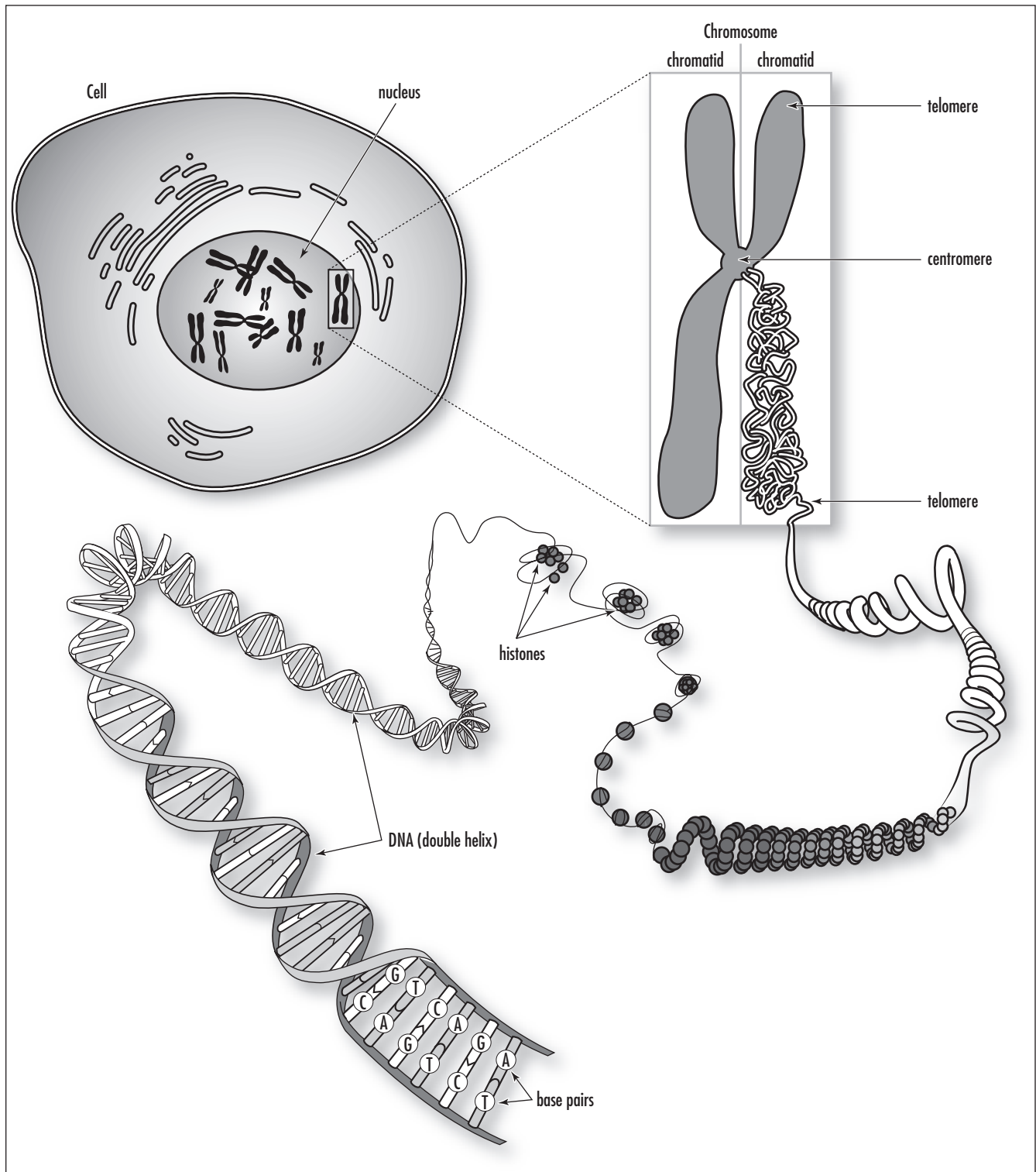
chronic Long lasting and severe; the opposite of acute. Examples of chronic diseases include: chronic atopic dermatitis; chronic bronchitis; chronic cough; chronic rhinitis; chronic ulcerative colitis.

chytrid A group of fungi not completely understood by science. Not visible to the eye, they are small, with a mycelium and central sporophore, looking like a miniature octopus. They reproduce by means of self-propelling spores.

cilium (plural, cilia) A hair-like oscillating structure that is used for locomotion or for moving particles. It projects from a cell surface and is composed of nine



A single-celled organism, *Paramecium caudatum*, that uses cilia for locomotion. (Courtesy Hideki Horikami)



A chromosome is one of the threadlike “packages” of genes and other DNA in the nucleus of a cell. Different kinds of organisms have different numbers of chromosomes. Humans have 23 pairs of chromosomes, 46 in all: 44 autosomes and two sex chromosomes. Each parent contributes one chromosome to each pair, so children get half of their chromosomes from their mothers and half from their fathers. (Courtesy of Darryl Leja, NHGRI, National Institutes of Health)

Human Cytogenetics: Historical Overview and Latest Developments

by Betty Harrison

Cytogenetics, the study of chromosomes, was revolutionized by the discovery that quinacrine staining under ultraviolet light produces a unique banding pattern. In 1970, Dr. Torbjorn O. Caspersson and his group discovered that human chromosomes fluoresce when stained with quinacrine mustard, giving a distinct banding pattern to each chromosome pair. It was later found that chromosomes show a similar banding pattern with the use of stain. Giemsa/Trypsin or Wright's/Trypsin stain is now preferable to quinacrine, as they allow the use of the light microscope and also provide stable preparations.

Banding of chromosomes allows pairing of, rather than grouping of, homologous chromosomes of similar size. The number of bands identified is routinely between 450 and 550, and high resolution is 550 and higher bands in a haploid set. A band is a region that is distinguishable from a neighboring region by the difference in its staining intensity. Banding permits a more detailed analysis of chromosome rearrangements such as translocations, deletions, duplications, insertions, and inversions.

Several types of banding procedures have been developed since the early 1970s in addition to Giemsa banding. R-banding or reverse banding is the opposite of Giemsa (Wright's) banding pattern. There are staining techniques for specific regions of the chromosomes: silver staining, which stains the nucleolus-organizing regions (NORs), and C-banding (constitutive heterochromatin), which stains the centromere of all chromosomes and the distal portion of the Y chromosome. The size of the C-band on a given chromosome is usually constant in all cells of an individual but is highly variable from person to person.

The development of banding techniques in the early 1970s was followed by the development of "high resolution banding" in the late 1970s. This technique divides the landmark bands into sub-bands of contrasting shades of light and dark regions. High-resolution or extended banding is produced by a combination of the induction of cell synchronization followed by the precise timing of harvesting. The cells are then examined in prophase, prometaphase, and early metaphase. At these stages of cell division, very small chromosome changes can be detected. This is useful clinically to find previously undetected chromosome aberrations not found at lower banding levels, to localize breakpoints in rearranged chromosomes, and to help establish phenotype-genotype relationships at a more precise level.

The normal chromosome complement of 46 is called diploid. If there are 46 chromosomes with structural abnormalities, it is referred to as pseudodiploid. Numerical abnormalities are called aneuploidy. When there are more than 46, it is called hyperdiploid, and when fewer, it is called hypodiploid. Chromosome loss in whole or part is a monosomy, while the gain of a single chromosome when they are paired is a trisomy. The presence of two or more cell lines in an individual is known as mosaicism. When, for example, the abnormal line is a trisomy with a normal line, the overall phenotypic effect of the extra chromosome is generally decreased.

The types of cells examined are usually from peripheral blood, bone marrow, amniotic fluid, chorionic villi, and solid-tissue biopsies. These tissues are analyzed in diagnostic procedures in prenatal diagnosis, multiple miscarriages, newborns and children with abnormal phenotypes and abnormal sexual development, hematological disorders, and solid tumors. Autosomal chromosome abnormalities generally have more serious consequences than sex chromosome abnormalities. Chromosome abnormalities are a major cause of fetal loss. These numbers decrease by birth, and since some trisomies result in early death, their frequency is lower in children and even lower in adults.

Numerical changes are the most common chromosome abnormalities. Most numerical changes are the result of nondisjunction in the first meiotic division. Mitotic nondisjunction typically results in mosaicism. Chromosome structural changes can be balanced or unbalanced. Structural abnormalities may be losses, rearrangements, or gains, while numerical abnormalities are losses or gains. Both numerical and structural changes may result in phenotypic abnormalities.

Chromosome abnormalities may be constitutional or acquired. Constitutional abnormalities may be associated with phenotypic anomalies (i.e., Down's syndrome, Turner syndrome) or result in a normal phenotype (i.e., balanced familial translocation). Acquired abnormalities are usually those associated with malignant transformation, such as cancers.

A significant advance in the past decade has been the addition of fluorescent in situ hybridization (FISH) or molecular cytogenetics. FISH has become both a diagnostic and a research tool in cytogenetic laboratories. These procedures involve the denaturation of DNA followed by hybridization with a specific probe that has been tagged with a fluorochrome and stained with a counterstain. These preparations are viewed through a fluorescent microscope with a 100-W mercury lamp and appropriate filter sets.

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Human Cytogenetics: Historical Overview and Latest Developments

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FISH, for example, provides rapid results in prenatal diagnosis. Chromosome analysis using classical chromosome analysis on cultured cells from amniotic fluid takes 1–2 weeks to complete. FISH is performed on the uncultured amniocytes and is complete in 24–48 hours. FISH screens for only numerical abnormalities in chromosomes 13, 18, 21, X, and Y. However, these chromosomes make up approximately 90 percent of the total chromosome abnormalities that result in birth defects.

FISH can be used for identification of marker chromosomes, microdeletion syndromes, rearrangements and deletions, detection of abnormalities in leukemia, myeloproliferative disorders, and solid tumors. For example, a chromosome deletion not clearly visible with standard chromosome analysis may be detected with a specific probe for the region (i.e., Di George syndrome).

Cytogenetic analysis of malignant cells proved valuable in the diagnosis and in some cases prognosis of hematological malignancies. FISH has increased the importance of chromosome analysis in the diagnosis of these patients. Many nonrandom cytogenetic abnormalities associated with a specific hematological malignancy have been found. These findings have contributed to the understanding and in some cases treatment of these malignancies. The use of

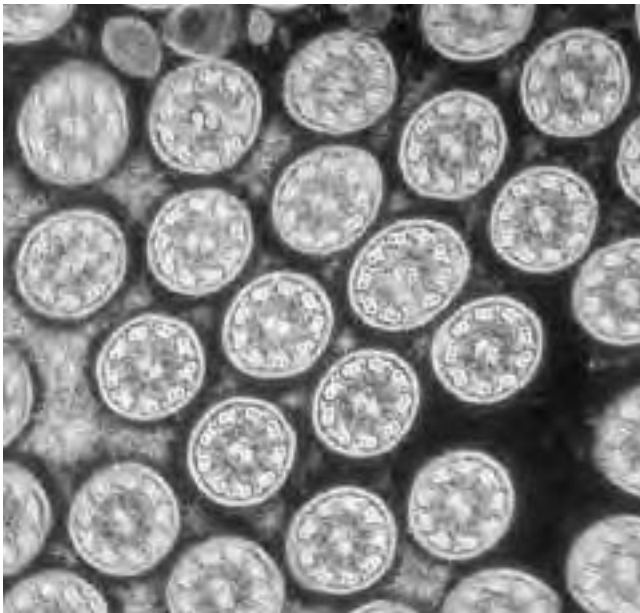
FISH techniques has greatly improved the diagnostic accuracy because, in addition to specific translocation probes, FISH can detect abnormalities in both interphase and metaphase cells.

A current FISH test that may be used for the identification of subtle rearrangements or to characterize complex translocations involving more than two chromosomes is spectral karyotyping (M-FISH, or multiplex in-situ hybridization). This test simultaneously identifies entire chromosomes using 24 different colors.

Recent research using telomere probes in cases of unexplained mental retardation has revealed that approximately 6 percent may be due to subtelomere rearrangements.

An additional research tool, especially in cancer cytogenetics, is comparative genomic hybridization (CGH). This technique reveals whole chromosome gains and losses as well as deletions and amplifications of very small chromosome segments. Cytogenetic analysis has been an extremely valuable tool for screening and for diagnosing genetic disorders, and it will continue to play a vital role in medical service and research.

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outer double microtubules with two inner single microtubules, and it is anchored by a basal body. Single-cell organisms, such as protozoa, use them for locomotion. The human female fallopian tubes use cilia to transport the egg from the ovary to the uterus.

Colored transmission electron micrograph (TEM) of a cross section through cilia (circles), from the lining (epithelium) of the human trachea, or windpipe. Cilia in the trachea are hairlike projections that beat rhythmically to move mucus away from the gas-exchanging parts of the lungs, up toward the throat where it can be swallowed or coughed up. They project in parallel rows, with 300 on each cell, measuring up to 10 μm in length. Each cillium contains a central core (axoneme), which consists of 20 microtubules arranged as a central pair, surrounded by nine peripheral doublets (as seen). Magnification: $\times 40,000$ at 6×7 cm size. (Courtesy © Science Photo Library/Photo Researchers, Inc.)

circadian rhythm A biological process that oscillates with an approximate 24-hour periodicity, even if there are no external timing cues; an internal daily biological clock present in all eukaryotes.

circular dichroism (CD) A spectroscopic method that measures the difference in absorbance of left- and right-handed circularly polarized light by a material as a function of the wavelength. Most biological molecules, including proteins and NUCLEIC ACIDS, are CHIRAL and show circular dichroism in their ultraviolet absorption bands, which can be used as an indication of SECONDARY STRUCTURE. Metal centers that are bound to such molecules, even if they have no inherent chirality, usually exhibit CD in absorption bands associated with LIGAND-based or ligand-metal CHARGE-TRANSFER TRANSITIONS. CD is frequently used in combination with absorption and MCD studies to assign electronic transitions.

cis In inorganic nomenclature, *cis* is a structural prefix designating two groups occupying adjacent positions. (The term is not generally recommended for precise nomenclature purposes of complicated systems.)

See also TRANS.

cisplatin *cis*-Diamminedichloroplatinum(II). An anti-tumor drug highly effective in the chemotherapy of many forms of cancer. Of major importance in the anti-tumor activity of this drug is its interaction with the NUCLEIC ACID bases of DNA.

cistron A segment of DNA that codes for a single polypeptide domain; another name for a gene.

cladistics A way to classify organisms by common ancestry, based on the branching of the evolutionary family tree. Organisms that share a common ancestor and have similar features are put into groups called clades. At each diverging line, there are two branching lines of descendants, and evolution plays a role in future changes in characteristics.

cladogenesis The evolutionary splitting of lineages; one or more new species comes from an existing parent species, i.e., speciation. Also called branching evolution.

cladogram A pictorial representation of a branching tree that depicts species divergence from a common ancestry.

class The taxonomic ranking of plants and animals that is between phylum and order.

See also TAXON.

classical conditioning The presentation of two stimuli at the same point in time: a neutral stimulus and a conditioned stimulus; the changes in behavior arising from the presentation of one stimulus in the presence of another. The pairing leads to the neutral stimulus associating with the properties of the conditioned.

cleavage The process of cell division in an early embryo. Initial stages in embryonic development where the zygote converts to a ball of cells through divisions of clearly marked blastomeres, usually from a succession from first through sixth cleavages (2–64 cells). Each species of organism displays a characteristic cleavage pattern that can be observed. Cleavage divides the embryo without increasing its mass.

cleavage furrow A groove composed of actin-rich contractile microfilaments that draws in tight to separate daughter cells during cytokinesis. Also called the contractile ring.

cleistogamous A flower that does not open and is self-pollinated. Pollen is transferred directly from the anthers to the stigma of the same flower.

cleptoparasite The parasitic relation in which a female seeks out the prey or stored food of another

female, usually of another species, and appropriates it for the rearing of her own offspring.

climax The final stage in succession where the constituent species populations fluctuate normally instead of acting as replacements of other species. The constituent species will self-perpetuate as long as all natural conditions are favorable and continue.

cline The establishment of plant populations over a specific geographic range that have adapted to different locations and have become slightly different from one

another. The plants show a gradient of change over the range, with the frequency of a particular gene either increasing or decreasing over the range. Under the right conditions, speciation may occur over time.

cloaca An all-purpose opening that serves as a digestive, excretory, and reproductive tract for most vertebrates, with the exception of the majority of mammals.

clonal deletion A mechanism whereby the loss of lymphocytes of a particular specificity is due to contact with either “self” or an artificially introduced antigen.



The faces of identical “Megan” and “Morag,” the world’s first cloned sheep aged 9 months. These Welsh mountain sheep were the product of research by Dr. Ian Wilmut and colleagues at the Roslin Institute in Edinburgh, Scotland. The research involved culturing identical embryonic cells from sheep to produce a “cell line.” Next, a sheep egg cell had its DNA removed, and one of these embryonic cells was implanted into the egg. A spark of electricity then stimulated the egg to grow into a lamb, nourished in the womb of a surrogate sheep. The ability to clone farm animals, first achieved in 1996, may provide benefits to agriculture and biotechnology. (Courtesy © James King-Holmes/Photo Researchers, Inc.)

clonal selection theory (Burnett theory) Clonal selection theory states that the specificity and diversity of an immune response are the result of selection by an antigen of specifically reactive clones from a large repertoire of preformed lymphocytes, each with individual specificities.

clone A population of organisms, cells, viruses, or DNA molecules that is derived from the replication of a single genetic progenitor. In the case of B cells, each B cell has a typical Ig, and so all the cells that descend from one B cell (the clone) have the same Ig. Typically, a cancer is a clone of cells. Sometimes, *clone* is also used to refer to a number of recombinant DNA molecules all carrying the same inserted SEQUENCE.

cloning vector Any organism or agent (virus, plasmid) that is used to introduce foreign DNA into host cells.

closed circulatory system A type of circulatory system where the blood is contained within a system of vessels and the heart; blood vessels carry blood through all the organs.

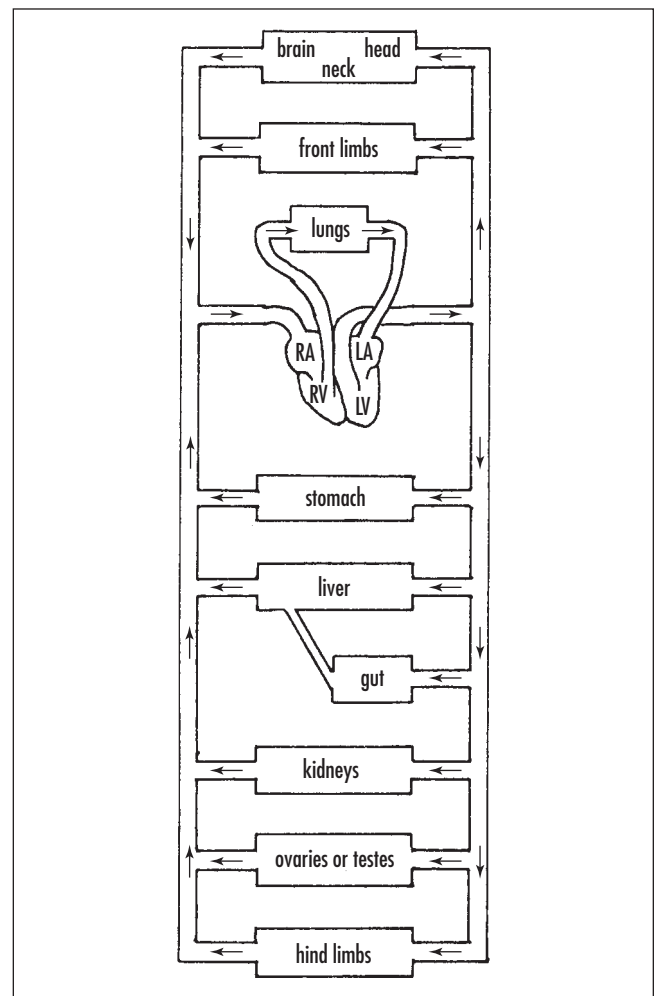
cluster A number of metal centers grouped closely together that can have direct metal-bonding interactions or interactions through a BRIDGING LIGAND, but are not necessarily held together by these interactions. Examples can be found under the entries [2FE-2S], [4FE-4S], FERREDOXIN, HIPIP, IRON-SULFUR CLUSTER, FEMO-COFACTOR, FERRITIN, METALLOTHIONEIN, NITROGENASE, and RIESKE IRON-SULFUR PROTEIN.

clusters of differentiation (CD) Cluster of antigens, with which antibodies react, that characterize a cell surface marker.

Lymphocytes can be divided into subsets either by their functions or by surface markers. The availability of monoclonal Abs raised against lymphocytes has allowed for the demonstration of several lymphocyte subsets, which express a combination of certain

molecules on their surfaces. These surface markers have been designated clusters of differentiation (CD). Already, 78 CDs have been identified as well as the monoclonal Abs used to define them, their molecular weights, and cellular distribution. For example, CD23, the receptor for the FC portion of IgE and CD8 (T8), a protein embedded in the cell surface of suppressor T lymphocytes.

CD4 One of the most infamous CDs due to its importance in AIDS. CD4 (T4) is the protein embedded on the surface of T helper and other white blood cells to which HIV attaches itself. It is also found to a lesser degree on the surface of monocytes/macrophages, Langerhans cells, astrocytes, ker-



A closed circulatory system, where the blood is contained within a system of vessels and the heart.

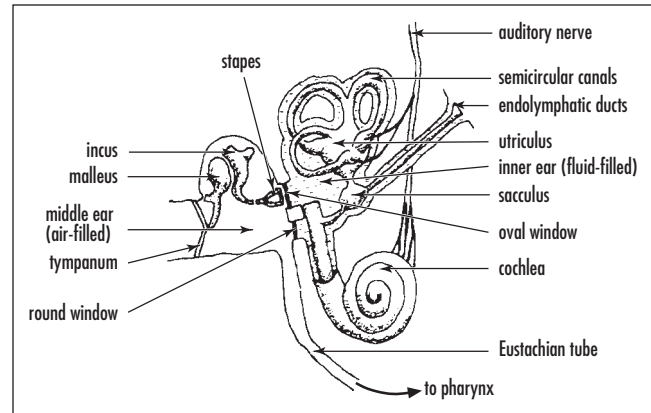
atinocytes, and glial cells. HIV invades cells by attaching itself to the CD4 molecule (CD4 receptor). The number of T4 cells in a blood sample is used to measure the health of the immune system in people with HIV.

Helper T cell (CD4 cell, helper, helper cell, T helper cell, T helper lymphocyte, T4 cell) A subset of T cells that carry the T4 marker and are essential for turning on antibody production, activating cytotoxic T cells, and initiating other immune responses. The number of T4 cells in a blood sample is used to measure the health of the immune system in people with HIV. T helper lymphocytes contain two subsets, TH1 and TH2 cells.

CD8 cell (T suppressor cell, T8 cell) The existence of these cells is a relatively recent discovery, and hence their functioning is still somewhat debated. The basic concept of suppressor T cells is a cell type that specifically suppresses the action of other cells in the immune system, notably B cells and T cells, thereby preventing the establishment of an immune response. How this is done is not known with certainty, but it seems that certain specific antigens can stimulate the activation of the suppressor T cells. Discrete epitopes have been found that display suppressor activity on killer T cells, T helper cells, and B cells. This suppressor effect is thought to be mediated by some inhibitory factor secreted by suppressor T cells. It is not any of the known lymphokines. A fact that renders the study of this cell type difficult is the lack of a specific surface marker. Most suppressor T cells are CD8 positive, as are cytotoxic T cells.

clutch The eggs laid in a nest by an individual bird.

cobalamin (vitamin B₁₂) A vitamin synthesized by microorganisms and conserved in animals in the liver. Deficiency of vitamin B₁₂ leads to pernicious ANEMIA. Cobalamin is a substituted CORRIN-Co(III) complex in which the cobalt atom is bound to the four nitrogen atoms of the corrin ring, an axial group R and 5,6-dimethylbenzimidazole. The latter is linked to the cobalt by the N-3 nitrogen atom and is bound to the C-1 carbon of a ribose molecule by the N-1 nitrogen atom. Various forms of the vitamin are known with different R groups, such as R=CN, cyanocobalamin;



Sound signals pass from the cochlea via the oscillating hair cells, which transform them into electrical signals along the auditory nerve to the brain stem, where they activate other nerves in the brain.

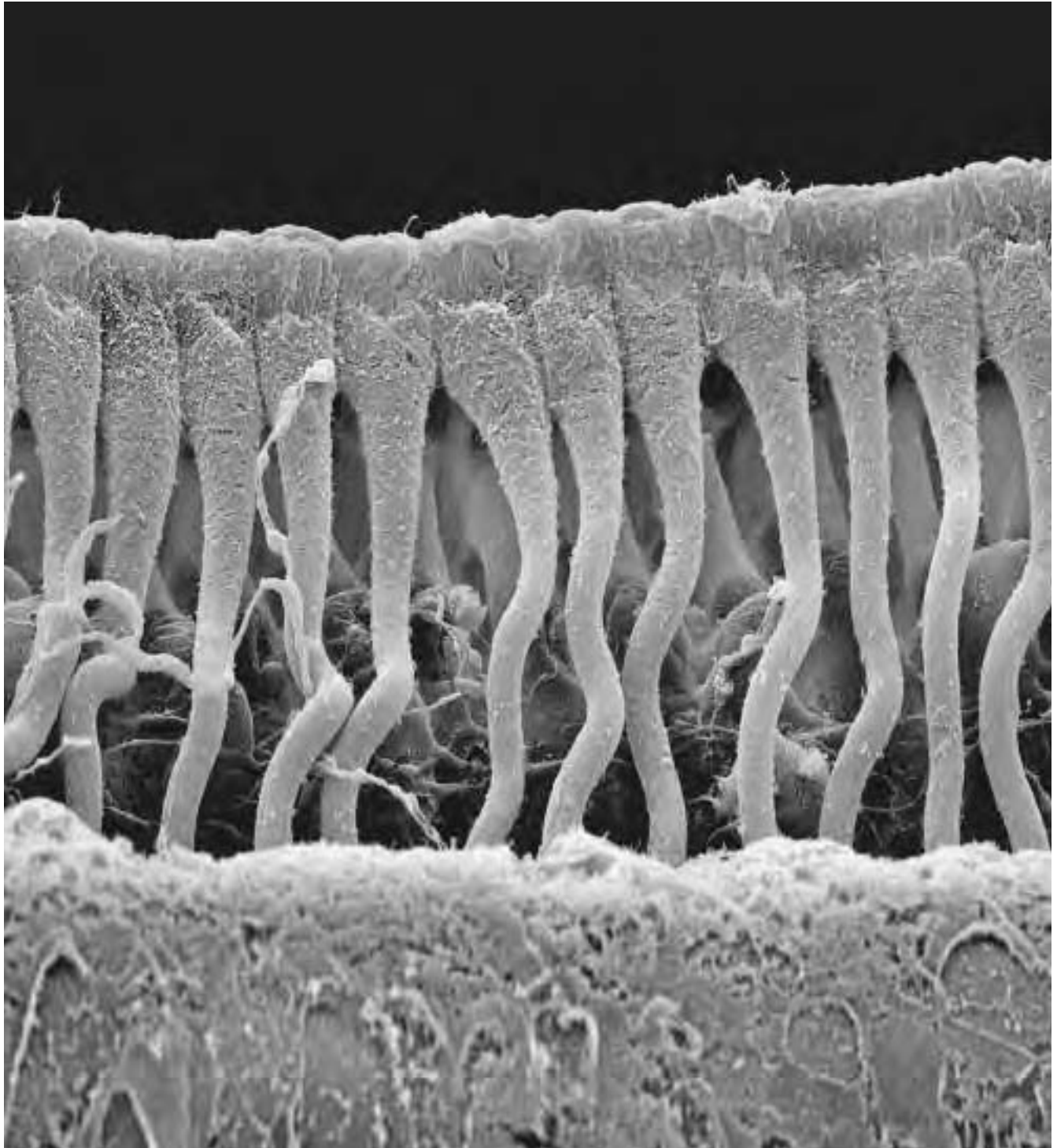
R=OH, hydroxocobalamin; R=CH₃, methylcobalamin; R=adenosyl, COENZYME B12.

cochlea The inner ear; a circular or coiled snaillike shell that contains a system of liquid-filled tubes with tiny hair cells. Sound signals pass from the cochlea via the oscillating hair cells, which transform them into electrical signals along the auditory nerve to the brain stem, where they activate other nerves in the brain.

cockroach The order Blattodea that contains the insects also known as the “cucaracha,” black beetle, water bug, Yankee settler, shiner, and a host of other names; it is one of the most hated insects known to man. There are 4,000 species, but only about 12 are commonly associated with humans. Common species include: *Blatella germanica*, *Blatta orientalis*, *Periplaneta americana*, *Periplaneta australasiae*, *Periplaneta brunnea*, *Periplaneta fuliginosa*, and *Supella longipalpa*.

codominance When both alleles in a heterozygote are expressed phenotypically.

codon A sequence of three consecutive NUCLEOTIDES that occurs in mRNA and (a) directs the incorporation



Scanning electron micrograph (SEM) of a vertical section through part of the cochlea inside a human ear. The section shows part of the row of columnar outer pillar cells that runs along the organ of Corti, the auditory sense organ. The outer pillar cells arise from the basilar membrane (across bottom), and their upper surfaces (across top) form part of the surface of the organ of Corti. This organ lies on the basilar membrane, an internal surface of the cochlear duct. The organ of Corti also contains hairlike cilia (not seen) and an overlying tectorial membrane (removed). Sound waves deform hairlike cilia and trigger auditory nerve impulses. Magnification: $\times 600$ at 6×7 cm size. (Courtesy © Science Photo Library/Photo Researchers, Inc.)