Glossary

Acetylation The addition, catalyzed by acetyltransferases, of acetyl groups to amino acid side chain nitrogens on target proteins.

Action potential Self-regenerating pulse of electrical activity that propagates down axons and is generated by the opening and closing of sodium and potassium channels.

Active zone Region of the presynaptic axon terminal containing the machinery for neurotransmitter release.

Adaptive immune response Immune response unique to vertebrates involving antigen recognition and the production of antibodies.

Adapter proteins Nonenzymatic proteins that contain protein-protein interaction domains and serve as intermediaries that allow signaling proteins that would otherwise not be able to communicate to do so.

Agonist A molecule that binds a receptor and induces the same response in the receptor as the one triggered by the natural ligand.

Allosteric modification Shifts in equilibria between two preexisting populations of conformational states, brought on either by ligand binding or by covalent attachment of groups. In an allosteric modification, binding at one location in the molecule is able to alter how other portions of the molecule respond to their binding partners because of the conformational changes that accompany the shifts in equilibrium.

Anchor proteins Nonenzymatic proteins that attach to the plasma membrane and to membranes of organelles, and provide platforms for signaling proteins to dock in close proximity to receptors and ion channels.

Angiogenesis The late stages of vasculogenesis in which an initial set of tubules is refined through further differentiation, sprouting, and branching to form a mature vascular system containing arterial and venous structures.

Antagonist A molecule that binds a receptor, but the receptor does not transmit a signal in response to the binding event. Drugs that bind in an antagonistic fashion are known as **blockers**.

Antibiotic Biomolecules synthesized by fungi and bacteria that kill competing microbes.

Antibodies Receptors synthesized by B cells that recognize and bind antigens.

Antigen (antibody generator) Foreign substance, derived from a pathogen and expressed either on the outer surface of the pathogen or on the surface of an antigen-presenting cell, that triggers the production of antibodies.

Antigenic variation Systematic alterations in the antigens expressed on the outer surface of a pathogen.

Apoptosis Programmed cell death, in which there is an orderly disassembly of the cell that avoids harming neighboring cells. Also called **cell suicide**.

Apoptosome The major control point for converting internal stress signals into apoptotic responses. It is located just outside the mitochondria and is activated by the release of cytochrome c.

Associative learning Changes in the behavioral response to the weak stimulus that has been paired with a strong (positive or negative) stimulus.

Autocrine A signaling mode in which hormones secreted from a cell act back on the cell releasing them.

Auxiliary spice sites Sites where splicing regulators bind. Auxiliary sites located within exons are called **exonic splice enhancer** (ESE) and **exonic splice inhibitory** (ESI) sites, depending on which regulatory outcome is supported. Similarly, intronic sites are termed **intronic splice enhancer** (ISE) and **intronic splice inhibitory** (ISI) sites.

Bacteriophage Virus that infects bacteria; also called a phage.

Biofilm A bacterial colony formed on exposed surfaces and exhibiting cooperative behavior between members.

Branching morphogenesis Growth, invasion, and proliferation of cells that form branched tubular structures that carry fluids in the vasculature, lungs, kidneys, and mammary glands.

Caspases Proteolytic enzymes that catalyze the cleavage of specific molecules in response to apoptosis signals.

Catch bond A bond that is strengthened by the external forces. The force-driven enhancements in the lifetime of these bonds allow leukoctytes to be captured by the walls of the blood vessels and begin rolling.

Caveolae (little caves) Tiny flask-shaped invaginations in the outer leaflet of the plasma membrane that are detergent-insoluble, enriched in glycosphingolipids, cholesterol, and lipid-anchored proteins, and in **caveolins**, a coatlike material.

Cell adhesion Cell-to-cell and cell-to-ECM attachment mediated by long modular and flexible glycoproteins expressed on opposing surfaces acting as receptors and counterreceptors or ligands.

Cell fate The determination of which tissue or organ a particular cell becomes a member of during embryonic development.

Cell polarity The asymmetric distributions of cellular components that arise during development. In the case of nerve cells it produces striking differences in morphology—axons at one end, dendrites at the other; in epithelial cells it gives rise to apical and basolateral plasma membrane domains.

Central pattern generators Circuits built from small numbers of neurons that are used to drive the rhythmic firing of muscles responsible for activities such as walking and swimming, breathing, and chewing and digesting.

Chaperones Proteins that help other proteins to fold into their native state, shuttle proteins to their correct locations in the cell, prevent unwanted aggregation, and assist in recovering and refolding proteins that have become misfolded due to cellular stresses.

Checkpoints Signaling pathways that ensure that a cell cycle or assembly process does not begin before a prior necessary process is completed.

Chemotaxis The process whereby a unicellular organism senses nutrients and noxious substances in its local environment, and, in response, moves towards the nutrients and away from the harmful chemicals.

Chromatin In eukaryotes, material from which chromosomes are made, consisting of DNA wrapped around proteins called histories.

Chromophore Groups of atoms or molecules that act as pigments, imparting color to the materials in which they reside by absorbing light at some wavelengths and scattering it at others.

Competence The ability of a bacterium to take up exogenous DNA from its environment.

Conjugation A form of horizontal gene transfer in which bacteria establish direct contact with one another; sex pili are formed, and genetic material in the form of plasmid are sent from donor to recipient.

Control point Locations in the cell where environmental and regulatory signals converge, integrate, and convent to cellular responses.

Cytokines Small signaling proteins synthesized and secreted by leukocytes, most commonly, macrophages and T cells. They convey a variety of instructions to leukocytes and to other cells such as neurons.

Death-inducing signaling complex (DISC) The name given to the control point responsible for converting external death signals into apoptotic responses. It is organized by death receptors at and just below the plasma membrane.

Denatured state The ensemble of states that a newly synthesized protein, or an unfolded protein, populates.

Dephosphorylation The removal catalyzed by protein phosphatases of phosphoryl groups previously added to amino acid side chain hydroxyls on protein substrates by protein kinases.

Desensitization The process whereby a G protein-coupled receptor, or any other receptor, loses its responsiveness to binding by its ligand.

Diffraction Scattering of light by atoms, molecules, and larger objects resulting in departures from rectilinear motion other than reflection or refraction.

Diffusion Thermally driven movement of particles in a fluid from one locale to another produced by random collisions of the particles with the molecules of the fluid.

Distal sites DNA regulatory regions where long-range interactions between regulatory proteins and the basal transcription machinery take place. They may be located upstream of the core promoter, downstream of the core promoter, in between coding regions, and inside introns. Positively acting transcription factors that bind at these sites are called **enhancers**, while negatively acting transcription factors are referred to as **silencers**.

Domain fold Stable arrangements of multiple secondary structure elements and of two or more structural motifs into independent folding units.

Efficiency of synaptic transmission Magnitude of the response generated in a postsynaptic neuron when an action potential is generated in the presynaptic neuron.

Electrostatic complementarity The matching of hydrophobic patches, the complementary pairing of hydrogen bond donors and acceptors, and the matching of positive and negative charges of basic and acidic polar residues from one surface to the other of the interface.

Endocrine A signaling mode in which hormones are secreted into the bloodstream and other bodily fluids by specialized cells and travel large distances to reach multiple target cells.

Endocytosis The process whereby plasma membrane proteins and materials captured at the cell surface are packaged into vesicles and shipped to digestive compartments for processing and recycling.

Energy landscape A graphical depiction of how the number of states available to a protein at each value of the potential energy varies as a function of a few significant degrees of freedom.

Envelope Lipid/carbohydrate membrane derived from the host cell that surrounds a viral capsid.

Euchromatin Transcriptionally active chromatin with an open shape that permits transcription factors and the basal transcription machinery to access promoters.

Exocytosis The packaging and shipping of newly synthesized proteins destined for export and use in the plasma membrane in vacuoles that move over the rail system and fuse with membranes at their destination.

Exons Short coding sequences separated from one another by introns in pre-messenger RNAs.

Focal adhesions Points of contact and adhesion between the cell and the supporting extracellular matrix. They serve as control points where growth and adhesion signals are integrated together to govern the overall growth and movement of the cell.

Folding funnel The shape of the potential energy landscape that arises because there are many high energy states and few low energy ones.

Gate The part of the ion channel that opens and closes the pore through which ions pass.

GDP dissociation inhibitors (GDIs) Enzymes bind and maintain pools of inactive GTPases by inhibiting the dissociation of GDP from the GDPase.

Glycosylation A common posttranslational modification to proteins destined for insertion in the plasma membrane in which covalently linked oligosaccharides that extend out from their extracellular side are added. The modified proteins are referred to as **glycoproteins**.

Glycosyl phosphatidylinositol (GPI) anchors Posttranslational modifications to proteins that allow them to attach to the outer, or exoplasmic, leaflet of the plasma membrane. GPI anchors are made from a complex sugar plus a phosphatidylinositol grouping.

Growth cones Sensory structures located at the tip of advancing axonal and dendritic processes sent out from neurites. They explore, interact with, interpret, and respond to signaling molecules in their local microenvironment.

Growth factors Molecules that stimulate growth and development.

GTPase-activating proteins (GAPs) Enzymes that catalyze the hydrolysis of the GTPase-bound GTP to GDP.

GTPases Small enzymes that hydrolyze GTP and function as molecular switches and timers. They are activated when bound to GTP and deactivated when bound to GDP.

Guanine nucleotide exchange factors (GEFs) Enzymes that catalyze the dissociation of GDP from the GTPase.

Habituation Weakening of a behavioral response to a harmless stimulus through repeated exposures to that stimulus.

Heterochromatin Transcriptionally inactive chromatin with a tightly compacted shape that prevents transcription factors and the basal transcription machinery from accessing promoters.

Holoenzyme Inactive enzyme (apoenzyme) plus additional noncovalently bonded biomolecules, either loosely bound cofactors or tightly bound prosthetic groups, required for full catalytic activity.

Homeostasis Physiological process by which a cell, tissue, or organism balances and stabilizes internal conditions such as temperature, pH, excitability, and cell type in the presence of external perturbations.

Horizontal gene transfer Lateral transfer of genetic information between distantly related species through conjugation, transduction, and transformation.

Hydrophilic A water-loving amino acid; a water molecule would rather bind to this amino acid than to another water molecule.

Hydrophobic A water-hating amino acid; a water molecule would rather bind to another water molecule than to this amino acid.

Inflammatory response Set of physiological responses including fever and pain, redness and swelling. A local environment is formed that promotes migration of leukocytes to the infection site, the destruction of the invasive agents, and the repair of damaged tissues.

Innate immune response Immune response involving recognition by leukocytes of molecules situated on the outer surface of pathogens that are characteristic of the pathogen.

Insulators DNA sequences that mark boundaries between independent sections of DNA.

Interface Region of surface contact between two macromolecules through which binding and communication take place.

Internalization The removal of a receptor from the plasma membrane through endocytic mechanisms.

Introns Long noncoding, or intervening, sequences situated in between exons in pre-messenger RNAs.

Ion channels Membrane-spanning proteins forming narrow pores that enable specific inorganic ions, typically Na^+, K^+, Ca^{2+} or Cl^-, to passively diffuse in a directional manner through cell membranes.

Ionotropic Receptor ion channel that opens and closes in response to neurotransmitter binding.

Juxtacrine A signaling model in which messages are conveyed by direct contact between a receptor on one cell and a cell surface-bound ligand or counterreceptor on an adjacent cell.

Kinetic proofreading A cellular mechanism for improving the fidelity of a process by tying it to a series of intermediate time- and energy-consuming steps. In receptor-ligand binding, differences in affinity are converted to differences in signaling because of the intermediate time- and energy-consuming steps.

Kinetic trap A set of states forming a local minimum in the energy landscape and enclosed by energy barriers large compared to the thermal energy.

Labile Readily undergoes change or breakdown.

Lateral inhibition Process whereby a cell adopting a particular cell fate inhibits its neighbors from adopting the same fate.

Learning The adaptive process whereby changes in behavior are induced in response to experience.

Leukocytes White blood cells; highly motile and short-lived cells that move through the cardiovascular and lymphatic systems into damaged tissues where they kill bacterial, protozoan, fungal and multicellular pathogens, destroy cells infected with viruses and bacteria, and eliminate tumor cells.

Lipid rafts Plasma membrane microdomains that are detergent insoluble and enriched in cholesterol and sphingolipids. Unlike caveolae, they do not contain caveolins and are not cavelike in shape but instead are flat.

Long-term facilitation Strengthening of the behavioral response to a mild touch to the tail that has been paired with an electric shock to the siphon, an experimental model of associative learning in the *Aplysia* siphon withdrawal circuit.

Long-term potentiation Strengthening of the postsynaptic response to a presynaptic action potential brought on by pairing a series of presynaptic

action potentials with a postsynaptic depolarization or action potential, an experimental model of associative learning in the rodent hippocampal CA1–CA3 regions.

Lysogenic Life cycle in which phage DNA is integrated into the host cell DNA and the bacteriophage becomes a prophage, replicating as part of the bacterial host's chromosome.

Lytic Life cycle in which phage DNA is replicated and multiple virus particles are formed and escape from the cell by rupturing the cell's plasma membrane.

Matrix protein Associates with the inner layer of the viral envelope and is situated in between the inner layer and the capsid.

Memory The record underlying the changes in behavior brought on by learning.

Metabotropic receptors G protein-coupled receptors (GPCRs) that activate their cognate heterotrimeric G proteins in response to neuromodulator binding.

Metastasis The process whereby cancer cells break away from their point of origin, the primary tumor, enter the circulatory system, and invade other organs, where they form secondary tumors.

Methylation The addition catalyzed by methyltransferases of methyl groups to amino acid side chain nitrogens on target proteins.

Morphogens Signaling proteins expressed either on cell surfaces or secreted into the extracellular spaces in the form of concentration gradients that are read by other cells to determine their developmental fate.

Motor neurons Supply input to muscles that drives their contractions, and receive input from upstream sensory and control neurons.

Mutual inhibition Pairs of neurons that are reciprocally connected and sequentially inhibit each other's firing activities.

Native state A stable state of the folded protein. It is a state of minimum Gibbs free energy at physiological temperatures and conditions.

Neuromodulators Signaling molecules secreted in a broader manner than neurotransmitters; they modify the excitability of large numbers of target cells by regulating the activities of their ion channels.

Neurotransmitters Signaling molecules released from the presynaptic terminal of a neuron and diffuse in a directional manner across the synaptic cleft to the postsynaptic terminal of a neighboring neuron, where they bind receptor ion channels.

Nucleocapsid The viral capsid plus its nucleic acid core.

Nucleosome The fundamental repeating unit of chromatin. Nucleosomes, 146 base pairs of DNA wrapped about a histone octamer, are strung together like beads on the string by means of linker segments.

Oncoproteins Proteins that operate in the signal transduction, integration, and regulatory pathways involved in cellular growth, multiplication, differentiation, and death, that when mutated stimulate unregulated cell growth and proliferation thus promoting the development of cancer.

Operon DNA sequences that encode one or more proteins and the upstream sequences for attachment of the RNA holoenzyme and regulatory proteins in bacteria.

Organizing centers Localized groupings of cells that secrete morphogens that impart patterns of cell fates to fields of progenitor cells.

Pacemaker neuron Neurons that generate the rhythmic firing patterns without requiring any rhythmic input.

Paracrine A signaling mode in which molecules are secreted into the extracellular spaces by an originating cell and travel no more than a few cell diameters to reach their target cell.

Pathogen (bacterial) Organisms possessing genes that encode virulence factors and are situated on plasmids and other mobile genetic elements that can be readily transferred and exchanged between species.

Permeability The propensity of a membrane to allow passage of certain ions and molecules.

Permeability transition pore complex (PTPC) Also known as the **permeability transition pore (PTP)**, this control point is formed at points of contact between the inner and outer mitochondrial membranes. The PTPC is a conduit for the passage of agents such as cytochrome c and Smac/DIABLO that trigger apoptosome assembly and activation of caspase 9, and is the major site for regulation by Bcl-2 proteins.

Phosphorelay A signal transduction system consisting of a hybrid sensor unit, a histidine phosphotransfer protein, and a response regulator. Compared to the two-component system, the hybrid sensor unit contains an extra module, an aspartate-bearing receiver, and a histidine phosphotransfer protein is situated in between the sensor unit and the response regulator.

Phosphorylation The reversible addition, catalyzed by protein kinases, of phosphoryl groups to amino acid side chain hydroxyls on target proteins.

Plasmid Extrachromosomal DNA found in bacteria and encoding sets of functionally related genes.

Plateau potentials Stable membrane potentials occurring at depolarizations greater than that of the resting membrane potential. When a membrane is at a plateau potential it is far more excitable and can repeatedly fire action potentials even in the absence of sustained excitatory input from synapses.

Platelets Cytoplasmic fragments of bone marrow cells called **megakaryocytes** that form clots that block blood flow at sites of injury.

Pleiotropic Multifunctional.

Polypeptide hormones Small compact polypeptide growth factors that bind to receptor tyrosine kinases.

Pores Membrane-spanning proteins found in the outer membrane of Gram-negative bacteria, mitochondria, and chloroplasts forming channels that enable hydrophilic molecules smaller than about 600 Da to pass through.

Post-inhibitory rebound A strong hyperpolarization that is quickly terminated and followed by a rapid depolarization leading to the firing of an action potential.

Postsynaptic density Region of the postsynaptic dendrite terminal containing the machinery for neurotransmitter signal transduction.

Pre-initiation complex (PIC) Also known as the basal transcription machinery the PIC consists of RNA polymerase II and a set of general transcription factors.

Pre-messenger RNA (pre-mRNA) Eukaryotic RNA molecule produced by transcription from DNA. It contains exons, introns, and regulatory sequences that provide binding sites for the splicing machinery and regulatory proteins.

Primary splice sites Consist of (i) the **5′ splice site** characterized by the presence of a binding sequence containing a guanine-uracil (GU) pair within a longer GURAGU-like sequence, where R is a purine; (ii) the **branch site** characterized by the nucleotide sequence YNYURAY, where Y is a pyrimidine; (iii) the **pyrimidine tract**, a string of pyrimidine nucleotides; and (iv) the **3′ splice site** characterized by either a CAG sequence or a UAG sequence.

Primary structure The protein's covalent structure, the linear sequence of amino acids linked to one another by peptide bond plus all disulfide bonds formed during folding.

Promoter Transcriptional regulatory region of DNA containing binding and start sites for RNA polymerase II and binding sites for the transcription control elements.

Protease See proteolysis.

Protein backbone The main chain, the set of repeating $NC_{\alpha}C$ units covalently linked to one another by peptide bonds.

Protein folding The process whereby newly synthesized linear polypeptide chains spontaneously fold into functional three-dimensional forms.

Protein kinases Enzymes that catalyze the transfer of phosphoryl groups to amino acid side chain hydroxyls on protein substrates using ATP as the donor.

Protein phosphatases Enzymes that catalyze the removal of phosphoryl groups previously added to selected amino acid side chain hydroxyls on protein substrates by protein kinases.

Proteolyis The process of chopping up proteins by proteolytic enzymes, or proteases, which cleave peptide bonds at specific residues.

Proteosomes Multisubunit complexes situated in the cytosol that degrade ubiquitin-tagged proteins.

Proximal sites DNA regulatory regions situated upstream of the core promoter. Proteins that stimulate transcription when they bind at these sites are called **activators** while those that impede transcription are called **repressors**. DNA sequences that provide sites for attachment of coactivators and corepressors and mediate long-range enhancer-promoter interactions are called **tethering elements**.

Pumps Membrane-spanning proteins that actively transport ions and molecules across cellular and intracellular membranes.

Quaternary structure In multisubunit (chain) proteins, the ensemble of subunits and how they are arranged.

Quorum sensing Cell-to-cell signaling used by bacteria to determine the density of fellow bacteria in their local environment.

Reactive oxygen species (ROS) Molecules possessing unpaired electrons (free radicals) involving oxygen. These molecules have a tendency to take electrons from other molecules, in many cases breaking bonds to acquire them.

Receptors Transmembrane proteins that function as sensors of environmental stresses and as receivers of chemical messages. They transmit and, in the process, convert the signals from an external outside-the-cell form to an internal inside-the-cell one that can be understood and further processed.

Rectifying Ion channels that allow the passage of ions in one direction only.

Regulon Sets of operons located at well-separated loci along the chromosome-encoding proteins involved in a common physiological response.

Response regulator In a two-component system, this unit functions as the receiver of the transferred phosphoryl group and as an output unit for the signal. Most output response regulators function as transcription factors.

Responsive elements Transcriptional control points, consisting of short DNA sequences located in promoters, where transcription factors come together and bind in a sequence-specific manner to regulate transcription.

Reversal potential The value of the membrane potential for a particular ion species that exactly cancels out the flow of those ions through the membrane arising from concentration differences in that ion.

Rhythmic bursting Multiple sequences of action potentials in which each sequence, or burst, consists of a train of closely spaced action potentials separated by large interbust intervals.

Robustness A property of a system with respect to one or more of its parameters in which feedback damps out the effect of variations in the value of the parameter(s) on the performance of the system.

Scaffold proteins Nonenzymatic proteins that enable signaling proteins that must work together to attach in close proximity to one another.

Secondary structure The ensemble of short segments of the polypeptide chain that fold into a geometrically regular, repeating structure, such as alpha helices and beta sheets, that are stabilized by networks of hydrogen bonds.

Second messengers Signaling intermediaries that tie together events taking place at and just below the plasma membrane subsequent to ligand binding. Acting as coactivators and allosteric regulators they help to recruit and organize the proteins that function as receptors and intracellular signal transducers.

Selectivity The ability of an ion channel to pass some ions through while preventing passage of other ions.

Selectivity filter The part of the ion channel that selects which ions are able to pass through the pore.

Senescence A nondividing stage of cellular life entered into when a cell's telomeres become critically shortened.

Sensitization Strengthening of a behavioral response to a noxious stimulus through repeated exposures to that stimulus.

Sensor unit In a two-component system, this unit functions as a receptor and plasma membrane signal transducer. It possesses a histidine kinase activity that promotes autophosphorylation on a histidine residue, followed immediately by a phosphotransfer operation.

Shape complementarity The propensity of the surfaces of two molecules to geometrically fit together so that multiple contacts can be established at their interface.

Signal transduction The process of relaying messages and, in the process, converting them from one form to another that can be understood by the downstream signaling targets.

Slip bond A bond that is weakened by external applied forces. The force-driven reductions in lifetime of these bonds allow rolling leukocytes to detach from surface tethers at the right time while maintaining good adhesion to that place on the surface at earlier times.

Spike frequency adaptation Hyperpolarization of the postsynaptic membrane brought on by calcium entry into the cell decreases its excitability. The sequence of pulses exhibits an increasing time lag between successive pulses and eventually reaches a steady-state firing frequency.

Spindle oscillations 7- to 14-Hz oscillations that wax and wane with a 1- to 3-second period and are associated with early stages of quiescent sleep.

Spliceosome Machinery consisting of a family of small nuclear RNA molecules responsible for removing introns and selected exons from pre-mRNAs.

Stable (equilibrium) state Long-lived states of a system. In these states, small perturbations and thermal fluctuations are rapidly damped out so that the behavior of the system is not appreciably altered.

Steroid hormones Small lipophilic growth factors that are synthesized from cholesterol and bind to nuclear receptors.

Structural motif Stable arrangement of secondary structure elements into small compact structures.

Synaptic A signaling mode in which neurotransmitters and neuromodulators diffuse across the synaptic cleft between the membranes of a pair of pre- and postsynaptic cells.

Synaptic plasticity The use-dependent, or adaptive, changes in the efficiency of synaptic transmission between pre- and postsynaptic cells.

Telomere A capping structure consisting of a series of TTAGGG repeats and associated proteins that screen the ends of DNA strands from double-strand DNA repair machinery.

Tertiary structure The ensemble of structural motifs and domains in the protein and how they are arranged.

Tonic firing Trains of unitary action potentials generated either at regular time intervals or irregularly spaced in time.

Transcription factors Proteins that bind to DNA in a sequence-specific manner and regulate the transcription of protein-coding and associated sequences into RNA molecules.

Transduction A form of horizontal gene transfer in which a bacteriophage picks up genetic material from one bacterium and delivers it to another.

Transformation A form of horizontal gene transfer in which bacteria become competent to capture exogenous DNA from their local environment.

Trophic factors Molecules that stimulate growth and development.

Tumor suppressors Similar to oncoproteins. They, too, are proteins that operate in the signal transduction, integration, and regulatory pathways involved in cellular growth, multiplication, differentiation, and death, except, unlike oncoproteins, they normally act as brakes on growth. Whey they suffer critical mutations these brakes on growth are removed.

Two-component system A signal transduction system consisting of a **sensor unit** and a **response regulator**. The sensor unit possesses a histidine kinase activity and catalyzes the transfer of the phosphate group to the response regulator, which contains an aspartate residue that receives the transferred phosphate group.

Ubiquitination The process of tagging and preparing proteins for proteolytic destruction by the proteosome. It involves sequential operations by E1 ubiquitin-activating enzyme, E2 ubiquitin-conjugating enzyme, and E3 ubiquitin-ligase enzyme.

Vasculogenesis Creation of blood vessels to supply oxygen and nutrients to newly formed tissues and remove waste products from them.

Virulence factors Bacterial products such as toxins and surface adhesion molecules that enhance bacterial survival in hostile host environments and cause disease.

Zymogen Enzyme synthesized as an inactive precursor that is made into an active form by proteolytic cleavage and removal of a prodomain.

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