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E-mail policy and chat room:

1. The teaching assistant and I will not answer any science questions about the course material via email. Please ask these during, before, or after lecture, or during office hours. Also, please ask questions in the chat room on the eCommons website. I encourage you to answer peers' questions. I will periodically check in the chat room to make sure that the questions are getting the correct answers.
2. You may email us regarding any administrative issues.

Course overview

This course mainly examines the biology of microorganisms of the Bacterial Domain and some in the Archaeal Domain. These prokaryotic microorganisms make up the vast majority of biomass on the earth, and are capable of growing under very diverse conditions, just about any condition. Some bacteria are pathogens causing diseases but most of them help us and our environment. Throughout the course, we will learn how scientists design experiments to study these very small creatures.

Learning objectives

After completing this course, students will be able to explain the biology of bacteria. Specific topics include: (1) Bacterial and Archaeal cell structure and function; (2) Bacterial and Archaeal metabolism —how they live on just about anything; (3) How bacteria grow and divide; (4) Bacterial molecular biology; (5) Diseases caused by bacteria; (6) How prokaryotes interact with diverse environments and how we use their abilities. Student will obtain this information via lectures, participating in-class activities and readings. Students will also learn to design and critically evaluate experiments that answer questions about Bacterial and Archaeal biology.

Prerequisites

Biochemistry 100 or 100A is a prerequisite for this class.

Textbook

- ⇒ Prescott's Microbiology (9th edition). *Required.*
- The BayTree bookstore has a custom Prescott's textbook for sale, that is less expensive because it lacks chapters that are not being used for the course. The custom textbook comes with on-line access, which gives you access to the missing chapters if you are interested.
 - Three copies of the Prescott's textbook are on reserve in the Science Library.
 - Please refer to the syllabus for suggested reading. In the syllabus, I provided page numbers corresponding to the regular Prescott's Microbiology (9th edition). There is a dual page numbering system in the custom textbook. Smaller page numbers correspond to the page numbers in the regular textbook. Please make sure to follow smaller page numbers in the custom textbook as for the suggested reading.

Lecture Notes

I will provide lecture notes for each lecture at eCommon. These documents are only meant to be learning tools. They will have some missing information. You can use the notes as a format to your own notes. Please come to the class to fill-in missing information as I will not provide updated version of lecture notes. Also, please be aware that I may add new material during class.

Class Participation

This is highly recommended! We tend to comprehend at higher levels (% 70) when we participate in discussions meaning when we SAY or TALK to others. We will have class activities to facilitate your learning in a group environment with discussions.

Webcasts

Webcasts of the lectures will be available. Go to <https://webcast.ucsc.edu> to access them.

Course Website

The course website can be accessed through eCommons. Go to eCommons.ucsc.edu. Login using your Cruz ID and Gold password. You should see the course site (METX119) come up on your eCommons homepage

under “My Workspace” and Worksite Title”. It is important that you be able to access the site, so please see me if you know this will be an issue for you.

Chat Room

There will be a chat room within the course website where you can post questions. I encourage you to answer your peers’ questions in the chat room. I will check in the chat room time to time and try to answer your select questions and make sure that questions are being answered correctly. I may use your questions in exams too! So, please participate with your questions, and ask good ones!

Course Requirements

To pass this course, students must complete all three exams. Each exam will count towards one third of the final grade (100 points each, 300 points total). The questions on the exam will come from material presented in the lecture. The textbook readings will aid your understanding of the material. Don’t worry about something in the textbook that you are sure I did not go over in class. If you are unsure, please ask.

Final Grade

The final grade will be calculated from the scores on the three exams (100 points each, 300 points total). All three exams will have a “group exam” component. The group exam will be carried out immediately after the regular exam. You can benefit extra credit points from group exams when group score is higher than highest scoring individual in that group. I will give the difference as bonus for all. Maximum of 5 % extra credit points can be earned from group exams. If group score is lower, this will not change your grade. Extra credit points up to 8 % can be earned from challenge questions and one-minute papers (see below). Also, you may earn up to 3 % extra credit points just participating in “Case Study” discussions. Final grades assigned on a straight percentage. 100 - 90 % will earn a “A”, 89 – 78 % will earn a “B”, 77 – 60 % will earn a “C”, 59 – 50 % will earn a “D”, below 50 % will earn a “F”.

Challenge Questions / One-minute Papers:

During 4 random lectures (between 6/25 and 7/14), I will give you independently a set of challenge questions and a short essay writing “one-minute paper” assignments that you answer / write and hand back in class. How you do in these activities will NOT hurt your grade. You have a chance to boost your grade by up to 8 % if you get a perfect score on all of them. Challenge questions and writing assignments are meant to get you really thinking about the course material.

“Case Study” Discussions

There will be “Case Study” discussions as part of the class activity at indicated lectures. The “Case Study” materials and instructions will be posted in advance at eCommon. We will discuss exercises in these case studies in groups in class. We will then go over the “Case Study” exercise together as a class. Each group will report their findings to the rest of the class. You will find the “Case Studies” interesting because issues presented there are common and relevant to today’s problems in public health. Exercise questions intend to develop your critical thinking skills. I will pick some of the exercise questions from “Case Studies” for exams. So it pays to participate. In addition, I will give you 1 % extra credit points for participating in the activity alone. If you participate all three, this will earn you 3 % extra credit points.

Policy on missing exams

To pass this course, you must take all three exams. If you have to miss a midterm for a legitimate reason (illness, accompanied by medical doctor’s note, or family emergency), you must notify me in advance of the exam by email or in-person. Make up exams will be oral / written exams given directly by me within one week of the scheduled exam. There will be no make up final exam, therefore you must take the scheduled final.

Academic Integrity

By enrolling in the university, students are automatically agreeing to abide by its policies including those on academic misconduct. Academic dishonesty will not be tolerating under any circumstances. Plagiarism and cheating are very serious academic offenses. Penalties include a failing grade on that exam in the course, and/or suspension or expulsion from the university. Students are expected to follow university’s Rules of Conduct regarding student conduct and discipline: <http://www2.ucsc.edu/judicial/handbook.shtml>.

Students with Disabilities

“If you qualify for classroom accommodations because of a disability, please submit your Accommodation Authorization Letter from the Disability Resource Center (DRC) to me as soon as possible, preferably within the first week of the term. Contact DRC by phone at 831-459-2089 or by email at drc@ucsc.edu for more information.”

Lecture	Date	Topics	Reading in Prescott's
1	6/23	Welcome and Introduction What is microbiology? -historical perspective Microbes, prokaryotes and their diversity	Ch 1 pg. 1-19 Ch 19 pg. 459 – 464 (endosymbiotic theory) Ch 4 pg. 83 Table 4.1 Ch 5 pg. 109 Table 5.2 Ch 19 pg. 447 – 458 (phylogeny)

Lecture summary: I will introduce myself and then discuss the design, content and objectives of the course. Microbiology studies microscopic cellular organisms. Microbiologists divide cellular organisms into three domains: Bacteria, Archaea, and Eukarya. Three domain organization was emerged from the studies by Carl Woese in 1970s (Ch 9 Fig 19.3), Small Subunit (SSU) rRNA sequence comparisons. Domains Bacteria and Archaea consists of prokaryotic microorganisms. The eukaryotic microbes (protists and fungi) are placed in Eukarya. Viruses are acellular entities that are not placed in any of the domains. Microbiology is defined not only by the organisms it studies but also by the tools it uses. Microscopy and culture-based techniques have played important roles in the evolution of this discipline, including demonstration of the relationship between a pathogen and a disease (Koch's postulates). Bacteria are ancient. Mitochondria and chloroplasts are thought to evolve from bacterial endosymbionts of ancestral cells in the eukaryotic lineage. Concept of a microbial species is based on evolution. Individuals that acquire adaptive mutations are the source of microbial diversity. Horizontal gene transfer is also important in microbial evolution. Nucleic acid sequencing is the most powerful and direct method for comparing genomes. Microbes are classified by incorporating information from genetic, phenotypic, and phylogenetic analysis.

Learning outcomes: 1) The structure and function of microorganisms have been revealed by the use of microscopy. 2) Cells, organelles (e.g., mitochondria and chloroplasts), and all major metabolic pathways evolved from early prokaryotic cells. 3) The evolutionary relatedness of organisms is best reflected in phylogenetic trees.

2	6/25	Prokaryotic cell biology Microbial physiology cell movement, transport and growth	Ch 3 pg. 42 - 48 (cell envelope) pg. 53 – 62 (cell wall) pg. 69 – 76 (external structures) pg. 49 – 53 (nutrient uptake) pg. 72 - 76 (chemotaxis) Ch 14 pg. 342 – 345 (chemotaxis signaling) Ch 7 pg. 133 - 134 Fig 7.1 (growth) pg. 160 – 162 (growth phases) pg. 76 - 79 (endospore) pg. 141 – 148 (environment)
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Lecture summary: Typical bacterial cell shapes are rods and cocci, but they can be unusual as well such as spiral, filamentous or comma shapes. Bacterial cell structures include a cell wall, plasma membrane, cytoplasm, nucleoid, fimbriae, inclusions, capsule, ribosomes, and flagella. Microorganisms require nutrients that are used in energy conservation and biosynthesis. Substances move through the membrane by number of mechanisms, including passive diffusion, pores or channels, or active transport, uses metabolic energy. There are several types of cell movements: swimming and swarming by flagella, spirochete motility, twitching, and gliding motility. Motile cells can respond to gradients of attractants or repellents, a phenomenon known as chemotaxis. Bacterial signal transduction in chemotaxis is a sophisticated system, and it is one of the best-studied signal transduction in the model microbe *Escherichia coli*. Most common type of cell division among Bacteria and Archaea is binary fission. Two overlapping pathways function during bacterial cell cycle: the pathway for chromosome replication and segregation, and the pathway for septum formation. Environmental factors such as solute concentrations and water availability can adversely affect microbes. Some bacteria initiate a sporulation pathway to make spores under adverse conditions. Spore is a dormant form and resistant to heat. Each microbial species has an optimum pH and a range of temperature for growth. Microbes can differ in their response to the presence of oxygen because of the production of hydrogen peroxide, superoxide radical, and hydroxyl radical. These are toxic to cells, and these substances are destroyed by the enzymes superoxide dismutase, catalase, and peroxidase.

Learning outcomes: 1) Bacteria and Archaea have specialized structures (e.g., flagella, endospores, and pili) that often confer critical capabilities. 2) Bacteria have unique structures that can be targets for antibiotics, immunity, and phage infection. 3) The growth of microorganisms can be controlled by physical, chemical, mechanical, or biological means.

3	6/27	Prokaryotic metabolism I Catabolism: energy release and conservation Prokaryotic metabolism II Anabolism: use of energy in biosynthesis	Ch 10 pg. 210 - 219 (introduction) Ch 11 pg. 230 – 251 (chemoorganotrophy) pg. 248 – 250 (fermentation) pg. 253 – 255 (chemolithotrophy) pg. 256 – 262 (prototrophy) Ch 12 pg. 266 – 267 Fig. 12.1
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Lecture summary: All organisms require a source of carbon, energy, and electrons. Many different ways to fulfill these requirements: light as an energy source (prototrophs), oxidation of chemicals as an energy source (chemotrophs). Electrons can come from two sources; reduced inorganic substances (lithotrophs) or reduced organic compounds (organotrophs). Carbon source can be reduced form of organic molecules (heterotrophs) or CO₂ may be a sole source of carbon (autotrophs). Fueling reactions in catabolism is designed to generate three main products; *i*. ATP, which is primary molecule used to conserve energy supplied by an energy source; *ii*. reducing power, molecules that serve as a ready supply of electrons for a variety of chemical reactions; *iii*. precursor metabolites, small organic molecules that provide the carbon skeletons needed for biosynthesis of important chemical building blocks such as amino acids. When a microbe oxidizes an organic energy source, electrons are released, and then are accepted by electron carriers such as NAD⁺ and FAD. When reduced electron carriers (e.g., NADH, FADH₂) in turn donate the electrons to an electron transport chain (ETC), the metabolic process is called respiration. Two different types of respiration can occur: aerobic respiration (oxygen is the final electron acceptor) and anaerobic respiration (terminal electron acceptor is other than oxygen such as NO₃⁻, SO₄²⁻, CO₂, Fe³⁺ or SeO₄²⁻). As electrons pass through ETC, a type of potential energy called the proton motor force (PMF) is generated and used to synthesize ATP. Some microbes do not have ETC. These microbes can generate energy by fermentation. In contrast to respiration, fermentation uses an electron acceptor that is endogenous (from within the cell). This is usually an intermediate (e.g., pyruvate) of the catabolic pathway used to degrade and oxidize the organic energy source. During fermentation, ATP is synthesized by substrate-level phosphorylation (phosphate is transferred to ADP from a high-energy molecule e.g. phosphoenol pyruvate). ATP has a high phosphate transfer potential. This means that it can readily donate its phosphate to other molecules, and energy is released. The released energy can be used toward chemical, transport or mechanical work.

Learning outcomes: 1) Bacteria and Archaea exhibit extensive, and often unique, metabolic diversity. 2) Survival and growth of any microorganism in a given environment depends on its metabolic characteristics.

Lecture	Date	Topics	Reading in Prescott's
4	6/30	Microbial ecology	Ch 12 pg. 277 – 278 (N ₂ fixation) Ch 28 pg 632 – 638 (N cycle) Ch 30 pg. 664 (Wingogradsky column) Ch 31 pg. 690 – 693 (rhizobia) Ch 7 pg. 150 – 153 (biofilms, cell-cell sig) Ch 29 pg. 646 - 658 (methods)

Lecture summary: The sum of microbial, physical, and chemical processes drive the flow of elements between sediments, water and the atmosphere. This is called biogeochemical cycling. Bacteria and Archaea play an important role in biogeochemical cycling as we will discuss in the case of nitrogen that only few Bacteria and Archeae can reduce atmospheric gaseous nitrogen to ammonia (Eukaryotes can't do this). Ammonia is then readily incorporated into amino acids. The process is also known as nitrogen fixation. A specialized group of bacteria collectively called rhizobia form nitrogen-fixing nodules with legumes. This is a beneficial symbiotic association. Bacteria transfer ammonia for plant. In return, plant provides certain amino acids to bacteria. Microbes are in diverse ecosystems such as coastal, open ocean, freshwater, frozen lakes, rivers or terrestrial. Ecosystems can be modeled in Winogradsky columns. Many microbes grow as biofilms –aggregated on surfaces in nature and are profoundly affected by nutrient limitations and other adverse factors. Cell-to cell communication can occur within microbial populations in biofilms. Bacteria use chemical signals to communicate each other and carry out particular activities at high cell density. Chemical signals are also used communicating with large organisms such as animals. Most microbes can't grow in pure culture but novel approaches have been developed that have resulted in the isolation of previously uncultured microorganisms. Some of the developed methods do not require microbe cultivation include staining techniques such as fluorescent in situ hybridization (FISH), survey of SSU rRNA sequences and microarrays that have SSU rRNA as probes. Microbial community activities can also be assessed by variety of methods such as microelectrodes that measure physical and biological parameters, nutrient flux analysis, functional gene arrays to measure microbial gene expression and metaproteomics to identify proteins expressed by a microbial community. Enrichment cultures are also used to promote the growth of one type of microbe, while suppressing the growth of others. This is accomplished by designing media and culture conditions that favor the growth of the desired microorganisms but limit the growth of others.

Learning outcomes: 1) The interactions of microorganisms among themselves and with their environment are determined by their metabolic abilities. 2) Most bacteria in nature live in biofilm communities. 3) Microorganisms are ubiquitous and live in diverse and dynamic ecosystems.

5	7/2 1:00 –2:15 pm 2:15 – 3:15 pm	Exam I Group Exam	
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6	7/7	Bacterial molecular biology gene expression and regulation Genetic variation acquisition of new DNA elements and DNA mutations	Ch 13 pg. 301 – 311 (transcription) pg. 311 – 318 (translation) Ch 14 pg. 325 – 342 (regulation) Ch 18 pg. 434-436 (transcriptome analysis) Ch 13 pg. 288 – 290 Fig. 13.1 – 13.2 Ch 16 pg. 372 – 398 (genetic variation) Ch 17 pg. 418 – 419 (section 17.5)
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Lecture summary: Nature has coding and decoding mechanisms. Cellular organisms use DNA to store genetic information in codes. Cells devise methods for replicating, recoding, recording, and decoding genetic information. These processes generate polymers that are required for survival. Inheritance of characteristic traits is only possible with polymerization reactions. These polymers are DNA, RNA and proteins, which are also called informational molecules. Despite having a prokaryotic-type cell architecture, Archaea is more related to Eukaryotes in respect to genetic information processing. Bacteria have significant advantages as model organisms for genetic studies. The genome is haploid, and it replicates rapidly. The knowledge that DNA is the genetic material for cells came from transformation experiments by Fred Griffith in 1928 and by Oswald Avery in 1944 (Ch 13). The genetic code is carried in the form of nucleotide triplets called codons. Genes are nucleotide sequences that code for polypeptides, tRNAs or rRNAs. Genes of related functions are often organized into transcriptional units (operons), which are catalyzed by RNA polymerase to generate mRNA (transcription). Ribosomes are complex organelles consists of rRNA and many polypeptides. Ribosomes attach to mRNA to synthesize a polypeptide (translation). Gene expression can be controlled at many levels, including various stages of transcription, translation and posttranslation. Control mechanisms include regulatory proteins (activators or repressors), sigma factors, riboswitches, sRNAs, small chemicals such as secondary messengers, autoinducers or small peptides. Methods such as DNA microarrays or RNA-seq help us to do transcriptome analysis to understand which genes expressed at any given time. Bacterial cell has a circular DNA and one replication of origin. Replication initiates at the origin and DNA helix is unwounded. Each single stand serves as a template for the new complementary strand according to base-pairing rules. DNA replication is fairly accurate. Frequency of error rate is 10⁻⁹ or 10⁻¹⁰ per base pair. However, still genomes of microbes are subject to alterations in various ways, and this results in genetic diversity in a population. A mutation is a stable, heritable change in the nucleotide of the genetic material and that generates genetic diversity. Consequences of acquired mutation may either be neutral, detrimental or helpful in terms of the organisms' survival and evolutionary advantage. Mutations can occur in one of the two ways: *i.* spontaneous mutations; and *ii.* induced mutation in which an added substance, called mutagen causes a change in DNA. Horizontal gene transfer (HGT) is an important mechanism for creating genetic diversity in Bacteria and Archaea. Formation of new microbe by HGT requires a long stretch of DNA and incorporation of DNA by homologous recombination. Acquisition of new DNA can also occur by mobile genetic elements that DNA segments move by transposition. Genes can be transferred between cells by conjugation, which depends on direct cell-to-cell contact. Genes can also be transferred from viruses to cells by transduction.

Learning outcomes: 1) Although the central dogma is universal in all cells, the process of replication, transcription, and translation differ in Bacteria, Archaea, and Eukaryotes. 2) The regulation of gene expression is influenced by external and internal molecular cues and / or signals. 3) The traditional concept of species is not readily applicable to microbes due to asexual reproduction and the frequent occurrence of horizontal gene transfer. 4) Cell genomes can be manipulated to alter cell function. 5) Mutations and horizontal gene transfer, with the immense variety of microenvironments, have selected for a huge diversity of microorganisms.

7	7/9	Antibiotics and antibiotic resistance & "Case Study" discussion Super Bug: Antibiotics and Evolution (Part I & Part II)	Ch 9 pg. 189 – 200 (antimicrobial drugs) Ch 16 pg. 398 – 401 (antibiotic resistance) "Case Study" material will be provided
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Lecture summary: Why would a microbe expand materials and energy to make antibiotics? How do antimicrobials contribute to ecology of the microbe? Do they serve a purpose other than killing other microbes? We do not fully know the answers to these questions. This area of study is almost started serendipitously, by the rediscovery of Penicillin by Alexander Fleming in 1928 (Ch 9 pg. 190). Penicillin is a natural product produced by a mold and has a killing activity against bacteria. But, bacteria can also develop resistance to antibacterial drugs, and this happens by various ways. The target of the antibiotic could be modified by an acquired mutation in a gene that functions in the synthesis of the target. Another way is

that antibacterial drug could be inactivated by degradation by enzymes. Antibacterial drug could be pumped out as soon as it enters in cell, usually by an efflux pump or translocase. These efflux pumps can expel many different kinds of drugs therefore they often confer multi-drug resistance. Finally, cells may increase the production of the target metabolite or may have a capability acquiring target metabolite from surrounding. Genes encoding antibiotic resistance can be found on chromosomes, or on plasmids bearing antibiotic resistant genes, called R plasmids, and on transposable elements. Thus resistance genes readily move from one cell to another by HGT.

Learning outcomes: 1) Genetic variations can impact microbial functions (e.g., in biofilm formation, pathogenicity, and drug resistance). 2) Human impact on the environment influences the evolution of microorganisms (e.g., emerging diseases and the selection of antibiotic resistance).

Lecture	Date	Topics	Reading in Prescott's
8	7/11	Regulation of complex cellular processes cell-to-cell communication: quorum sensing intracellular signaling in biofilms: cyclic-di-GMP & "Case Study" discussion Super Bug: Antibiotics and Evolution (Part III)	Ch 14 pg. 346 – 348 (quorum sensing) pg. 339 – 340 (cyclic-di-GMP) "Case Study" material will be provided

Lecture summary: Some cellular processes are quite complex that require the action of multiple operons. These networks form global regulatory systems. There are many layers of regulations within these systems. Mechanisms such as global regulatory proteins, two-component signal transduction systems, phosphorelay systems, quorum sensing signals, second messengers, and alternate sigma factors are often used. Quorum sensing is a type of cell-to-cell communication mediated by small signaling molecules such as N-acylhomoserine lactone (AHL). Quorum sensing couples cell density to regulation of transcription. The regulation of bioluminescence in *Vibrio* ssp. represent one of the well-studied examples in quorum controlled gene expression. Quorum sensing plays an important role in virulence gene expression and pathogenesis in many microbes. Moreover, some microorganisms are better pathogens than others. For example, the infectious dose 50% (ID₅₀) is lower in those that are successful pathogens with higher infectivity. ID₅₀ is the measurement for number of cells needed to infect the host. These better pathogens can be distantly related to each other but they have similar common mechanisms to cause disease; that is ID₅₀ correlates with presence of virulence factors and thus acquisition of virulence factors by HGT. Virulence factors are usually encoded by specific gene sequences called pathogenicity islands. Successful pathogens adapt to selective pressures imposed by the host. Pathogens require virulence factors to assist them in accessing a host. These include the ability to adhere to host cells, produce chemicals that permit cell and tissue degradation and processes mediators that overcome host defenses (Table 35.2). Exotoxins are secreted proteins that have biological activity. Endotoxins are the lipid A components of the lipopolysaccharide found in most Gram-negative bacterial envelopes. Biofilms are a unique environment for bacteria to exchange genetic information and collectively resists antimicrobial agents and host defense mechanisms. Microorganisms have evolved many strategies for avoiding host defenses. Pathogens are transmitted to and between hosts by several common routes, including air, direct contact, arthropod vectors, and vehicles. Growth can be rapid or slow and may occur as extracellular or intracellular. Host susceptibility is an additional factor in determining infectious disease. Global emerging and reemerging infectious diseases are on the rise. Also, health-care associated infections are becoming increasingly problematic. Health-care associated infections result from pathogens acquired by patients while in a hospital stay. This is usually caused by noninvasive bacteria, which are part of the normal human microbiota. Some examples are methicillin- and vancomycin-resistant *Staphylococcus aureus* (MRSA and VRSA, respectively). The key factor for this outcome is the excessive or inappropriate use of broad-spectrum antibiotics. *Pseudomonas aeruginosa* is a ubiquitous opportunistic pathogen that suppresses host immune response when forms biofilms in the lungs of cystic fibrosis patients (Fig 35.8). Phagocytes cannot fully destroy *P. aeruginosa* biofilms. *Yersinia pestis* is the causative agent of plague. It is transmitted through flea-rodent-human by direct contact or inhalation of contaminated airborne droplets. *Y. pestis* multiply in the blood and lymph. *Listeria monocytogenes* is an intracellular pathogen. This pathogen invades host cell and also releases its toxin. *L. monocytogenes* is transmitted through contaminated food.

Learning outcomes:

1) Microorganisms and their environment interact with and modify each other. 2) Microorganisms, cellular and viral, can interact with both human and non-human hosts in beneficial, neutral, or detrimental ways.

9	7/14	Why don't we get sick all the time? Basic immunology Pathogenesis disease transmission bacterial toxins <i>Pseudomonas</i> (waterborne, biofilm) <i>Yersinia</i> (arthropod-borne) <i>Listeria</i> (food-borne)	Ch 33 pg. 723 – 728 (innate immunity) pg. 735 – 739 (cells of immune system) pg. 743 – 748 (phagocytosis) Ch 35 pg. 789 – 795 (pathogenesis) pg. 797 – 798 (exotoxins) pg. 802 – 806 (transmission) Ch 39 pg. 914 – 919 (tetanus, botulism) Table 39.3 – 4, Box 39.3, Fig. 39.25 Ch 37 pg. 841 – 843 (Health-care acquired) Ch 35 pg. 799, 801 Fig. 35.8 (<i>Pseudomonas</i>) Ch 39 pg. 910 Box 39.2 (biofilm) Ch 39 pg. 899 – 900 (<i>Yersinia</i>) Ch 41 pg. 964 – 965 (<i>Listeria</i>)
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Lecture summary: There are two interdependent components of the immune response to invading microorganisms and foreign material; innate resistance and adaptive immune response. Innate resistance is a general mechanism and it offers substantial host defense. This non-specific response has no immunological memory; that is, nonspecific. The adaptive immune response has three major functions: *i.* to recognize that anything is foreign to the body ("non-self"); *ii.* to respond to this foreign material; and *iii.* to remember the foreign invader.

Learning outcomes: 1) Microorganisms and their environment interact with and modify each other. 2) Microorganisms, cellular and viral, can interact with both human and non-human hosts in beneficial, neutral, or detrimental ways.

10	7/16 1:00 – 2:15 pm 2:15 – 3:15 pm	Exam 2 Group Exam	
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11	7/18	<i>Salmonella</i> (food-borne) <i>Vibrio</i> (waterborne) <i>Legionella</i> (airborne) & "Case Study" discussion <i>Helicobacter pylori</i> and the Bacterial Theory of Ulcers	Ch 39 pg. 922 – 923 (<i>Salmonella</i>) Ch 37 pg. 837 Box 37.4 ("Typhoid Mary") pg. 918 – 920, 832 Box 37.2 (<i>Vibrio</i>) pg. 889 – 991 (<i>Legionella</i>) "Case Study" material will be provided
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Lecture summary: Some food and waterborne diseases of the intestinal tract caused by bacterial action on the cells of intestine. Others result from bacterial toxins. Over 2000 *Salmonella* serovars isolated from patients were traced back to one single source, *Salmonella enterica*. All caused Salmonellosis (*Salmonella* gastroenteritis). Typhimurium and Enteritidis are the most commonly isolated serovars from humans. This bacterium is found in the intestinal tracts of birds and other animals. Humans acquire *Salmonella* from contaminated water or food sources. Once ingested, *Salmonella* multiplies and invades intestinal mucosa, where they produce an enterotoxin and cytotoxin that destroys epithelial cells by inhibiting protein synthesis. Abdominal pain, cramps and diarrhea are common symptoms and the patient sheds high numbers of bacteria during the acute phase of disease. *Vibrio cholerae* is a true pathogen of humans. It is naturally found in terrestrial brackish waters. Small planktons such as copepods are the reservoir for *V. cholerae*. Pathogen transmission usually occurs by contaminated drinking water or food sources. Once the bacterium passes acidic stomach, it naturally colonizes small intestine and produces cholera toxin (cholera toxin). The toxin has A and B subunits in which the A subunit enter inside intestinal epithelial cell and it activates host adenylate cyclase enzyme by the addition of ADP-ribosyl group. This causes patient to lose high amount of water and dehydrate. Absorption of sodium ions is inhibited in this process. Thus, patient experiences a loss of electrolytes as well. If not treated immediately, patient can die from it. In the year 1976 with the news of an outbreak of pneumonia, *Legionella pneumophila* made its appearance. This bacterium was not known for its ability to cause disease previously. It is naturally found in soil and fresh water ecosystems, associating with amoebae and protozoa as reservoirs. Also, it is found in large numbers in air-conditioning systems. *L. pneumophila* transmission occurs through air. Bacterium finds its way to respiratory track and enters inside alveolar macrophages and multiplies inside the phagosomes of macrophages. It also produces cytotoxic exoprotease, which causes tissue damage. Since it is an intracellular pathogen, human-to-human transition can't occur. Elimination of the risk factors then could be chlorination, ozonation, heating of water and the cleaning of water-containing devices. About 50% of the world's human population estimated to be infected with *Helicobacter pylori* (Ch 39 pg. 904). *H. pylori* transmission believed to occur through direct contact (human-to-human). *H. pylori* colonizes only gastric mucus-secreting cells. Adherence to these cells believed to occur through surface fimbriae. *H. pylori* binds to Lewis B antigens, a part of blood group O. *H. pylori* also binds to the monosaccharide sialic acid, found in the glycoproteins on the surface of gastric epithelial cells. *H. pylori* is capable of producing significant amount of urease enzyme in which its activity increases local pH. This is helpful for bacterium's survival in highly acidic stomach environment. Virulence factors such as proteases, phospholipases together with host-induced inflammatory response potentially cause epithelial cell damage leading to development of gastric ulcers.

Learning outcomes:

- 1) Microorganisms and their environment interact with and modify each other.
- 2) Microorganisms, cellular and viral, can interact with both human and non-human hosts in beneficial, neutral, or detrimental ways.

Lecture	Date	Topics	Reading in Prescott's
12	7/21	Human microbiota general principles for how pathogens interact with humans & "Case Study" discussion Danielle's Difficulty: Risks, Treatments, and Prevention of <i>Clostridium difficile</i>	Ch 32 pg. 699 – 700 pg. 713 – 720 "Case Study" materials will be provided

Lecture summary: Symbiosis in a broader sense defines two unrelated organisms that live together. Human body is a diverse environment in and on which specific niches are formed, thus the microbes constitute microbial ecology of each human. We carry about 10 times more microbes than our own cells. Microorganisms commonly associated with the human body are known as the normal microbiota. Acquisition of normal microbiota represents a selective process, where a niche may depend on cellular receptors, surface properties, or secreted products. Microbiological niche is also related to age, gender, diet, nutrition, and environment. The human Microbiome Project is evaluating the role microbial genes and their products have in maintaining homeostasis in the host. Early indications suggest a much greater role for coevolution in defining microbial-human relationships. Many of the normal host microbiota compete with pathogenic microorganisms. An opportunistic microbe is generally harmless but it may become pathogenic when move to a different body location or a compromised host. A shift in proportions in a population can also generate a disease condition. For example, antibiotic-associated colitis is a spectrum of disease caused by overgrowth of *Clostridium difficile*. *C. difficile* is part of the human intestinal microbiota but is kept at low numbers by other bacteria. However, when the other bacteria are killed or inhibited by antibiotic treatment, *C. difficile* grows unchecked. The *C. difficile* associated diseases include uncomplicated diarrhea, pseudomembranous colitis, and toxic megacolon, which can in some instances, lead to sepsis and even death. *C. difficile* is an anaerobic, spore forming bacteria. It produces enterotoxin (toxin A) and cytotoxin (toxin B), both of which are responsible for the inflammation of the gut and diarrhea. *C. difficile* is commonly associated with diarrhea in hospitalized patients. This is due to the spores, which can be easily transmitted to one patient to another patient.

Learning outcomes:

- 1) Microbes are essential for life as we know it and the processes that support life.
- 2) Microorganisms, cellular and viral, can interact with both human and non-human hosts in beneficial, neutral, or detrimental ways.
- 3) Because the true diversity of microbial life is largely unknown, its effects and potential benefits have not been fully explored.

13	7/23	Food microbiology microbial growth and food spoilage microbiology of fermented foods and probiotics & Discussion of original paper "Plant lesions promote the rapid multiplication of <i>Escherichia coli</i> O157:H7" Brandl, M. T. 2008	Ch 41 pg. 964 - 966 (food-borne disease outbreak) pg. 965 Table 4.3 (food-borne-pathogens) pg. 969 – 975 (fermented foods) pg. 976 – 977 (probiotics)
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Lecture summary: As one can see in history, humankind long ago figured out how to harness microorganisms to transform raw foods into gastronomic delights, including chocolate, cheese, pickles, sausages, soy sauce, wines and beers. Another side of it is that microorganisms play a role in food spoilage too. Thus, there are two opposing roles of microorganisms in food production and preservation. We must consider microbial spoilage of food and take necessary precautions in food-borne disease outbreaks. Pathogens such as *Salmonella enterica*, *Campylobacter jejuni*, *Listeria monocytogenes*, and *Escherichia coli* can be transmitted by the food to the susceptible host. Food-borne infections involve the ingestion of the pathogen, followed by its growth in the host, including tissue invasion or the release of toxins. However, microbial growth in food products also can result in food intoxication. Intoxication produces symptoms shortly after the food is consumed because growth of the disease-causing microorganism is not required. Food-borne infection and intoxication sometimes hard to separate because toxins produced in the food can be associated with microbial cells or can be released by microbes growing in the host. The Enterohemorrhagic *E. coli* O157:H7 (EHEC) is known to cause life-threatening complication called hemolytic uremic syndrome with bloody diarrhea (Ch 39, pg 920 - 922). EHEC produce a Shiga-like toxin, in which the toxin is believed to damage vascular endothelial cells. EHEC naturally inhabits the intestine of mammals and its transmission can occur through the food that is contaminated with animal manure. **Fermented foods.** Dairy products can be fermented to yield a wide variety of cultured milk products. Throughout the world, at least 400 different fermented milks are produced that the economic value is high. Microbial growth causes a change in chemical properties or texture that allows product to be stored extended periods. A wide range of microbes carries out fermentation in food microbiology. These include lactic acid bacteria (LAB), acetic acid bacteria (AAB), *Streptococcus thermophiles*, and several yeasts. Growth of

lactic acid-forming bacteria can coagulate milk solids. These solids can be processed to yield a wide variety of cheeses. Both bacteria and fungi are used in cheese production processes. Wine is produced from pressed grapes by yeast (alcoholic fermentation) but the clearing and flavor development occurs during the aging process by bacteria (malolactic fermentation). Beer and ale are produced from cereals and grains. Starch found in these substrates is first hydrolyzed and fermentable worth is produced. Alcoholic fermentation is then carried out by yeast. Probiotic foods are distinguished from other foods because they have live-microbes in them. Specific microbial products associated with probiotics have a profound influence on immune system function, and Lactobacilli and Bifidobacteria have been shown to stimulate immune maturation and minimize inflammation.

Learning outcomes: 1) Microorganisms and their environment interact with and modify each other. 2) Humans utilize and harness microbes and their products.

Lecture	Date	Topics	Reading in Prescott's
14	7/25 1:00 –2:15 pm 2:15 – 3:15 pm	Exam 3 Group Exam	