CELL BIOLOGY [BI 203 / BI 281] Fall Term 2023

INSTRUCTOR:
Professor Uwe **BEFFERT;** e-mail: **ub1@bu.edu**, http://www.bu.edu/biology/people/profiles/beffert/
Office Hours: Wednesdays and Thursdays 12:00-1:30 PM in LSEB 506 (24 Cummington Mall).

BI218 Lab Instructor: Dr. Kristen Bushell (knb@bu.edu).
BI281 Lab instructor: Dr. Emily Taylor (et8789@bu.edu).

WEB SITE: http://www.bu.edu/tech/services/teaching/lms/blackboard/ Students must have a valid BU I.D. and Kerberos password for access (obtain through *Information Technology Help Center*, [ithelp@bu.edu], 617-353-4357). Please check the course site regularly as updates, text slides for lectures, discussion assignments, practice quizzes, mid-term exam grades and interim letter grades will be posted here. Your final course grade will be posted on *The Student Link*.

THE GOAL OF THE COURSE is to attain an understanding of the fundamental principles of cell and molecular biology. This field is not only one of the most rapidly moving areas of the life sciences, but also one that has a major impact on all our lives because of its central role in biotechnology and medicine. We therefore hope that students will not only learn the basic mechanisms that govern the behavior of cells, but also come to understand the experimental nature of contemporary research in this area of knowledge and begin to appreciate the ways in which progress in understanding cells is being made. The course focuses on providing fundamental background information as well as providing insight into experimental approaches and recent advances. Therefore, emphasis is placed on both the *"what*" (i.e., vocabulary) as well as the "*why*" and the '*how*" (i.e., concepts) underlying such understanding.

TEXTBOOK: The Cell: A Molecular Approach, Ninth Edition Oxford University Press, 2022. Several variations of the textbook are available at the BU Barnes and Noble Bookstore.

	US (USD)
Enhanced e-Book 9780197583913	**$60 (6-month access)**
Bound 9780197583722	**$194.99**
Looseleaf 9780197685570	**$146.99**
OICW 2.0: *9780197661727*	**$89.99**

LECTURES, DISCUSSIONS and LABS:

Lectures: First lecture: Tuesday, Sept. 5, 2023.
A1 section: Tue-Thurs 9:30-10:45 AM in SCI 109
A2 section: Tue-Thurs 3:30-4:45 PM in LAW AUD

Discussions: day & time according to your registration with rooms assigned by the Registrar. Discussions begin the week of Monday, **September 11**, 2023. All students (BI203 & BI281) MUST be registered for a Discussion section in addition to the lecture.

Labs (BI281 only): please check the syllabus for BI281.

PRE-REQUISITES for enrollment in this course are: CAS BI 108 and CAS CH 102 or equivalents. Concurrent enrollment in CAS CH 203 is also expected. FYI: successful completion of BI 203 fulfills a cell and molecular distribution requirement for biology majors.

GRADING AND EXAMINATIONS: THERE ARE **five** SCHEDULED EXAMINATIONS. The four mid-term exams will be held on Monday evenings 6:30-8:00 pm EST in CGS 129 and will be monitored by proctors. This time slot is part of the Registrar's *University Class Schedule*, thus scheduling conflicts are NOT acceptable grounds for missing the exam or requesting a make-up exam. Make-up exams will be scheduled only for exceptional circumstances which have been fully documented (in writing) and are at the sole discretion of the instructor. The final exam will be administered during the Final Examination period (December 15-21, 2023) and will be scheduled **by the University Registrar** at a future date. For the past several years, the final exam for this class has been scheduled for 9AM on the last day of exams, which would be Dec. 21, 2023. PLAN YOUR WINTER BREAK TRAVEL ACCORDINGLY, AS THE FINAL EXAM DATE AND TIME CANNOT BE CHANGED.

Grading Scale:

Number	Letter
90	A
85	A-
80	B+
75	B
70	B-
65	C+
60	C
55	C-
50	D
0	F

Examplify by EXAMSOFT

We will be using a secure software system called Examplify by ExamSoft to take midterms and the final exam in BI203. You will use your own laptop, tablet, or iPad to take the exams. You will be able to download the encrypted test file the day before the exam and then come to the examination room to receive a code to complete the exam. If you require a laptop or tablet to take your exam, then please let your professor know well ahead of the exam. You will be given instructions on how to access your account, which is free to you. If you need assistance with your device or need a temporary device for testing purposes, then please let your instructor know so that arrangements can be made.

BI 203 GRADING:

3 Mid-term Exams (best 3 out of 4)	45%
Discussion*	10%
Lecture questions	20%
Cumulative Final Exam	25%

BI 218 GRADING:

3 Mid-term Exams (best 3 out of 4)	32%
Discussion*	8%
Lecture questions	20%
Cumulative Final Exam	20%
Lab grade	20%

BI 281 GRADING:

3 Mid-term Exams (best 3 out of 4)	30%
Discussion*	7.5%
Lecture questions	18.75%
Cumulative Final Exam	18.75%
Lab grade	25%

*Discussions will be graded on attendance and participation. Final course letter grades should be available on *The Student Link* within 96 hours following the final exam [not including weekends].

TOPHAT: We will be using the Top Hat (www.tophat.com) classroom response system in class. You will be able to submit answers to in-class questions using Apple or Android smartphones and tablets, laptops, or through text message. You can visit the Top Hat Overview (https://success.tophat.com/s/article/Student-Top-Hat-Overview-and-Getting-Started-Guide) within the Top Hat Success Center which outlines how you will register for a Top Hat account, as well as providing a brief overview to get you up and running on the system. **Please remember to only use your BU email, official student name (no alternate or nicknames) and enter your student ID.**
Should you require assistance with Top Hat at any time, due to the fact that they require specific user information to troubleshoot these issues, please contact their Support Team directly by way of email (support@tophat.com), the in app support button, or by calling 1-888-663-5491.

DISABILITY SERVICES: If you will need additional time or a separate room for testing, you must work with the *Office of Disability Services* (19 Deerfield St., 2nd floor, 353-3658 [access@bu.edu]), and provide the instructor of this course at least one week prior to the first exam with full documentation from this Office in order to arrange these services. *Failure to provide written documentation prior to the first scheduled exam will result in denial of such services.*

PIAZZA: Rather than emailing questions to the teaching staff, I encourage you to use Piazza, an online forum where students can post questions anonymously and have them answered by teaching staff or other students. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Please sign up here: piazza.com/bu/fall2022/bi203
The homepage for the class will be here: piazza.com/bu/fall2022/bi203/home

EDUCATIONAL RESOURCE CENTER AND FREE PEER TUTORING:
The ERC focuses on helping students to become stronger learners through several free programs and services designed to complement your experience in class. Professional staff are available to help you craft a customized plan for academic success and to help you get connected to the wide variety of resources available at BU. In addition, free Peer Tutoring is available as another support for this course (subject to availability). For more information on these and other services: www.bu.edu/erc

STATEMENT ON COPYRIGHTED COURSE MATERIALS:
The syllabus, course descriptions, text slides, all recordings and handouts created by the Professors of this course, and all class lectures, are copyrighted by Boston University and Professor Beffert. Except with respect to enrolled students as set forth below, the materials and lectures may not be reproduced in any form or otherwise copied, displayed, or distributed, nor should works derived from them be reproduced, copied, displayed, or distributed without the written permission of the Professors. Infringement of the copyright in these materials, including any sale or commercial use of notes, summaries, outlines, or other reproductions of lectures, constitutes a violation of the copyright laws and is prohibited. Students enrolled in the course are allowed to share with other enrolled students course materials, notes, and other writings based on the course materials and lectures but may not do so on a commercial basis or otherwise for payment of any kind. Please note in particular that selling or buying class notes, lecture notes or summaries, or similar materials both violates copyright and interferes with the academic mission of the College and is therefore prohibited in this class and will be considered a violation of the student *Academic Conduct Code* of responsibility that is subject to academic sanctions (www.bu.edu/casadvising/advising-essentials/academic-conduct-code/).

ACADEMIC INTEGRITY:
As this course operates under the *CAS Academic Code of Conduct*, You should know and understand its provisions [available at http://www.bu.edu/academics/resources/academic-conduct-code/.] Thus, all quizzes and examinations must be your own work. However, for studying and reviewing for quizzes & examinations, you are strongly encouraged to work with your fellow students by forming study groups. Cases of suspected misconduct will be dealt with according to University guidelines and may be referred to the Dean's Office. All work submitted by a student, including responses to in-class questions, must be your own work.

BI 203 / BI 218 / BI 281 2023 SCHEDULE OF LECTURES AND EXAMINATIONS:

Lecture	Date	Chapter	Lecture Topic
1	Tue., Sept. 5	2	Introduction – Molecules and Membranes
2	Thur., Sept. 7	2	Molecules and Membranes
	Mon., Sept. 11		**DISCUSSIONS BEGIN**
3	Tue., Sept. 12	15	Plasma Membrane, Pt. 1
4	Thur., Sept. 14	15	Plasma Membrane, Pt. 2
5	Tue., Sept. 19	4	DNA, RNA, & the Genetic Code
6	Thur., Sept. 21	4	DNA, RNA, & the Genetic Code
	MON. Sept. 25 6:30pm EST	**2, 4, 15**	**Mid-Term 1 (6:30 - 8:00 PM EST in CGS 129)** Lectures 1-6
7	Tue., Sept. 26	4	Detection of Nucleic Acids and Proteins
8	Thur., Sept. 28	4	Gene Function in Eukaryotes
9	Tue., Oct. 3	4	Gene Function in Eukaryotes
10	Thur., Oct. 5	6	Chromosomes & Chromatin
	Tue., Oct. 10		**Last Day to Drop Classes without a "W" grade**
	Tue., Oct. 10		**NO CLASS: FOLLOW MONDAY SCHEDULE**
11	Thu., Oct. 12	7	The Mechanism of DNA Replication
	MON. Oct. 16 6:30pm EST	**4-7**	**Mid-Term 2 (6:30 - 8:00 PM EST in CGS 129)** Lectures 7-11
12	Tue., Oct. 17	7	DNA Repair and Recombination
13	Thu., Oct. 19	9	Transcription, pt. 2
14	Tue., Oct. 24	10	The Mechanism of Translation & Its Regulation
15	Thu., Oct. 26	10	Protein Processing & Regulation
16	Tue., Oct. 31	11	Nuclear Trafficking
17	Thu., Nov. 2	12	Protein Sorting & Transport in Eukaryotes
	MON. Nov. 6 6:30pm EST	**8-12**	**Mid-Term 3 (6:30 - 8:00 PM EST in CGS 129)** Lectures 12-17
18	Tue., Nov. 7	12	Vesicular Transport Mechanisms
19	Thu., Nov. 9	17	Cell Signaling
	Mon., Nov. 13		**Last Day to Drop Classes with a "W" grade**
20	Tue., Nov. 14	17	Signaling Pathways
21	Thu., Nov. 16	17	Signaling Pathways
	Tue., Nov. 21		
	Thu., Nov. 23		No lecture: Thanksgiving
22	Tue., Nov. 28	17	Signaling Pathways
23	Thu., Nov. 30	18	The Cell Cycle
	MON. Dec. 4 6:30pm EST	**12, 17-18**	**Mid-Term 4 (6:30 - 8:00 PM EST in CGS 129)** Lectures 16 - 23
24	Tue., Dec. 5	20	The Cell Cycle
25	Thu., Dec. 7	21	Course Evaluation; Programmed Cell Death
26	Tue., Dec. 12	22	Cancer
	Dec. 14		**Study Period**
	Final Exam Dec. 21, 9am EST (tentative)	**1-21**	**Final Exam - Lectures 1 – 25 Exact location and time determined by the Registrar**

BI203 / BI218 / BI281 Cell Biology - DISCUSSION SYLLABUS Fall 2023

Teaching Fellows (TFs): TBD

Note: office hours & contact info for all Discussion Leaders are listed under “Contacts” on the course web page. E-mail will be the most effective means of contact for all staff members.

The first Discussion meeting is during the week of September 11, 2023.

Week of:	DISCUSSION TOPIC	Notes
4 Sept.	No discussion	
11 Sept.	Active learning exercises	
18 Sept.	Active learning exercises	
25 Sept.	Midterm week – no discussion; review exam	
2 Oct.	Active learning exercises	
9 Oct.	Active learning exercises	
16 Oct.	Midterm week – no discussion; review exam	
23 Oct.	Active learning exercises	
30 Oct.	Active learning exercises	
6 Nov.	Midterm week – no discussion; review exam	
13 Nov.	Active learning exercises	
20 Nov.	Thanksgiving – no discussion	
27 Nov.	Active learning exercises	
4 Dec.	Midterm week – no discussion; review exam	

SPECIFIC CELL BIOLOGY LEARNING OBJECTIVES:

1. Understand the Molecules of the Cell
    a. Explain the properties of different types of chemical bonds.
    b. Diagram the structure of a simple carbohydrate.
    c. Compare the structures of fatty acids, phospholipids, and steroid hormones.
    d. Contrast the structures of RNA and DNA.
    e. Summarize the properties of the different groups of amino acids.
    f. Explain the roles of noncovalent bonds in protein folding.
2. Understand Enzymes as Biological Catalysts
    a. Explain why enzymes affect the kinetics of chemical reactions without changing the equilibrium between reactants and products.
    b. Summarize the mechanisms of enzymatic catalysis.
    c. Explain why regulating the activity of enzymes is important to cell function.
3. Understand the Role of Cell Membranes
    a. Illustrate the hydrophobic and hydrophilic interactions that lead to the formation of lipid bilayers.
    b. Explain the difference between integral and peripheral membrane proteins.
    c. Distinguish molecules that can diffuse through a lipid bilayer from those that require transporters to cross a membrane.
4. Describe the Structure of the Plasma Membrane
    a. Summarize the lipid composition of the plasma membrane.
    b. Illustrate how proteins are associated with the plasma membrane.
    c. Explain the significance of plasma membrane domains.
5. Describe the Transport of Small Molecules
    a. Describe the transport of small molecules by transport proteins.
    b. Contrast transport proteins and ion channels.
    c. Summarize the role of ion channels in transmission of nerve impulses.
    d. Describe the action of the sodium-potassium pump.
    e. Explain how ion gradients across the plasma membrane can drive active transport.
6. Describe Endocytosis
    a. Describe the mechanism of particle uptake by phagocytosis.
    b. Summarize the pathway of receptor-mediated endocytosis.
    c. Explain recycling of cell surface receptors.
7. Understand Heredity, Genes and DNA
    a. Explain the relationship between genes and chromosomes.
    b. Summarize the experiment that established DNA as the genetic material.
    c. Diagram the structure of DNA.
    d. Summarize the experimental evidence for semiconservative replication.
8. Understand Expression of Genetic Information
    a. Describe the roles of mRNA, tRNA, and rRNA in protein synthesis.
    b. Summarize the experimental evidence for a triplet code.
    c. Predict the effects of specific mutations on the amino acid sequence of an encoded protein.
    d. Summarize the experimental evidence for reverse transcription.
9. Understand Recombinant DNA
    a. Predict the average sizes of DNA fragments produced by cleavage with a restriction endonuclease with a known recognition site.
    b. Summarize how a fragment of host DNA is cloned in a plasmid vector.
    c. Explain how molecular cloning allows a unique fragment of DNA to be isolated from a mixture.
    d. Describe how DNA is sequenced with dideoxynucleotides.
    e. Identify the key features of a vector used to express cloned genes.
10. Detection of Nucleic Acids and Proteins
    a. Explain how DNA is amplified by the polymerase chain reaction (PCR).
    b. Summarize the methods used to separate and detect fragments of DNA or molecules of RNA.
    c. Describe how antibodies are used to detect proteins.
11. Gene Function in Eukaryotes
    a. Distinguish transient expression from stable transformation of animal cells in culture.

    b. Construct primers for the introduction of a desired mutation into a cloned DNA.
    c. Summarize the methods used to introduce mutations into homologous cellular genes.
    d. Describe the CRISPR/Cas system.
    e. Explain the difference between antisense RNA and RNA interference.
12. The Structure of Eukaryotic Genes
    a. Diagram the structure of typical genes in bacteria, yeast, and humans.
    b. Explain how an intron can encode a functional protein.
    c. Show how alternative splicing can generate multiple different proteins from a single gene.
13. Noncoding Sequences
    a. Distinguish miRNAs from lncRNAs.
    b. Describe the different types of repetitive DNA sequences.
    c. Explain how transposable elements can affect gene expression.
    d. Distinguish processed pseudogenes from pseudogenes that arose by DNA duplication.
14. Chromosomes and Chromatin
    a. Diagram the structure of chromatin.
    b. Describe the functions of centromeres and their epigenetic transmission.
    c. Summarize the role of telomeres in chromosome maintenance.
15. DNA Replication
    a. Compare the roles of DNA polymerases in E. coli with those in mammalian cells.
    b. Contrast the mechanisms of synthesis of the leading and lagging strands of DNA.
    c. Identify the proteins found at replication forks of bacteria and mammalian cells.
    d. Describe the mechanisms that ensure accurate DNA replication.
    e. Compare origins of replication in bacteria and mammalian cells.
    f. Summarize the action of telomerase.
16. DNA Repair
    a. Compare and contrast direct repair of DNA damage with the different types of excision repair.
    b. Explain why defects in DNA repair lead to cancer.
    c. Summarize the mechanisms cells use to repair double-strand breaks.
17. Transcription in Bacteria
    a. Explain how E. coli RNA polymerase initiates transcription.
    b. Diagram a bacterial promoter sequence.
    c. Describe the processes of transcriptional elongation and termination.
18. Eukaryotic RNA Polymerases and General Transcription Factors
    a. Summarize the roles of different eukaryotic RNA polymerases.
    b. Distinguish between the binding of bacterial and eukaryotic RNA polymerases to promoters.
    c. Describe the functions of the general transcription factors for RNA polymerase II.
    d. Summarize the organization of promoters transcribed by RNA polymerases I and III.
19. RNA Processing and Turnover
    a. Summarize the events involved in processing rRNAs and tRNAs.
    b. Diagram mRNA processing.
    c. Describe the roles of snRNAs in mRNA splicing.
    d. Illustrate patterns of alternative splicing.
    e. Describe RNA editing.
    f. Explain how mRNA degradation can be regulated by the environment.
20. Gene Regulation in E. Coli
    a. Explain how lactose regulates transcription of the lac operon.
    b. Distinguish between positive and negative control.
    c. Explain why repressors inhibit but activators stimulate transcription.
21. Transcription Factors in Eukaryotes
    a. Compare and contrast promoters and enhancers.
    b. Summarize the experimental approaches used to study the binding of transcription factors to DNA.
    c. Describe how activators and repressors affect transcription.
    d. Explain how transcriptional elongation is controlled.
22. Chromatin and Epigenetics
    a. Describe the effects of different histone modifications on transcription.

b. Summarize the action of chromatin remodeling factors.
c. Explain epigenetic inheritance based on histone modifications and on DNA methylation.
d. Describe the action of lncRNAs in gene repression and activation.

23. Translation of mRNA
    a. Explain the role of tRNAs in translation.
    b. Describe the structure and function of ribosomes.
    c. Contrast the initiation of translation in bacterial and eukaryotic cells.
    d. Outline the events of initiation, elongation, and termination of translation.
    e. Summarize the mechanisms that regulate translation.
24. Protein Folding and Processing
    a. Explain how chaperones facilitate protein folding.
    b. Give examples of diseases associated with protein mis-folding.
    c. Describe the reactions catalyzed by protein disulfide isomerase and peptidyl prolyl isomerase.
    d. Explain how proteolysis can convert an inactive precursor to an active protein.
    e. Summarize the modifications of proteins by additions of carbohydrates and lipids.
25. Regulation of Protein Function and Stability
    a. Explain how the binding of a small molecule can change the catalytic activity of an enzyme.
    b. Describe the roles of kinases and phosphatases in regulating protein activity.
    c. Explain how protein–protein interactions play regulatory roles.
    d. Summarize protein degradation by the ubiquitin-proteasome pathway.
26. The Nuclear Envelope and Traffic between the Nucleus and the Cytoplasm
    a. Illustrate the structure of the nuclear envelope and nuclear pore complex.
    b. Summarize how proteins and RNAs are transported into and out of the nucleus.
    c. Explain how transport across the nuclear envelope can regulate gene expression.
27. The Organization of Chromatin
    a. Explain chromosome territories and the methods used to study the organization of chromosomes within the nucleus.
    b. Summarize the relationship between transcriptional activity and chromosome localization.
    c. Describe replication and transcription factories.
28. Nuclear Bodies
    a. Explain the similarities and differences between nuclear bodies and cytoplasmic organelles.
    b. Describe the structure and function of the nucleolus.
    c. Compare Polycomb bodies and transcription factories.
    d. Summarize functions of Cajal bodies and nuclear speckles.
29. The Endoplasmic Reticulum
    a. Diagram the secretory pathway.
    b. Summarize the mechanisms that target proteins to the ER.
    c. Explain how proteins are inserted into the ER membrane.
    d. Describe protein folding and quality control in the ER.
    e. Distinguish the roles of smooth and rough ER.
    f. Explain transport to and retrieval from the Golgi apparatus.
30. The Golgi Apparatus
    a. Relate the structure of the Golgi apparatus to its function.
    b. Describe the types of protein glycosylation that take place in the Golgi.
    c. Summarize the role of the Golgi in synthesis of membrane lipids.
    d. Diagram the routes of protein export from the Golgi.
31. The Mechanism of Vesicular Transport
    a. Summarize the process of vesicle budding and cargo selection.
    b. Explain the role of coat proteins.
    c. Describe the mechanism by which vesicles fuse with the correct target membranes.
32. Lysosomes
    a. Describe the function of lysosomes.
    b. Explain how lysosomes are formed.
    c. Summarize the process of autophagy.
33. Cell Signaling
    a. Describe the principle modes of cell signaling.

b. Explain how steroid hormones regulate gene expression.
c. Compare the actions of different types of small signaling molecules.
d. Give examples of polypeptide growth factors.

34. G Proteins and Cyclic AMP
    a. Diagram the structure of a G protein-coupled receptor.
    b. Explain how G proteins carry signals to their target enzymes.
    c. Summarize the role of cAMP.
    d. Describe gene regulation by cAMP-dependent protein kinase.
35. Tyrosine Kinases and Signaling by the MAP Kinase and PI 3-Kinase Pathways
    a. Describe signaling by receptor tyrosine kinases.
    b. Compare and contrast the activities of receptor and non-receptor kinases.
    c. Explain how Ras and Raf are activated downstream of tyrosine kinases.
    d. Give an example of transcriptional regulation by MAP kinase signaling.
    e. Summarize signaling by PI 3-kinase and mTOR.
36. Receptors Coupled to Transcription Factors
    a. Compare and contrast TGFß/Smad and JAK/STAT signaling.
    b. Describe the NF-kB pathway.
    c. Explain the roles of proteolysis in the Wnt and Notch pathways.
37. Signaling Dynamics and Networks
    a. Diagram a feedback loop.
    b. Explain how the dynamics of signaling can alter biological response.
    c. Summarize the role of crosstalk in integrating cellular response to extracellular stimuli.
38. The Eukaryotic Cell Cycle
    a. Summarize the phases of the cell cycle.
    b. Describe growth factor regulation of cell cycle progression.
    c. Explain the significance of cell cycle checkpoints.
39. Regulators of Cell Cycle Progression
    a. Summarize the experiments that led to the discovery of MPF.
    b. Explain the role of cyclins.
    c. Describe the mechanism by which growth factors regulate cell cycle progression.
    d. Explain how the initiation of DNA replication is controlled.
    e. Summarize the operation of DNA damage checkpoints.
40. The Events of M Phase
    a. Describe the stages of mitosis.
    b. Summarize the targets of mitotic kinases.
    c. Explain the mechanism of chromosome condensation.
    d. Illustrate the operation of the spindle assembly checkpoint.
    e. Contrast cytokinesis in animal and plant cells.
41. Cell Renewal and Cell Death
    a. Give examples of tissue maintenance by the proliferation of differentiated cells.
    b. Summarize the key properties of stem cells.
    c. Explain the role of stem cell in bone marrow transplantation.
42. Programmed Cell Death
    a. Describe the events that characterize apoptosis.
    b. Explain the role of caspases in programmed cell death.
    c. Summarize the activities of Bcl-2 family members.
    d. Describe signaling pathways that prevent or induce apoptosis.
    e. Contrast cell death by autophagy or necroptosis with apoptosis.
43. The Development and Causes of Cancer
    a. Explain the difference between benign and malignant tumors.
    b. Describe tumor progression.
    c. Summarize the properties of cancer cells.
    d. Compare cancer induction by chemicals and viruses.
44. Oncogenes
    a. Explain how retroviral oncogenes were identified.
    b. Contrast oncogenes and proto-oncogenes.

c. Describe the way in which oncogenes are formed in human cancers.
d. Summarize the function of oncogene proteins.

45. Tumor Suppressor Genes
    a. Contrast tumor suppressor genes and oncogenes.
    b. Give examples of the functions of tumor suppressor gene products in signal transduction, cell cycle progression, and cell survival.
    c. Explain the major types of genetic alterations in human cancer.
46. Molecular Approaches to Cancer Treatment
    a. Explain the importance of early diagnosis.
    b. Describe the basis for selectivity of oncogene-targeted drugs.
    c. Summarize strategies of immunotherapy.