

Cross-Curricular Discussion

After students have had a chance to review the article "[Cancer's sweet cloak](#)," lead a classroom discussion based on the questions that follow. You can copy and paste only the questions that apply to your classroom into a different document for your students. Before starting the discussion, have your students watch Carolyn Bertozzi in "[The sugar coating on your cells is trying to tell you something](#)," a TedxStanford video. You may also encourage your students to explore some additional resources listed below.

Recommended textbook references on the biochemistry of sugars and other molecules, cancer and the immune system:

- Theodore E. Brown *et al.* *Chemistry: The Central Science*. 14th ed. Pearson, 2017. (See Chapter 24 on biological molecules.)
- Lisa Urry *et al.* *Campbell Biology*. 11th ed. Pearson, 2016. (See Chapter 5 on biological molecules; Chapters 11, 12 and 18 on various aspects of cancer; and Chapter 43 on the immune system.)
- Denise R. Ferrier. *Lippincott Illustrated Reviews: Biochemistry*. 7th ed. LWW, 2017.
- Lauren Sompayrac. *How Cancer Works*. Bartlett, 2004.
- Lauren Sompayrac. *How the Immune System Works*. 5th ed. Wiley, 2016.
- Lauren Pecorino. *Molecular Biology of Cancer: Mechanisms, Targets and Therapeutics*. 4th ed. Oxford, 2016.
- Abul K. Abbas, Andrew H. Lichtman, and Shiv Pillai. *Cellular and Molecular Immunology*. 9th ed. Elsevier, May 26, 2017.

CHEMICAL AND PHYSICAL SCIENCES

Discussion Questions:

1. Summarize the molecular composition of proteins. [*Proteins are long chains of amino acids joined together by peptide bonds. Amino acids have an amine or ammonia ($-NH_2$ or $-NH_3^+$) group at one end that assumes a positively charged state at normal physiological conditions (pH approximately 7), a carboxylic acid ($-COOH$ or $-COO^-$ with double bonds between one of the oxygens and the carbon) on the other end that assumes a negatively charged state at normal physiological conditions, and a CH bonded to a hydrocarbon side chain referred to as R. There are 20 common amino acids, which differ from each other in their side chains. Those side chains can be anything from a simple hydrogen to complex rings of atoms. Shorter proteins are sometimes called peptides.*]
2. What are lipids? Describe their typical chemical composition and physical properties. [*Lipids are fatty*

acids, triglycerides, cholesterol and other similar molecules. They are composed of mostly carbon (C) and hydrogen (H) atoms, so they don't have much electrical charge or electrical polarity. Because water molecules (H₂O) are very polar (fairly negative oxygen and fairly positive hydrogens), lipids are hydrophobic – they are insoluble in water. Thus lipids will float on the top of water or form clumps. That's why you have to use soap (another lipid) to get greasy residue off dinner plates, instead of simply rinsing them with water. Among other things, lipids form the outer membranes of cells. Lipids in soap and in cell membranes have charged phosphates connected to one end; the charged end can interact with water.]

3. What are carbohydrates or, more simply, sugars? [Sugars, or carbohydrates, are composed of carbon (C), hydrogen (H) and oxygen (O). The most well-known example is glucose (simple or blood sugar, C₆H₁₂O₆). Other examples are fruit sugar (fructose), table sugar (sucrose) and milk sugar (lactose). Individual sugars can be strung together in various ways to make everything from starch to cell walls. Sugars may be called glycans or saccharides when they are part of other molecules.]

Extension Prompts:

4. Define a peptide bond and the reaction that occurs when it is formed. [Peptide bonds form as a result of a dehydration synthesis reaction between two amino acids. Specifically, the carboxyl group of one amino acid bonds with the amino group of a second amino acid and a water molecule is produced.]
5. What is meant by secondary, tertiary and quaternary structures of a protein? [Interactions of the amino acids within a sequence as well as interactions with the surrounding environment contribute to a protein's secondary, tertiary and quaternary structures. Alpha-helices and beta-sheets (parallel- and antiparallel-pleated sheets) are secondary structures. Tertiary structures are formed when all of the alpha-helices and beta-sheets fold into a three-dimensional structure. When proteins are made up of more than one polypeptide chain, the three-dimensional organization of the protein subunits is called the quaternary structure.]
6. What are lipoproteins? What are glycoproteins? What are glycolipids? [Lipoproteins: soluble proteins that combine with lipids to transport them in blood plasma. Glycoproteins: sugar and protein molecules bonded together. Glycolipids: sugar and lipid molecules bonded together.]

Chemical and Physical Sciences Question Bank

Summarize the molecular composition of proteins.

What are lipids? Describe their typical chemical composition and physical properties.

What are carbohydrates or, more simply, sugars?

Define a peptide bond and the reaction that occurs when it is formed.

What is meant by secondary, tertiary and quaternary structures of a protein?

What are lipoproteins? What are glycoproteins? What are glycolipids?

BIOLOGICAL SCIENCES

Discussion Questions:

1. What biological job can be served by sugars attached to proteins? *[Sugars can help the protein fold in a particular way for a specific function, give the protein a unique shape and/or sticky surface that can be recognized by some receptor, or protect the protein from degradation, among other examples.]*
2. Though they are complementary systems, what are the major distinctions of the innate/nonspecific and adaptive/acquired immune systems? How does the adaptive immune system specifically attack things that should not be in your body? How does the innate immune system nonspecifically attack things that should not be in your body? *[The innate immune system provides nonspecific defense against pathogens. Macrophages and natural killer cells respond quickly, and have membrane receptors with broad specificity. These immune cells can respond to both unique and common signals from pathogenic microorganisms. The membrane receptors that mediate adaptive immunity selectively respond to specific pathogens. Adaptive immunity is typically classified as either cell-mediated or antibody-mediated. In cell-mediated immunity, a cell binds through receptors to its target cell – known as contact-dependent signaling. An antibody-mediated response occurs when secreted antibodies combine with pathogens to make them more visible to immune cells.]*
3. How is cell growth and division controlled in normal cells? *[Cells need growth factor molecules made by the body to sustain continued growth. Cells have receptors that operate as sensors to detect the right growth factors, internal signaling pathways to communicate the signal and suppressor pathways to block cell division or even kill a cell if the correct signals are not received.]*

Extension Prompts:

4. In terms of cell growth and division, what is one of the major differences between cancer cells and normal cells? *[Cancer cells grow and divide when they are not supposed to, whereas normal cell growth is controlled. Cancer cells may have some combination of hyperactive growth factor receptors and growth factor internal signaling pathways, as well as mutated and inactive suppressor pathways that promote this growth.]*
5. How do cancer cells avoid getting attacked by the immune system? How do bacteria avoid getting attacked by the immune system? *[Among other ways, cancer cells can cover themselves with specific proteins or extra sugar molecules that silence the immune system. Bacteria can also have cell-surface “sugar cloaks.” They have sugar-rich walls of peptidoglycan or lipopolysaccharide, and some surround themselves in a polysaccharide capsule for an extra protective coat of sugar. After bacteria encounter host defense cells, they may rapidly adapt in other ways to avoid immune detection.]*

Biological Sciences Question Bank

What biological job can be served by sugars attached to proteins?

Though they are complementary systems, what are the major distinctions of the innate/nonspecific and adaptive/acquired immune systems? How does the adaptive immune system specifically attack things that should not be in your body? How does the innate immune system nonspecifically attack things that

should not be in your body?

How is cell growth and division controlled in normal cells?

In terms of cell growth and division, what is one of the major differences between cancer cells and normal cells?

How do cancer cells avoid getting attacked by the immune system? How do bacteria avoid getting attacked by the immune system?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions:

1. How can monoclonal antibodies be used to treat cancer? [*Monoclonal antibodies – identical antibodies that all specifically bind to the same molecular target – can be designed to bind to a surface feature that is found on certain cancer cells but not normal cells, or at least is found in much greater quantities on cancer cells. Then the monoclonal antibodies can be mass-produced and injected into patients. When they bind to the cancer cells, they can attract the attention of the immune system. In some cases, monoclonal antibodies are designed to carry a toxin that can be delivered to cancer cells.*]
2. If you had a two-part molecule as a drug and you wanted to test its effect compared with the individual drugs, how would you generally design the experiment? [*Test one molecule by itself, the other molecule by itself and then the two molecules linked together. If it is a successful possible treatment, the effect of either molecule by itself should be much smaller than the effect of the two linked molecules.*]

Extension Prompts:

3. What is the EC_{50} or IC_{50} of a therapeutic, and why should it be as low as possible? [*The concentration of the therapeutic required to achieve half the maximum effect is called the effective concentration or inhibitory concentration for 50 percent of the effect, EC_{50} or IC_{50} . These concentrations are commonly used as a measurement of a drug's potency. The lower it is, the less of a therapeutic you have to produce, store and administer. Minimizing the concentration of a therapeutic required to achieve a beneficial effect also minimizes the chance that there will be unwanted side effects or toxicity.*]
4. Based on the immunotherapies mentioned in the article, your knowledge of cell growth and division, and the different types of immune responses, suggest another possible cancer treatment strategy. [*Answers will vary but may focus on preventing cancer cell division or manipulating cell-surface sugars in another way.*]

Engineering and Experimental Design Question Bank

How can monoclonal antibodies be used to treat cancer?

If you had a two-part molecule as a drug and you wanted to test its effect compared with the individual drugs, how would you generally design the experiment?

What is the EC_{50} or IC_{50} of a therapeutic, and why should it be as low as possible?

Based on the immunotherapies mentioned in the article, your knowledge of cell growth and division, and the different types of immune responses, suggest another possible cancer treatment strategy.