YALE NATIONAL INITIATIVE
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Curriculum Units by Fellows of the National Initiative
2011 Volume VII: Organs and Artificial Organs

Introduction

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The human heart is one of the world's most fascinating machines, as is the human brain and kidney and each of the organs that operate in concert to make our bodies work. We now understand the working mechanisms of the organs in the human body, often in sufficient detail to describe how the organ does its job, and how it fails in cases of disease. Further, we have learned how to make artificial or synthetic organs – including the heart and the lung and the kidney – which can be used to replace human organs that have lost their function due to disease. This seminar presented an overview of the mechanisms of operation of the human body by considering each major organ, one at a time. The structure of each organ, as well as its anatomy or arrangement of parts, was examined with particular attention to how that structure leads to reliable, efficient function. Then, we discussed plans for an artificial organ, or a replacement part, for each organ that can be built with man-made materials.

The work from this seminar should be of interest to teachers at many grade levels, since instruction in biology happens throughout the K-12 curriculum. In addition, the seminar introduced elements of design, particularly design that works by mimicking nature. Because the design process depends on mathematics and geometry and creative thinking, math and art teachers may also find the work of this seminar helpful.

Specifically, the seminar covered the following topics:

1. Cell Physiology

2. Lung Physiology

3. Heart and Blood Vessels

4. Kidney, Liver, Pancreas

5. Dialysis and Related Artificial Organs

6. Tissue Engineering

7. Growing Organs in Bioreactors

8. Making Materials for Artificial Organs

9. Ethics of Organ Transplantation

The discussions in the seminar were enhanced by our reading from: *The Physiology Coloring Book*, Kapit, Macey, and Meisami, Addison Wesley Longman, Second Edition (2000); *Biomedical Engineering*, W. Mark Saltzman, Cambridge University Press (2009); and selected physiology text books including *Textbook of Medical Physiology,* Second Edition (2009) by Walter Boron and Emile Boulpaep, (B&B) Saunders Elsevier.

The Fellows prepared curriculum units that covered a breadth of information on organs and artificial organs. The material presented in the units assembled in this volume span an impressive range and are designed for use in classrooms from upper elementary (fourth to sixth grade) through high school.

Many of the units focused on material that is appropriate for high-school students. Kristin Peterson prepared a unit called "The Perfect Team–Our Heart and Lungs," which is designed for advanced high-school biology students (such as the IB Biology students that Kristin teaches). The unit provides an overview of heart/lung physiology and includes information on transplantation and health. Vanessa Vitug prepared a unit titled "Under Pressure! The Circulatory System and Hypertension," which is designed for 11th- and 12th-grade students but can also be adapted for middle-school health classes. Vanessa's unit describes the cardiovascular system with a focus on blood pressure, and includes information on health and hypertension, which is a substantial health problem in the U.S. Richard Taylor prepared a unit called "Dimensional Analysis: A Mathematical Tool to Dissect the Circulatory System," which presents concepts in dimensional analysis using examples from the cardiovascular system. Richard's unit is appropriate for introducing concepts of unit conversion and graphical analysis to high school students. Mary Whalen prepared a unit called "Your Liver, Can It Survive Your Abuse?" which is directed to high-school health and biology students. Mary's unit describes the function of the liver, and focuses on problems that can develop with viral infection and drug abuse. Eric Laurenson prepared a unit titled "Building a Heart – The Function and Mechanics," which describes the mechanical function of the heart and uses prior student knowledge of mechanics to design artificial systems that replicate heart function. Luis Magallanes prepared a unit titled "There Is Math in Your Heart," which uses concepts from cardiovascular physiology to enhance student interest in critical math skills such as scientific notation, ratio and proportion, and graphs. Deborah Smithey prepared a unit on "Heart Disease, Transplants, and New Technology," which presents information on the cardiovascular system to introduce high-school students to the underlying basis of selected heart diseases. Most of these units can be adapted for use in middle-school classrooms, as well.

Four units focused on material specifically designed for middle-school students. Shamsu Abdul-Aziz prepared a unit called "Symmetry and Fractals in the Lungs," which presents a description of fractal geometry and uses it to examine lung structure. Deanna Boyd prepared a unit titled "A Recipe for Success: The Semi-Sweet Pancreas," which introduces the important concepts on pancreas function, focusing on the role of the endocrine pancreas in producing insulin for control of sugar metabolism. Deanna's unit discusses diabetes, with particular attention to the effect of diabetes on female students and self-esteem. Stephen Griffith prepared a unit called "The Cardiovascular System: Mechanics and Dynamics," which focuses on flow through the blood vessels, with particular attention to mechanisms of oxygen delivery. Amanda Reasoner prepared a unit called "Teaching Osmosis and Diffusion through Kidney Dialysis," which uses the function of kidney to enhance understanding of the important – and difficult to teach – concepts of diffusion and osmosis.

Finally, Jolene Smith prepared a unit aimed at upper elementary students, such as the sixth graders that she teaches. The unit – called "Diabetes, the Silent Enemy" – describes the essential functions of the pancreas, with particular attention to presenting these physiological concepts together with the Navajo Philosophy of Life and Navajo language.

W. Mark Saltzman