MATERIALS SCIENCE (8B)

Technology is based on the use and application of a great variety of materials whose properties determine their potential uses. In recent decades, materials processing has focused increasingly on the synthesis of materials with entirely new properties. The rapid growth of materials processing has lead to the rapid use of materials, raising concerns about the depletion of resources and the disposal of used materials. Solving these problems will require systematic efforts that include both social and technological innovations and, hence, the need for an informed public.

The map is organized around three strands—*physical properties, synthesis and use of materials,* and *resource depletion and recycling*. In the elementary grades, the focus is on properties, uses, and recycling of objects and materials. In middle school, the focus is on the production of new materials through chemical reactions and issues related to resource depletion and disposal of used materials. In high school, the emphasis shifts to using chemical principles to design new materials and to the need for social and technological solutions to issues of depletion and disposal of materials.

This map shares many ideas with maps in Chapter 4: THE PHYSICAL SETTING, particularly the **ATOMS AND MOLECULES** and **CHEMICAL REACTIONS** maps in *Atlas 1* and **USE OF EARTH'S RESOURCES** and **ELECTRICITY AND MAGNETISM** maps in this volume.

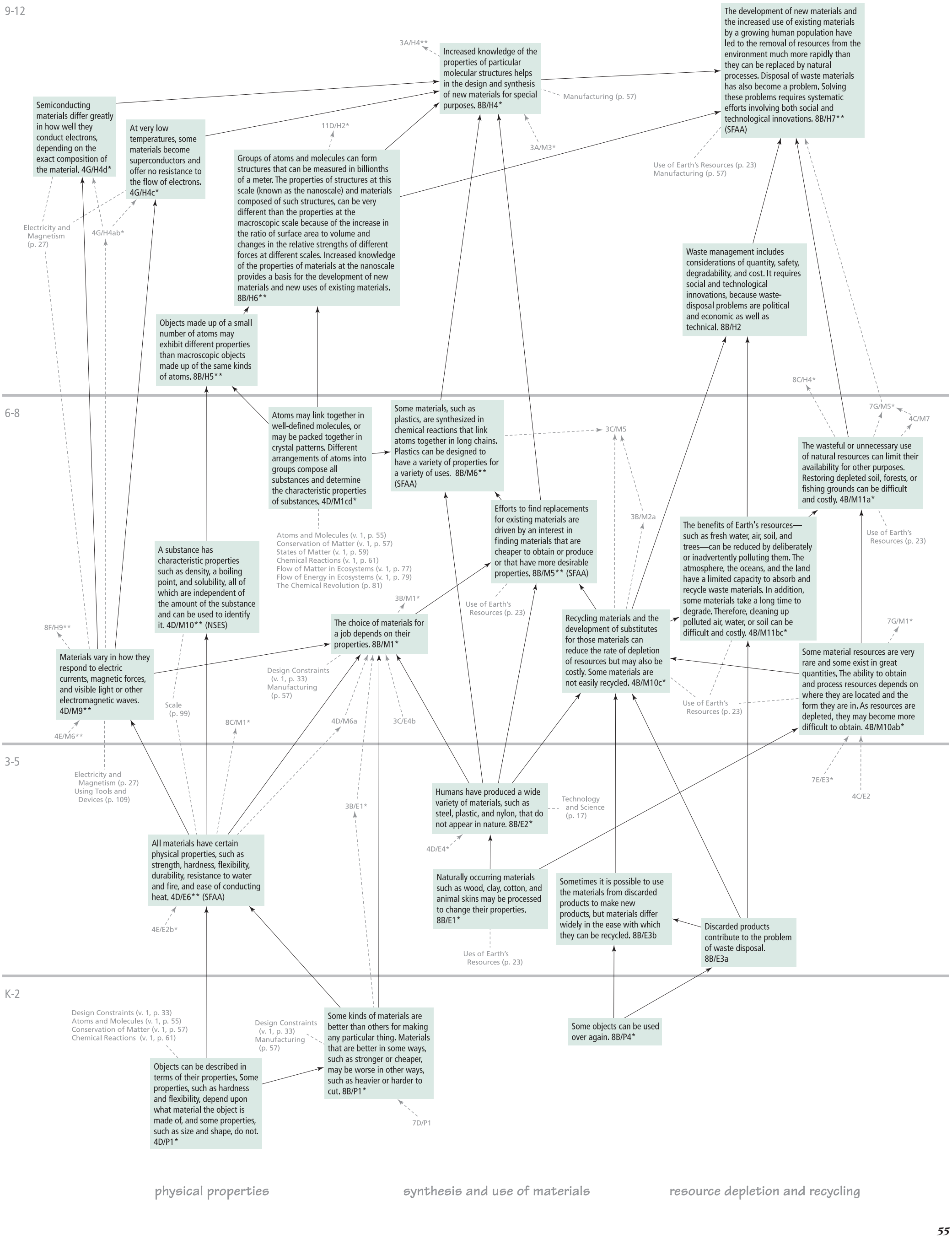
NOTES

In the *physical properties* strand, the progression of understanding begins with differentiating between objects and the materials that make them up, and between properties of objects and properties of materials. In grades 3-5, those properties are further elaborated. In grades 6-8, the concept of material is extended to the formal concept of substance that is identified by fixed and reproducible properties. Two new 9-12 benchmarks focus on the nanoscale: "Objects made up of a small number of atoms…" distinguishes properties of macroscopic objects from those of structures made up of small numbers of atoms, and "Groups of atoms and molecules…" relates differences in properties to differential effects of scale.

The *synthesis and use of materials* strand illustrates the importance of science to technology and the difficulty of clearly separating the two domains. The 9-12 benchmark "Increased knowledge of the properties…" provides a particularly appropriate context for exploring how scientific knowledge fuels technological advances and how technology creates new scientific knowledge.

RESEARCH IN *BENCHMARKS*

Benchmarks in THE DESIGNED WORLD chapter are associated with knowledge and skills needed for other literacy goals. For example, they draw upon benchmarks in THE MATHEMATICAL WORLD chapter for knowledge of shapes, estimation, measure, and the ability to use scale, and upon benchmarks in THE PHYSICAL SETTING chapter for knowledge of materials and their properties, forces, and energy. As a result, the literature on student understanding of these topics provides some insight into when and how students may understand concepts of THE DESIGNED WORLD. For example, research on student understanding of materials suggests that the tasks of classifying objects according to what they are made of and of comparing properties of materials can be challenging for early elementary-school children. In addition, elementary-school children may have limited knowledge or hold misconceptions about the origins and transformations of materials (Russell, Longden, & McGuigan, 1991).


9-12
3A/H4**
Increased knowledge of the properties of particular molecular structures helps in the design and synthesis of new materials for special purposes. 8B/H4*
Manufacturing (p. 57)
The development of new materials and the increased use of existing materials by a growing human population have led to the removal of resources from the environment much more rapidly than they can be replaced by natural processes. Disposal of waste materials has also become a problem. Solving these problems requires systematic efforts involving both social and technological innovations. 8B/H7** (SFAA)
3A/M3*
Use of Earth's Resources (p. 23)
Manufacturing (p. 57)
Semiconducting materials differ greatly in how well they conduct electrons, depending on the exact composition of the material. 4G/H4d*
At very low temperatures, some materials become superconductors and offer no resistance to the flow of electrons. 4G/H4c*
11D/H2*
Groups of atoms and molecules can form structures that can be measured in billionths of a meter. The properties of structures at this scale (known as the nanoscale) and materials composed of such structures, can be very different than the properties at the macroscopic scale because of the increase in the ratio of surface area to volume and changes in the relative strengths of different forces at different scales. Increased knowledge of the properties of materials at the nanoscale provides a basis for the development of new materials and new uses of existing materials. 8B/H6**
Electricity and Magnetism (p. 27)
4G/H4ab*
Waste management includes considerations of quantity, safety, degradability, and cost. It requires social and technological innovations, because waste-disposal problems are political and economic as well as technical. 8B/H2
Objects made up of a small number of atoms may exhibit different properties than macroscopic objects made up of the same kinds of atoms. 8B/H5**
8C/H4*
7G/M5*
4C/M7
6-8
Atoms may link together in well-defined molecules, or may be packed together in crystal patterns. Different arrangements of atoms into groups compose all substances and determine the characteristic properties of substances. 4D/M1cd*
Some materials, such as plastics, are synthesized in chemical reactions that link atoms together in long chains. Plastics can be designed to have a variety of properties for a variety of uses. 8B/M6** (SFAA)
3C/M5
The wasteful or unnecessary use of natural resources can limit their availability for other purposes. Restoring depleted soil, forests, or fishing grounds can be difficult and costly. 4B/M11a*
Use of Earth's Resources (p. 23)
Atoms and Molecules (v. 1, p. 55)
Conservation of Matter (v. 1, p. 57)
States of Matter (v. 1, p. 59)
Chemical Reactions (v. 1, p. 61)
Flow of Matter in Ecosystems (v. 1, p. 77)
Flow of Energy in Ecosystems (v. 1, p. 79)
The Chemical Revolution (p. 81)
A substance has characteristic properties such as density, a boiling point, and solubility, all of which are independent of the amount of the substance and can be used to identify it. 4D/M10** (NSES)
Efforts to find replacements for existing materials are driven by an interest in finding materials that are cheaper to obtain or produce or that have more desirable properties. 8B/M5** (SFAA)
3B/M2a
The benefits of Earth's resources—such as fresh water, air, soil, and trees—can be reduced by deliberately or inadvertently polluting them. The atmosphere, the oceans, and the land have a limited capacity to absorb and recycle waste materials. In addition, some materials take a long time to degrade. Therefore, cleaning up polluted air, water, or soil can be difficult and costly. 4B/M11bc*
3B/M1*
Use of Earth's Resources (p. 23)
8F/H9**
The choice of materials for a job depends on their properties. 8B/M1*
Recycling materials and the development of substitutes for those materials can reduce the rate of depletion of resources but may also be costly. Some materials are not easily recycled. 4B/M10c*
7G/M1*
Some material resources are very rare and some exist in great quantities. The ability to obtain and process resources depends on where they are located and the form they are in. As resources are depleted, they may become more difficult to obtain. 4B/M10ab*
Materials vary in how they respond to electric currents, magnetic forces, and visible light or other electromagnetic waves. 4D/M9**
Design Constraints (v. 1, p. 33)
Manufacturing (p. 57)
Scale (p. 99)
8C/M1*
4D/M6a
3C/E4b
Use of Earth's Resources (p. 23)
4E/M6**
3-5
7E/E3*
4C/E2
Electricity and Magnetism (p. 27)
Using Tools and Devices (p. 109)
3B/E1*
Humans have produced a wide variety of materials, such as steel, plastic, and nylon, that do not appear in nature. 8B/E2*
Technology and Science (p. 17)
4D/E4*
All materials have certain physical properties, such as strength, hardness, flexibility, durability, resistance to water and fire, and ease of conducting heat. 4D/E6** (SFAA)
Naturally occurring materials such as wood, clay, cotton, and animal skins may be processed to change their properties. 8B/E1*
Sometimes it is possible to use the materials from discarded products to make new products, but materials differ widely in the ease with which they can be recycled. 8B/E3b
Discarded products contribute to the problem of waste disposal. 8B/E3a
4E/E2b*
Ues of Earth's Resources (p. 23)
K-2
Design Constraints (v. 1, p. 33)
Atoms and Molecules (v. 1, p. 55)
Conservation of Matter (v. 1, p. 57)
Chemical Reactions (v. 1, p. 61)
Design Constraints (v. 1, p. 33)
Manufacturing (p. 57)
Some kinds of materials are better than others for making any particular thing. Materials that are better in some ways, such as stronger or cheaper, may be worse in other ways, such as heavier or harder to cut. 8B/P1*
Some objects can be used over again. 8B/P4*
Objects can be described in terms of their properties. Some properties, such as hardness and flexibility, depend upon what material the object is made of, and some properties, such as size and shape, do not. 4D/P1*
7D/P1
physical properties
synthesis and use of materials
resource depletion and recycling