

Form, Function, and Beauty

KEY QUESTION: What factors make a structure useful and attractive?

Looking Ahead

- The product development process considers human wants and needs, and also societal and environmental factors.
- Structures that are symmetrical are usually more stable and more aesthetically pleasing than those that are asymmetrical.
- Structures intended for human use need to be designed for human characteristics.
- The skills of scientific inquiry can be used to study the ergonomics of everyday tools.

VOCABULARY

symmetry

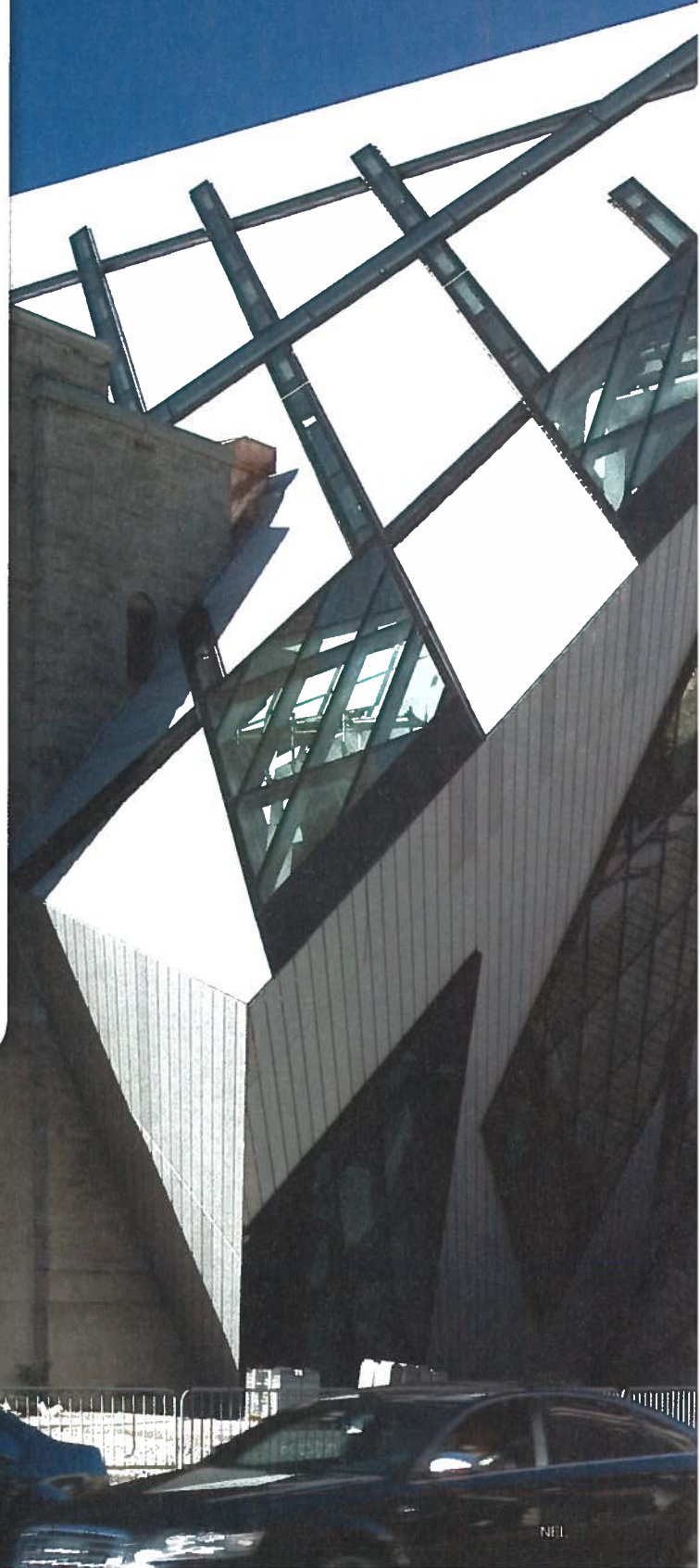
line of symmetry

aesthetics

ergonomics

repetitive strain injury

universal design



The Michael Lee-Chin Crystal

The Michael Lee-Chin Crystal is the official name of the Royal Ontario Museum's (ROM) recent addition. It is named after Michael Lee-Chin, who donated \$30 million to its construction. The addition was designed by architect Daniel Libeskind, who was inspired by the museum's gem and mineral collection and sketched his initial concept on a napkin. The original design called for stunning glass walls, a triumph of form over function.



However, it was impossible to build the Crystal as planned. The glass walls were not strong enough to support the weight of ice and snow. There were also fire and safety concerns. All of this resulted in significant changes to the outside structure. The 3000 steel beams making up the skeletal framework are now mostly covered by aluminum siding rather than glass. Only a few small slits were left for windows and light. Libeskind's original design shape, however, remains intact.

The Michael Lee-Chin Crystal opened on June 1, 2007, to a very mixed reception. Some people thought it was a striking architectural gem. Other people saw it as an ugly structure that did not match the classical design of the ROM. Many people said that it resembled a spaceship that had crashed into the ROM.

The interior design makes installing exhibits difficult. Most visitors agree that the dinosaur galleries seem to make effective use of space. However, even here, unusual angles and unused spaces are everywhere.



LINKING TO LITERACY

Process for Determining the Main Idea

To determine the main idea of a text, look for key information in the topic sentences. Often, the first sentence of a paragraph will be the topic sentence. For example, the sentence that begins with "The Michael Lee-Chin Crystal is the official..." is the topic sentence.

Here is a process you can follow to help you formulate the main idea for this text:

- 1 Locate the topic sentence for each paragraph.
- 2 Write each topic sentence in your journal or notebook. Then, cross out any unnecessary information. (You may need to change or add a few words to connect the remaining information into sentences.)
- 3 Now, state the general or "big picture" idea from these sentences in your own words. This will be the main idea of the text.

12.1

The Product Development Process



Figure 1 Many Canadian students use backpacks for school every day.

Companies consider three important sets of factors before they build a new product or redesign an existing product—design, manufacturing, and sales. To discuss the factors involved in these processes, we will focus on the design, manufacture, and sale of a specific product that you use regularly: backpacks (Figure 1).

Design Factors

A company wants to sell backpacks to students. Designers and managers hold a brainstorming session to decide what factors to consider before they begin designing and manufacturing new backpacks. Each factor listed below is followed by questions that designers and managers ask. Think of questions you would add in each category.

- **Individual users:** Should we create a one-size-fits-all backpack, or a backpack with adjustable features? Should the backpack have an outer frame, an inner frame, or no frame at all? Should we use detachable components for storage? Is a backpack the best design, or should we consider front packs or side packs?
- **Society:** Do consumers care if we transport raw materials and finished products all over the world, using valuable resources for shipping?
- **The economy:** Should the backpack components be made in Canada, or should we reduce costs by using overseas manufacturers?
- **The environment:** Should we make as many components as possible recyclable (Figure 2)?
- **Safety and health:** How can we make sure that the packs are the best size and weight to prevent back and shoulder problems? The static load should be no more than 15 % of the user's weight.
- **Legal aspects:** Do we need to worry about lawsuits? What if, without our knowledge, our suppliers have dangerous levels of toxins, such as lead, in the materials they provide?

After discussing these questions, the company begins market research to determine what features customers want in a backpack. Then, the company can decide what improvements are needed.

To learn more about the City of Toronto's garbage and its plans for recycling and composting,

Go to Nelson Science



Figure 2 From April to August 2007, the City of Toronto trucked nearly 12 000 tonnes of garbage to the Green Lane landfill near London, Ontario, almost 200 km away.

Manufacturing Factors

Companies consider factors related to the manufacturing process before the process begins. Each factor is followed by some brainstorming questions:

- **Suitability of materials:** Should the materials be waterproof? Which, if any, parts should be made of metal, hard plastic, flexible plastic, fabric, or Velcro? Will the fabric deteriorate in sunlight? How strong should the thread be? Will the materials be attractive to consumers (Figure 3)?
- **Availability and cost of materials:** Are the required materials and labour force for manufacturing available in Canada at a reasonable cost? If manufacturing is located elsewhere, are there concerns about worker rights and safety, and environmental conditions (Figure 4)?
- **Shipping costs:** How can shipping costs be kept as low as possible?
- **Disposal:** Should we make the backpacks to last, or should they break down so that we can make money selling replacements?

Following the brainstorming sessions, the company develops the new designs and manufacturing procedures for producing the new product.



Figure 3 Companies try to choose colours and styles that appeal to as many people as possible.



Figure 4 Companies using overseas manufacturers must consider worker rights and safety.

TRY THIS: Market Research for Backpacks

SKILLS MENU: planning, analyzing, evaluating, communicating



In this activity, you will use backpacks as the focus to analyze the needs and wants of the intended customers.

1. In a group, brainstorm what you think are the most important design and manufacturing factors to consider in creating backpacks. Use the factors that are described above and add more ideas of your own.
2. Choose three design factors and three manufacturing factors that your group agrees are most important. Create six to twelve survey questions for those six factors. (You can refer to the questions mentioned above, but you must add questions of your own.) Make your questions easy to answer and evaluate.
3. Discuss and record the answers to your own questions.
4. Trade survey questions with another group, and answer each other's questions.
 - A. Summarize the answers to your group's survey questions.
 - B. Analyze the answers to your survey questions and draw conclusions about each of the design and manufacturing factors your group considered.
 - C. How will the results of the survey help your group design and manufacture a better backpack?
 - D. What are some limitations of market research surveys? How can we overcome these limitations?

Mind Map

Use a mind map to note and visualize details or ideas that are related. To create a map for this text, follow these directions:

- Write the words “Sales Factors” in the centre of a blank sheet of paper.
- Write the words “packaging,” “sale price,” “advertising,” and “customer support” around the words Sales Factors.
- Draw an arrow from “Sales Factors” to each of the words you added.
- Read through the text to locate words that tell you about packaging, sale price, and so on. Write these words on your mind map.

Sales Factors

Once a product has been manufactured, it is made available to potential customers. To sell a product, the company must consider the following:

- **Packaging design, displays, and labelling:** Packaging is designed to protect the product in transport and storage. Packaging may also be used to attract customers (Figure 5). Labels provide product information and the company’s identity. What packaging and displays make backpacks more attractive to customers? What packaging is environmentally friendly? What should be on the labels?
- **Sale price:** The price of a product determines who can afford to buy it (Figure 6). The price reflects the cost of production and the profit a company makes in selling the product. What is a reasonable price for a backpack? How might the price be related to quality?
- **Advertising:** Advertising informs potential customers of the availability of products. It allows customers to compare different products. How should backpack companies advertise?
- **Customer Support:** After a product is sold, customers may need more information on the product, especially if something goes wrong. What form of customer support should companies provide? Should the support be free?



Figure 5 Displays help attract customers to a product.



Figure 6 Price determines who can afford a product.

Design, manufacturing, and sales factors are all important considerations for companies when they decide to create a new product. Companies need to ensure that what they create will be desirable to the market, but they must also consider the impact that building the product will have on society and the environment.

To learn more about the manufacturing and sales process,

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✓ CHECK YOUR LEARNING

1. What do you think is the most important set of factors for a company to consider—design, manufacturing, or sales? Explain your reasoning.
2. What three factors do companies consider before they build a new product?
3. Consider a company that would like to start designing, building, and selling new bicycles.
 - (a) Describe one economic, one environmental, and one health and safety factor the company could consider.
 - (b) Describe one packaging, one advertising, and one customer support factor the company could consider.

A Megatron in Townsville

Townsville is a community in Central Ontario. Many businesses in its downtown area are closing. Consumers are being drawn to the large shopping mall on the outskirts of town.

The Chamber of Commerce of Townsville wants to install a large high-definition television (HDTV) billboard at the main intersection of town. The proposed HDTV Megatron would be larger than the Videoboard at the Rogers Centre in downtown Toronto (Figure 1). The Chamber is hoping that having “the largest HDTV panel in Canada” will attract visitors, businesses, and investment downtown. The Megatron is very expensive. The Chamber claims that the HDTV Megatron will eventually pay for itself by attracting businesses and by selling advertising time on its screen.



Figure 1 The Videoboard at the Rogers Centre measures 34 m × 10 m and is capable of displaying 4.3 trillion colours.

The Issue

The Townsville Heritage Society is concerned about how the Megatron will look in their small, Victorian town (Figure 2). The Society thinks the new billboard will drive away tourists. The local Friends of the Environment group is worried about the amount of power the new screen will use. They are also worried about the added light pollution that may disrupt the flight of migratory birds. The townspeople are concerned about extra noise and accidents caused by drivers who are distracted by the giant screen.

Should Townsville install the Megatron? You are being asked to participate in a town hall meeting to discuss this important issue.

Goal

To evaluate the Townsville Chamber of Commerce’s plans for installing a Megatron at the main intersection of Townsville.

SKILLS MENU

- Defining the Issue
- Researching
- Identifying Alternatives
- Analyzing the Issue
- Defending a Decision
- Communicating
- Evaluating



Figure 2 How will a Megatron look in a small, Victorian town, such as Goderich, Ontario?



LINKING TO LITERACY

Writing a Persuasive Text

In your presentation, you will need to convince your audience of the benefits or costs of the Megatron. Authors persuade their readers of their position. They

- present information in a logical, organized way
- clearly express their opinions
- provide evidence to support their opinions by clearly showing the causes and effects of actions
- use words like “concern” to draw on readers’ emotions

Be sure to check that you have included all of these details in your presentation. Start by stating your position. Then, list and describe facts that support it. End with a concluding statement to restate and confirm your beliefs.

Gather Information

How will you prepare for the town hall meeting? You might investigate the purchase costs, the power cost, and how long the TV would last before needing replacement. You could research how many birds die from striking buildings and other human-made structures. What are the causes and effects of driver distraction? Where could you find more information about small town renewal projects in Ontario?

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Identify Solutions

You may want to consider the following to help you identify solutions:

- Can the Megatron be designed and constructed in a way that minimizes its negative effects on the environment and still attracts people and businesses to Townsville’s downtown?
- Are there more structural ways to revitalize Townsville’s downtown area that still fit with its Victorian style?

Table 1 offers some different points of view about the new Megatron.

Table 1 The Megatron: Points of View

Role	Points of View
Chamber of Commerce	Local businesses are failing. The Megatron will show businesses and investors that Townsville is a good place to do business.
Townsville Heritage Society	Townsville’s Victorian architecture should be preserved. The Megatron will look terrible. Tourists who are looking for small-town atmosphere will be driven away.
Friends of the Environment	Migratory birds will be killed due to the light pollution of the new sign. The Megatron wastes energy.
Townsperson #1	All that extra noise and distraction will ruin our town. There will be more car accidents.
Townsperson #2	We had to close down our business this year; everyone is shopping at the new mall. Townsville needs something to bring business back to the downtown core.

Make a Decision

Choose a point of view and make a clear decision about whether to install the Megatron or not. What criteria did you use in coming to your decision?

Communicate

Participate in the town hall meeting. When the meeting is over, write a brief report on the outcome. Explain what the final decision was and how it was made.

Symmetry in Form and Function

We immediately notice a structure's shape and size when we look at it. The shape of an object helps us identify it. The shape also helps us distinguish it from other objects. One aspect of shape is symmetry. A structure displays **symmetry** (is symmetrical) if it can be divided in half, creating two pieces that are mirror images of each other. A **line of symmetry** is an imaginary line that divides a symmetrical object into two mirror image halves (Figure 1).

symmetry: an exact reflection on opposite sides of a line dividing an object in half

line of symmetry: a line that divides an object in half; helps display symmetry

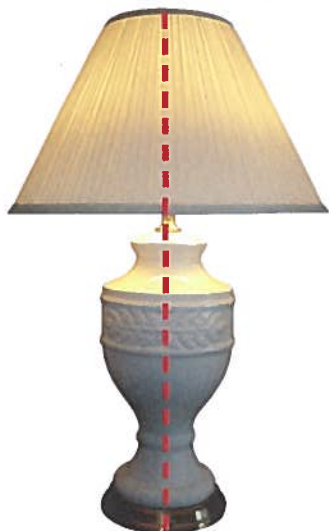
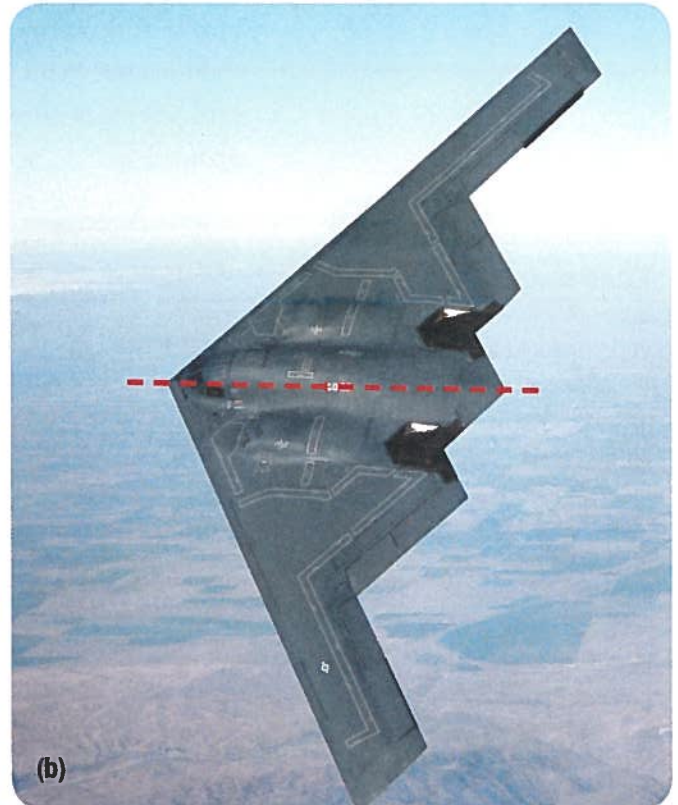


Figure 1 The CN Tower (a), jet aircraft (b), table lamp (c), and butterfly (d) all display symmetry.

Symmetry in Nature

Symmetry is an important principle in nature. Look at yourself in the mirror. Pretend that there is a line going down from your forehead, over the tip of your nose, through the middle of your chin, and then straight down the centre of your body. You will notice that the two halves of your body on each side of this imaginary line are nearly mirror images of each other. (No one is perfectly symmetrical.) The entire human body is nearly symmetrical when a line of symmetry is drawn in this way (Figure 2). Humans usually have two kidneys, two lungs, two symmetrical rib cages—even the human brain is divided into two symmetrical lobes. Is the human body symmetrical if viewed above and below the waistline?

Humans exhibit symmetry. Dogs, cats, butterflies, flowers, leaves, and sea stars all exhibit symmetry. Symmetrical structures are all around us.

LINKING TO LITERACY

Expressing Point of View

Symmetry seems to be an important factor in determining the appeal of something. The *Vitruvian Man* is shown as an example of symmetry in art, while the *Hundertwasser* building (on the next page) is an example of asymmetry in architecture.

Work with a partner to discuss ways in which Leonardo da Vinci and Friedensreich Hundertwasser's opinions about art would have differed. Then, discuss your own preferences in art—symmetry or asymmetry. Explain why you prefer one or the other.

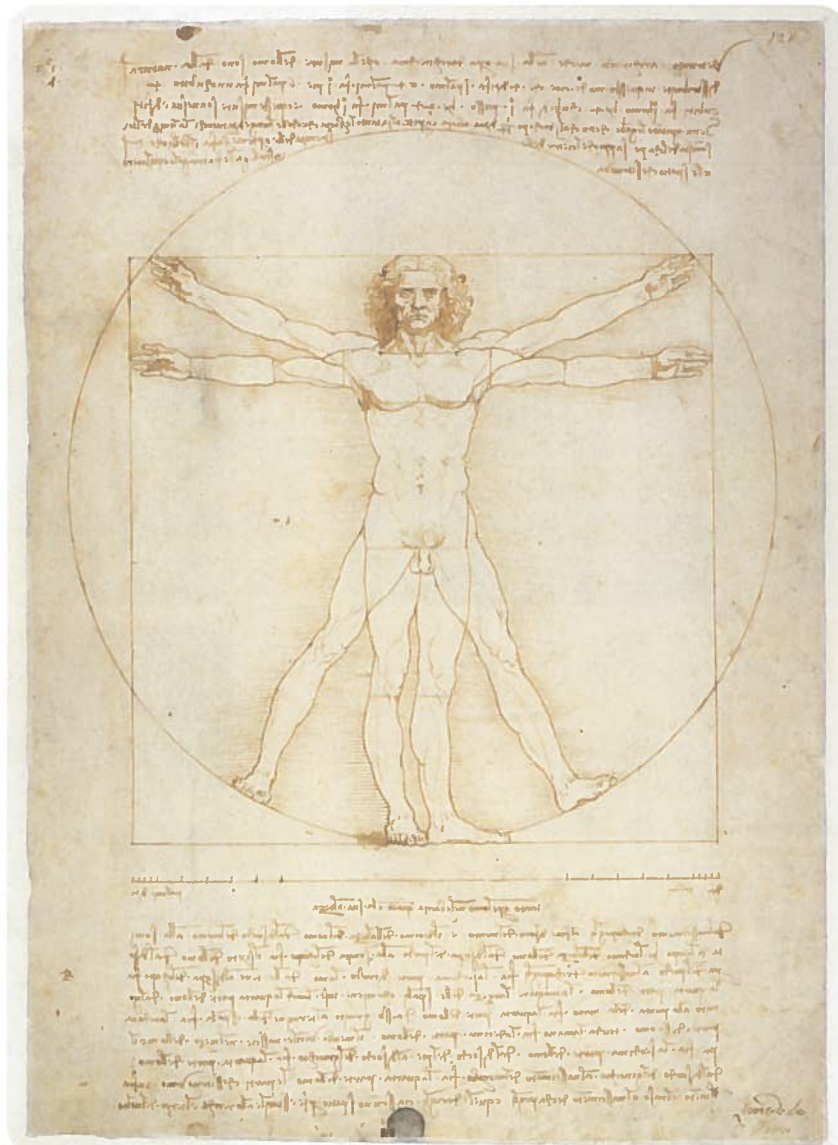


Figure 2 In 1492, Leonardo da Vinci illustrated the symmetry in the human body in one of his most famous drawings, the *Vitruvian Man*.

The Role of Symmetry

Symmetry is an important idea when considering the aesthetics of a structure. **Aesthetics** determine how visually appealing something is. Many people consider objects that are symmetrical to be more appealing than objects that are asymmetrical (not symmetrical) (Figure 3).

Asymmetrical Design

Would you like to live in a building where the walls were not straight, the floor was uneven, and none of the windows were the same size? These designs were all used in structures designed by Austrian artist Friedensreich Hundertwasser (1928–2000). Hundertwasser is famous among modern artists for rejecting symmetry as a design principle. Most of Hundertwasser's structures (Figure 4) and designs are controversial. Today, people find Hundertwasser's designs to be interesting because they are unique. It remains to be seen whether his structures will still be appreciated years from now. 🌐

aesthetics: the concept of how visually attractive or beautiful something is

To learn more about Friedensreich Hundertwasser and his designs,

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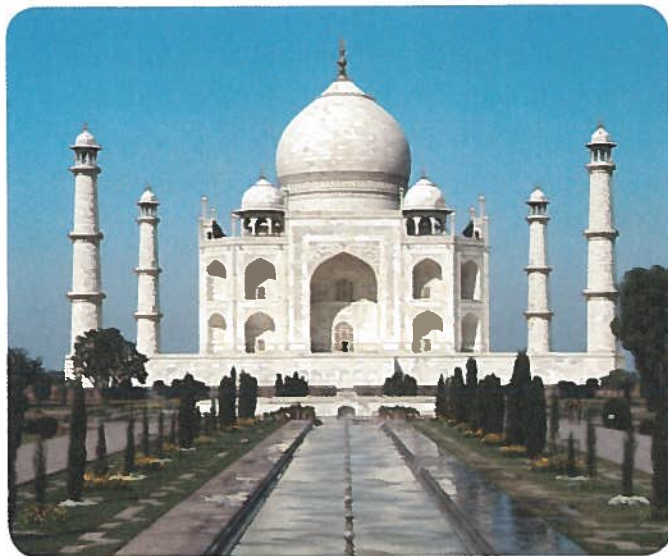


Figure 3 The Taj Mahal was designed to highlight the visual appeal of symmetry.

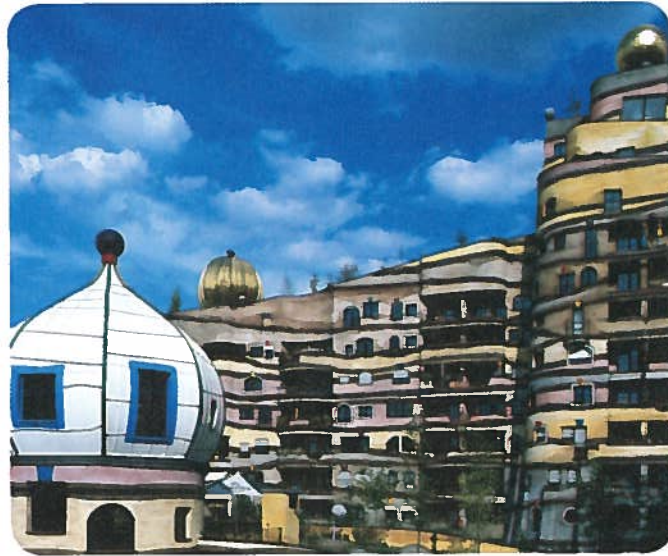


Figure 4 Hundertwasser rejects symmetry in his designs, but do they still have aesthetic appeal?



TRY THIS: Choosing an Apartment

SKILLS MENU: performing, evaluating, communicating



SKILLS HANDBOOK
8.B.2.

In this activity, you will role-play a real estate agent and an apartment hunter, and explore the benefits of symmetry and asymmetry in an apartment.

1. Work with a partner for this activity. Choose one of you to role-play the real estate agent and one the apartment hunter.
 2. The real estate agent will prepare a convincing argument on why an asymmetrical apartment is better than an apartment in a more symmetric building.
 3. The apartment hunter will evaluate the argument and decide whether it would convince him or her to live there.
 4. Now, switch roles. This time, have the new real estate agent prepare a persuasive argument on the benefits of a symmetric apartment. The new client will evaluate the argument.
- A.** Were your partner's arguments convincing? Why or why not?
- B.** Now that you have completed this activity, which apartment would you prefer? Explain.

Symmetry, Centre of Gravity, and Stability

Symmetry is usually considered attractive. It is also useful in the design of stable structures. The dead load of a symmetrical structure is usually spread more evenly along the length of the structure. This makes the structure more stable.

A designer constructs a more stable structure by considering the location of the centre of gravity in a structure's design. The location of the line of symmetry can sometimes help to locate a structure's centre of gravity. In Figure 5, the pyramid is completely symmetrical. A line of symmetry could be drawn through any of the four triangular faces of the pyramid. In this case, the centre of gravity is located directly below where the lines of symmetry would meet, deep in the very centre of the pyramid. Pyramids like this are very stable.

While lines of symmetry sometimes help to locate a structure's centre of gravity, this is not always true. A structure's centre of gravity is only located on its line of symmetry when the mass of the structure is evenly spread out. A line of symmetry is only visual. It does not account for the mass of a structure and how that mass is arranged. Consider Figure 6. The pyramid is still symmetrical. However, the centre of gravity is no longer on any line of symmetry because the mass of the pyramid is no longer evenly spread out. One side has more mass than the other side.



Figure 5 El Castillo, located in Chichen Itza, Yucatan, Mexico, was built by the Mayans between the eleventh and thirteenth centuries CE.

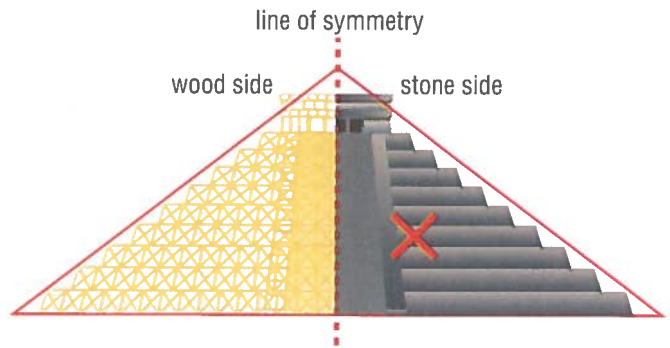


Figure 6 The left side of this pyramid has been built out of wood. The centre of gravity is no longer on the line of symmetry.

Unit Task

How can you apply your understanding of symmetry to the Unit Task?

✓ CHECK YOUR LEARNING

1. Draw three symmetrical geometrical figures. Clearly mark the line of symmetry on each figure.
2. Why is symmetry considered to be an important principle in the design of structures? Give two reasons in your explanation.
3. (a) Give two examples of symmetrical objects from nature, and two that have been built by humans.
(b) Find an example of an asymmetric structure, either human-made or from nature. Evaluate the structure in terms of stability and aesthetics.

Ergonomics: Designing for Human Comfort and Safety

You use tools every day. You may use a knife, shovel, or toothbrush (Figure 1) in your everyday life. Does the tool fit comfortably into your hand? When you type an e-mail message or open a car door, is the task completed quickly and easily? The science of designing structures and systems that help people do tasks comfortably and safely is called **ergonomics**.

Small design changes can make a big difference in a structure's ergonomics. For example, using a snow shovel can mean getting a backache from all the bending and lifting. The ergonomic snow shovel in Figure 2 has a bent handle. This type of handle reduces the amount of bending a person has to do when shovelling. The design reduces back strain and helps prevent back injuries.



Figure 1 Ergonomic designs can be applied to many everyday structures.

ergonomics: the science of using knowledge of human characteristics to design structures and systems that are comfortable, safe, and efficient



Figure 2 The bent handle of this ergonomic snow shovel means less stress on the spine and reduced risk of back injuries.

LINKING TO LITERACY

Word Origin

Sometimes knowing where a word comes from helps us to understand its meaning. The word "ergonomics" comes from the Greek words *ergon*, meaning "work," and *nomos*, meaning "natural law."

In the 1600s, doctors knew that people who worked in awkward positions for long periods of time would develop illnesses and injuries. Today, ergonomics is often used in the design of workplace tools. Workers can complete tasks faster, more accurately, and with fewer injuries using ergonomic tools and workstations. Sitting at a computer for long periods of time can cause strain to your neck, wrists, lower back, and your eyes if your workstation is organized poorly. Now imagine a factory with heavy machinery. The risk of injury increases if the tools and workstations in a factory are not ergonomically designed.

Designers can create tools, workstations, and systems that are easier, more comfortable, and safer for workers using these principles of ergonomic design:

- Tools and workstations should allow workers to change their position regularly to other equally comfortable positions. Workers could stand at a workbench or sit on a stool to complete a task.
- Tools and workstations should reduce the amount of force or effort that a task requires. Workers should never strain at an activity. They could use power tools rather than hand tools.
- Tools and workstations should promote good posture for the body. A worker's back, neck, and wrists should remain straight. His or her arms should remain close to the body when working. Equipment should be positioned within easy and comfortable reach.

LINKING TO LITERACY

Making Connections: Text-to-World

Think about what you have learned about ergonomic design. Where in your everyday life have you seen something that you think was ergonomically designed? Explain your thoughts to a partner.

TRY THIS: Analyze Your Computer Workstation

SKILLS MENU: observing, analyzing, evaluating

Computers are a part of our daily lives. If computer workstations are not ergonomic, then they can lead to injuries. In this activity, you will work with a partner to examine your computer workstation for correct ergonomics.

Equipment and Materials: computer workstation

1. Examine Figure 3. Note how the student's eye level is about 5 cm from the centre of the top of the monitor screen. The monitor and keyboard are centred in front of her. The student's feet are flat on the footrest and her wrists are flat (not bent).
 2. Have your partner sit at a computer workstation as he or she normally would do. Observe your partner's sitting position and the arrangement of the computer workstation. Make notes and a sketch of your partner's sitting position.
 3. Now switch roles and complete step 2 again.
- A.** According to your observations, is your computer workstation designed ergonomically?
- B.** What, if any, recommendations would you make to improve your computer workstation?

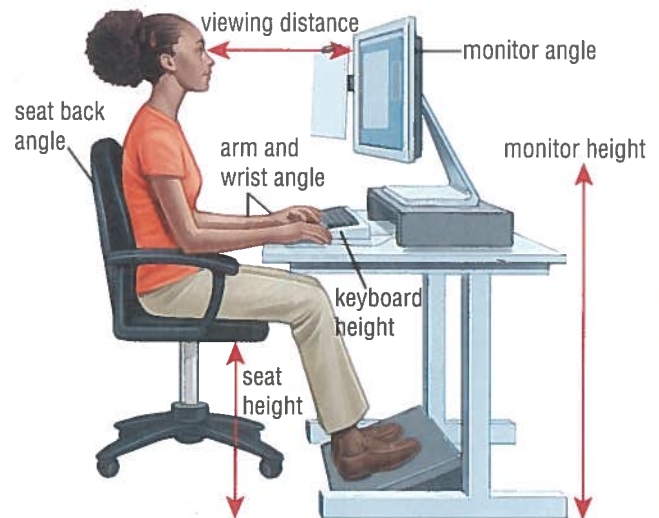


Figure 3 An ergonomic workstation

The knife, like the snow shovel, is another common tool that has been improved with the application of ergonomics. Humans have used knives for millennia. The first knife was probably as simple as a stone with a sharp edge, or a sharp piece of seashell (Figure 4). Today, knives are designed for specific needs (Figure 5). The ergonomic knife is designed to keep your wrist in a comfortable, straight position. Keeping the wrist straight decreases the risk of repetitive strain injuries. **Repetitive strain injuries** are sprains or strains of the small muscles of the hands or wrists that come from constant and repeated activities. Using ergonomically designed tools correctly reduces the risk of these injuries. Using any knife correctly can reduce the risk of accidental cuts.

repetitive strain injury: damage, usually to the small muscles of the wrists or hands, from repeated activities over a long period of time



Figure 4 This knife was carved from obsidian sometime between 300 BCE and 500 CE.



Figure 5 With this ergonomic chef's knife, your wrist is kept straight and your fingers are kept far away from the blade.

Unit Task

How could you apply your understanding of ergonomics to your plans for the Unit Task?



CHECK YOUR LEARNING

1. In your own words, define "ergonomics."
2. Choose a device that you use often (for example, cell phone, MP3 music player, computer, television remote control). Suggest some improvements to make this device more ergonomic, using the principles of ergonomics listed in this section.
3. The *ulu* (rocking knife), invented by Inuit (Figure 6), uses an efficient rocking motion that requires less strength to use. Discuss the benefits of this design.
4. What is a repetitive strain injury? How can people avoid getting such injuries?



Figure 6 An *ulu*

Applying Ergonomics— Making a Better Keyboard

In a mechanical typewriter, pressing down a letter key caused a metal arm with a raised form of the letter to lift up. The letter form would strike the piece of paper, leaving an imprint of that letter. Christopher Latham Sholes originally used alphabetical order for the keys. In this design, the metal arms would cross on their way to striking the paper, and frequently jam. He rearranged the keys with the most frequently typed letters spread out. This layout slowed the typist down and ensured that keys did not jam as often. Sholes's layout is called the QWERTY keyboard (Figure 1), named after the order of the first six characters in the upper row. In this activity, you will attempt to design a keyboard that is more ergonomic than the QWERTY Keyboard.

SKILLS MENU

- | | |
|--|--|
| <input type="checkbox"/> Questioning | <input type="checkbox"/> Performing |
| <input type="checkbox"/> Hypothesizing | <input type="checkbox"/> Observing |
| <input type="checkbox"/> Predicting | <input type="checkbox"/> Analyzing |
| <input type="checkbox"/> Planning | <input type="checkbox"/> Evaluating |
| <input type="checkbox"/> Controlling Variables | <input type="checkbox"/> Communicating |



Figure 1 The QWERTY keyboard

Purpose

To redesign a standard computer keyboard to make it more ergonomic.

Equipment and Materials

- one 200-word section of prose for each group; each piece of prose should be different
- 279 mm × 432 mm (11 in. × 17 in.) sheet of paper



200-word section of prose



279 mm × 432 mm sheet of paper

Procedure

1. Copy Table 1 into your notebook. Tally the number of times (the frequency) each letter of the alphabet appears in your group's section of prose. Record this number on your table.

Table 1

Alphabet	Tally
A	
B	
C	
D	

2. Draw another table, and reorder the letters from most frequent to least frequent. This is your frequency table.
3. Use your frequency table to redesign the order of letters on the keyboard. Consider these ergonomic tips in your keyboard design:
 - It is more comfortable to type when the typing alternates between the left and right hands. Typing too many letters with only one hand is tiring. Spread the most frequently used letters from your frequency table evenly between the left and the right sides of the keyboard.
 - Place the most frequently used letters from your frequency table in the middle row of your keyboard. This means that fingers will have to move the least distance.
 - The most difficult row for fingers to reach is the bottom row. Place the least frequently used letters on your frequency table on the bottom row.
 - The ring fingers and little fingers are less strong than the middle and index fingers of the hand. Use the ring finger and little finger for the less frequently used letters on your frequency table.
4. Draw a blank keyboard on a large piece of paper. Place your new arrangement of letters on the keyboard.
5. If time permits and if a computer keyboard is available, compare your typing efficiency using the QWERTY keyboard and your redesigned keyboard.

Analyze and Evaluate

- (a) Justify your keyboard arrangement. Why would your arrangement be more comfortable to use, and would it reduce stress injuries from repeated motions?
- (b) Compare your keyboard layout with the keyboard designs of your classmates. Identify similarities and differences.
- (c) Compare your list of the most frequently appearing letters with members of the class. Look at the top 10 most frequently appearing letters. Why are there differences in the frequency lists?
- (d) Conduct research on the DVORAK keyboard, a keyboard designed according to the ergonomic principles similar to those in this activity. Compare your final keyboard design to the DVORAK keyboard. Identify similarities and differences. Consider some reasons why the QWERTY keyboard is still widely used, despite the DVORAK keyboard being a better ergonomic design.

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Apply and Extend

- (e) Combine all of the original frequency charts from all the groups in the class to create a new master list. Working as a class, redesign the keyboard using the new master list. Compare your class's keyboard to your group's original keyboard. Why are there some differences?
- (f) Compare the class's keyboard to the DVORAK keyboard. Why are there differences?

Universal Design

How easily could you move around your school or community in a wheelchair (Figure 1)? People who use wheelchairs have special needs. People with vision or hearing difficulties, and people who are elderly, also have special needs. Children need help with many tasks that adults find easy. Many people have many different kinds of physical challenges. Buildings that are “accessible” are designed for people with special needs (Figure 2).



Figure 1 Accessible design allows everyone to have access to buildings.



Figure 2 Icons or symbols indicate accessible features of buildings.

People with special needs have had a long struggle to get their needs addressed in structural designs. Designers began to pay attention to special needs after World War II. Many war veterans returned home with injuries. Ramps to homes and office buildings were built. Elevators were designed to indicate the floor through buttons with Braille lettering and numbering, as well as through sight and sound.

Buildings need to be accessible for everyone. Buildings and parts of buildings are designed so that simple tasks are convenient for everybody. Everyone should be able to open a door (Figure 3), turn on a tap, or reach items on a shelf. A design that combines everyday usage with special needs usage is more universal.

Universal design is an arrangement of the parts of a structure or device that creates a user-friendly product.

universal design: an arrangement of the components of a structure or device resulting in the most user-friendly product possible



Figure 3 Imagine that your hands are damp as you try to turn each doorknob. Which doorknob design do you think would be easier to use?

Main Principles of Universal Design

There are specific principles of good universal design (Figure 4).

Universal design means that structures should be

- *equal* (as equal as possible) for all users
- *flexible* (useful for a wide range of abilities and choices)
- *simple* to use and *informative* (easy to use, whatever the user's experience, knowledge, language skills, or physical abilities)
- *safe and tolerant of errors* (provides warnings and safety features in case of errors by the users)
- *ergonomic* (provides enough space and reduces the need for excess force or repeated actions)

Universal design is more functional than basic accessible design.

Universal design considers special needs due to injury, illness, or old age to be a normal part of the human range. It is a way of saying, "We are all in this together."

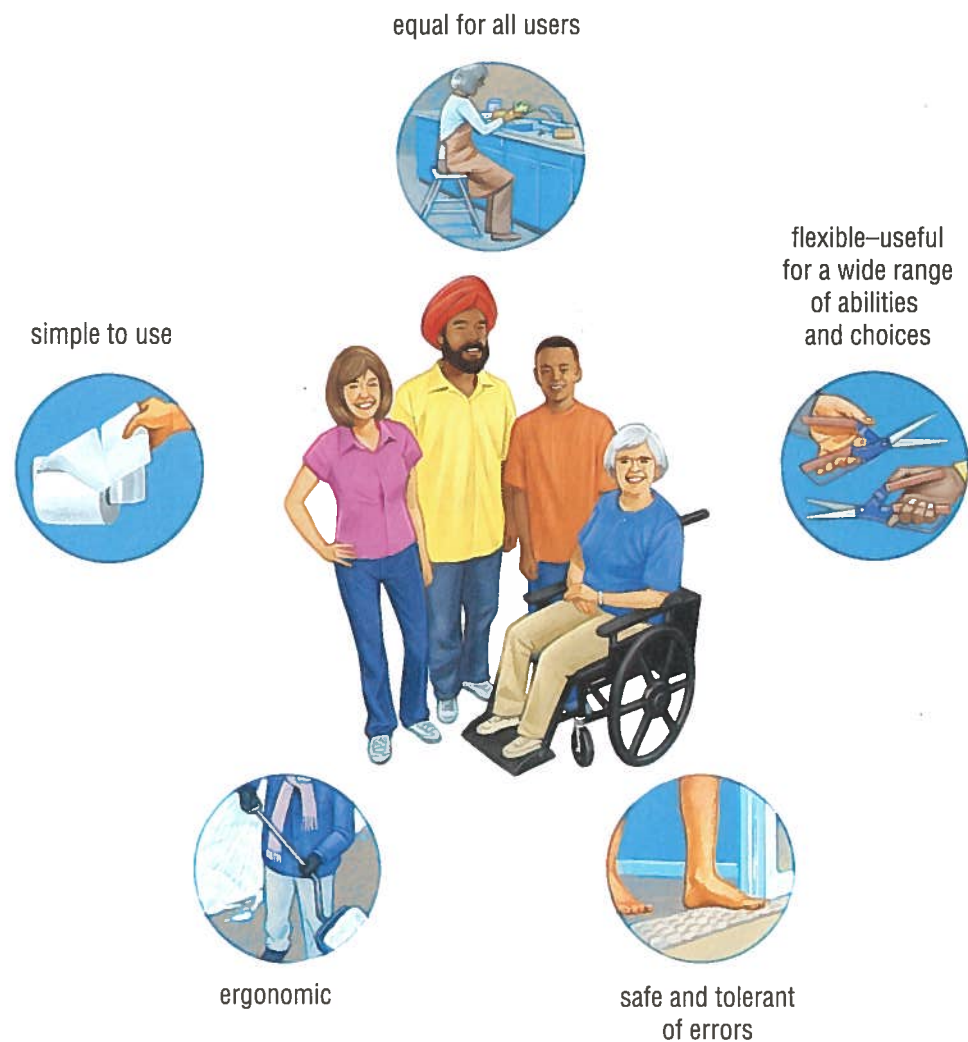


Figure 4 Universal design incorporates five main principles.

Universal designs are comfortable and convenient for anyone using the tool, not just those with special needs. Universal design is also better for the environment. Today's houses are built with wide hallways and doorways. This way, houses do not have to be renovated to accommodate someone in a wheelchair. That means less construction waste in landfills. Universal design is efficient design because it lasts longer.

TRY THIS: Using the Principles of Universal Design



SKILLS MENU: planning, analyzing, evaluating, communicating

Choose one of the items listed below. You may choose to work in partners or groups. On paper, create a universal design that would be appropriate for the greatest variety of people. As you plan and alter your diagrams, be sure to consider the five main principles of universal design.

- Design a bedroom closet that can be arranged for three generations of users: a 5-year-old child, someone your age, and an older person, such as a grandparent.
- A compost collection bin with two wheels is short and awkward to pull (Figure 5). Redesign a similar bin that is more universal. Consider both the homeowner and the workers who collect the waste.
- A city wants to improve the way bicycles can be placed onto a public bus to promote the use of bicycles. The design must be safe, secure, and fast to use.
- Choose a school spectator sport, either indoor or outdoor. Create a set of bleachers and communication methods so that every fan in the bleachers is able to follow the minute-by-minute action and know such details as the score and time remaining.



Figure 5 How can the design of this bin be made more universal?

- Is your design attractive and appealing enough for people to actually want to use it? Explain.
- Could your design be used by all people, no matter what their size or abilities? Who would not be able to use your design easily?
- How is your design environmentally responsible?
- Self-evaluate your design by giving it a mark out of 10 for each of the items described below, and then add the marks and express your evaluation as a percentage.
 - visual appeal
 - environmental responsibility
 - each of the five principles of universal design
- Describe two ways you could improve your design.

Unit Task How could you apply your understanding of universal design to your plans for the Unit Task?

CHECK YOUR LEARNING

- In your own words, define "universal design."
- When did designers start to pay attention to people with special needs? Explain why.
- List the five principles of universal design.
- State two examples of non-universal design based on your own observations and experience.
- For each of the following examples, state at least one principle of universal design that is *not* followed:
 - A stove has control knobs at the front of the burners.
 - A study lamp has a small-diameter switch that the user must rotate.
 - A backpack digs into your back and shoulders.
 - An umbrella flips inside out in the wind.
 - The support cables of a playground swing are made of strong but small-diameter metal wire.

The Golden Ratio

Sculptors, builders, and engineers have known for a long time that a particular height-to-width ratio is pleasing to the eye. This is known as the golden ratio. The golden ratio is also sometimes known as “phi” and is represented by the Greek symbol ϕ . The actual value of the golden ratio is approximately 1.618. Like the number pi (π), the numbers of phi go on forever without repeating. Ancient Greek mathematicians studied the golden ratio because it often appears in geometry. Discovery of this ratio is often attributed to Pythagoras.

The golden ratio was used in the design of the Great Pyramid of Giza. If you compare the height of the Great Pyramid to half its length, the result is the golden ratio. Artists also make use of the golden ratio. The dimensions of the height to the width of the face of Leonardo da Vinci’s *Mona Lisa*, one of the most famous paintings in the world, are in the golden ratio.

Most people find a rectangle with a width-to-height ratio of 1:1.6 (rounded to one decimal place) to be more pleasing to the eye than any other dimensions. A rectangle with these dimensions is known as a golden rectangle. The Parthenon in Greece exhibits many golden rectangles in its design (Figure 1).

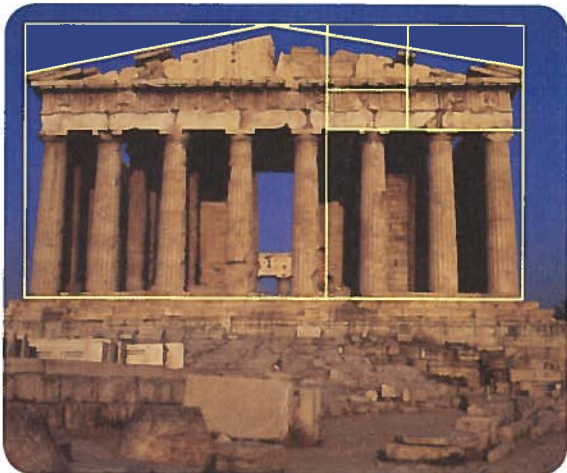


Figure 1 Built over 2500 years ago, the Parthenon has many golden rectangles throughout its structure.

Many objects in nature also exhibit the golden ratio. Examine the image of the tiger in Figure 2. Measure the length of the tiger’s body, and the length of its head. Divide these numbers by one another. What do you get? Try this with more animal pictures and check the validity of your first result.

To learn more about the golden ratio,

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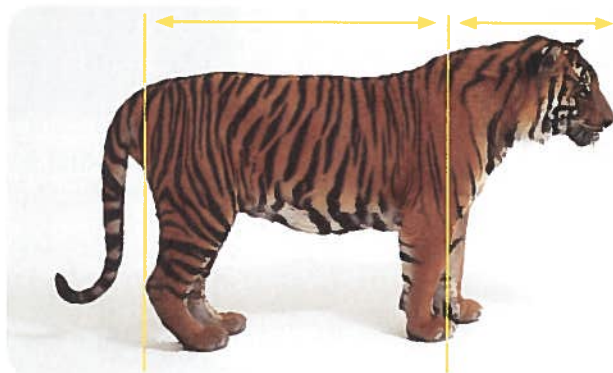


Figure 2 Discover the golden ratio in nature.

LINKING TO LITERACY

Making Inferences

Texts can have “literal” meanings or “inferred” meanings. “Literal” means that the text means exactly what it says. “Inferred” means that a text says something, but really means something more.

Readers make inferences by thinking about what they have read in a text. Then, they make a connection to what they already know, to make an informed guess about what the text really means.

See if you can infer the meaning of the following:

- If the tiger calculation equals the golden ratio, what “inference” can you make about calculations for other animals?

Form, Function, and Beauty

BIG Ideas

- Structures have a purpose.
- The form of a structure is dependent on its function.
- The interaction between structures and forces is predictable.

Looking Back

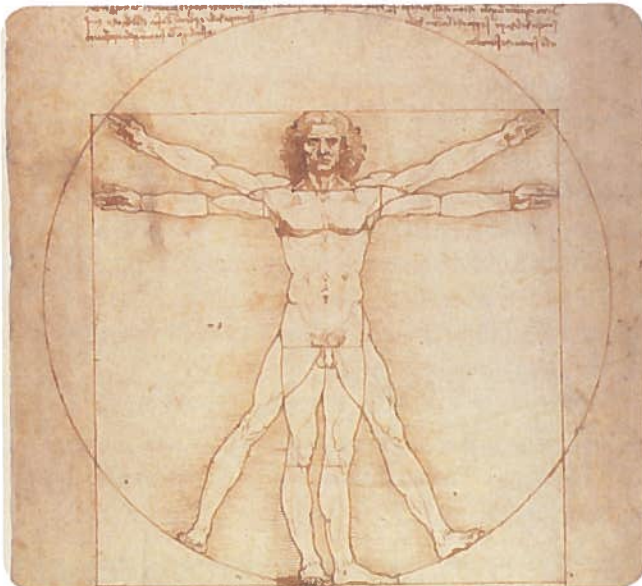
The product development process considers human wants and needs, and also societal and environmental factors.

- Design factors relate to designing the product.
- Manufacturing factors relate to manufacturing the product.
- Sales factors consider the places where a product will be sold, the price of the product, and support for the purchaser.
- Companies try to ensure that products will be successful by conducting market research.



Structures that are symmetrical are usually more stable and more aesthetically pleasing than those that are asymmetrical.

- Symmetry is present in nature and in the human-made world.
- Many people consider objects that are symmetrical to be more appealing than those that are asymmetrical.
- The line of symmetry can help to locate a structure's centre of gravity.



Structures intended for human use need to be designed for human characteristics.

- Ergonomics is an important consideration in the design, construction, and use of a product.
- Ergonomically designed structures are safer and prevent injuries.
- Different groups of people have different needs and require products that are designed for them.
- The principles of universal design help make structures accessible to all people of all abilities.

VOCABULARY

- symmetry, p. 323
- line of symmetry, p. 323
- aesthetics, p. 325
- ergonomics, p. 327
- repetitive strain injury, p. 329
- universal design, p. 332



The skills of scientific inquiry can be used to study the ergonomics of everyday tools.

- The QWERTY keyboard is a tool used by many people every day. The science of ergonomics can be used to redesign the keyboard to make it more efficient and easier to use.



What Do You Remember?

- (a) List the four design factors.
 (b) List two questions that you would ask for each of these factors when designing a product such as a running shoe. **K/U** **T/I**
- (a) What is market research?
 (b) Why is market research important to companies?
 (c) Why might market research be important to consumers? **K/U**
- In your own words, define “ergonomics.” **K/U**
- How are ergonomics and universal design related? **K/U**

What Do You Understand?

- (a) When thinking about a purchase, do you consider the product’s life cycle and disposal? Why or why not?
 (b) What benefits would be gained if everyone considered a product’s life cycle before making a purchase? Explain. **T/I**
- The Royal Bank Plaza towers in Toronto have over 70 000 g of real gold coating on their windows (Figure 1). One reason is to provide thermal insulation. What other reasons did the bank consider when they decided to use gold-coated glass? **K/U** **T/I**

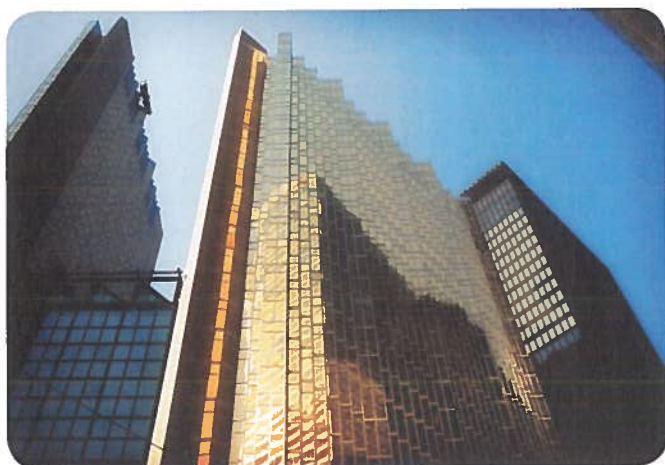


Figure 1

- (a) What is meant by the term “symmetry”?
 (b) List three structures that you have seen today that clearly exhibit symmetry. **K/U** **A**
- (a) How does market research benefit society? How does it cause harm to society?
 (b) How does market research benefit the environment? How does it cause harm to the environment? **K/U** **A**
- (a) Why is symmetry important in the natural world?
 (b) Is the importance of symmetry in human-made structures the same or different as in the natural world? Explain. **K/U**
- Did universal design lead to accessibility, or did accessibility lead to universal design? Explain. **K/U**
- (a) The amount of energy it takes to produce a product is an important factor for manufacturers to consider in the development of a new product. Why?
 (b) What other factors do manufacturers need to consider in a product’s development? **K/U**
- Why do some manufacturers want to build products that wear out quickly? **K/U**

Solve a Problem!

- (a) Why is ergonomics an important part of the design process?
 (b) Pick an item from your everyday life, such as your computer desk, a light switch, or a remote control, that you think could have a more ergonomic design. What would you do to improve its design?
 (c) Would you pay more for an ergonomically designed product? Why or why not? **K/U** **A**



Create and Evaluate!

14. (a) Using library resources and the Internet, research the Aeron chair.

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- (b) Is your classroom chair as ergonomic as the Aeron chair? Explain. In your notebook, copy and complete Table 1 to help you organize your thinking. **T/I A**

Table 1

Alike	Different

15. Municipalities often spend public tax dollars on the aesthetics of civic buildings.
- (a) How do governments justify spending large amounts of public money on aesthetics?
- (b) In your opinion, how reasonable is this point of view? **A C**
16. Manufacturers often use computer simulations when designing new products. What are the advantages and disadvantages of designing with computer simulations? Use a t-chart to organize your thinking. **A C**
17. Environmentalists often say that true conservation will only arrive when consumers pay the true cost of a product.
- (a) What do you think is meant by this statement?
- (b) Analyze some of the hidden costs in the manufacture of a backpack.
- (c) Do you believe that paying the true cost would result in real conservation? Justify your opinion.
- (d) Many products today advertise themselves as “green.” Why do they do this? Examine the claims of one such product, and evaluate the validity of the claims. **A**

18. Your parents are thinking of moving into a Hundertwasser design–inspired structure.
- (a) Compare the positives and negatives of such a move. Use a t-chart to help organize your thinking.
- (b) Would you like to live in such a building? Why or why not? **A C**
19. Examine the image in Figure 2. The BCE Place Galleria won a major architectural award. Assess the design styles used in the Galleria. Why was this structure found to be so outstanding? Do you find this design to be unique and interesting? Is it beautiful? If yes, explain why. If no, clearly outline your areas of criticism. **K/U T/I A C**



Figure 2

Reflect on Your Learning

20. In this chapter, you have learned that ergonomics is important to design.
- (a) What did you understand about ergonomics before reading about it in this chapter?
- (b) How has your understanding of ergonomics changed?
21. Think back to the Key Question on the first page of this chapter.
- (a) In a brief paragraph, answer the Key Question. You may use diagrams.
- (b) Write one or two more questions about the topic of this unit that you would like to explore.

Play Time Is the Best Time

Background

The modern playground is designed to be innovative, challenging, safe, and fun. New materials allow designers to come up with designs that would have been unlikely just a short time ago. Many playgrounds are designed to be accessible to children with disabilities.

Scenario

You work for an engineering firm that makes playground equipment. Your design team has been chosen to create a new piece of playground equipment. You and your team have three challenges:

- 1. Design and construct a model of a new piece of playground equipment.** Your model should include a scale diagram for construction, including a front, side, and top view. Your diagrams should include an explanation of why you selected the design that you used. Be sure to include the ages of the children who will be using the equipment and whether your equipment will be accessible to children with disabilities (Figure 1).



Figure 1 Will your new playground equipment be accessible to children with disabilities?

- 2. Promote your new equipment.** You will prepare an advertisement for your playground equipment. Your advertisement must include audio (verbal) and visual parts. It must be designed to inform and persuade communities that are building new playgrounds to use your design. They must see the advantages of your piece of playground equipment. Remember to write in a persuasive but truthful way.
- 3. Prepare your presentation.** You will prepare a multimedia presentation for your board of directors. The presentation will explain how your team met the challenge of designing an exciting and safe piece of playground equipment, and created a way to promote the equipment to the community.

Design Brief

In your design brief, clearly describe your piece of playground equipment and why you have selected this particular piece to build. You should also include a description of your design and how you intend to build your model. Include a description of who will use the equipment.

Equipment and Materials



Make a list of all the equipment and materials your team will need to complete your challenge. Use as many found materials as possible. Remember to consider whether your materials can be reused or recycled. Make sure to include the materials you will need for parts 2 and 3 of your challenge, as well as those you will need for your model.

Research and Consider

Research what kinds of playground equipment already exist, what equipment is popular, and what needs the popular equipment meets.

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Plan and Construct

Write step-by-step instructions of how you will build your model and assign tasks to your team members. Make sure that everyone contributes equally. Try to be innovative in your design. Remember that the playground must be both fun and safe. You may decide that you want your equipment to be accessible to children of all ages and abilities. If so, then this will be a major factor in your design process.

Test and Modify

Make sure you leave enough time to test your model and make changes, if necessary. Use jot notes to keep track of ideas for your promotion and your presentation.



Evaluate

Does your equipment model meet its design criteria? Is it to scale, strong enough to support loads, stable, and fun for the children who will use it? Use the Assessment box to help you.

Communicate



Your promotional material should stress safety design factors, innovation, creativity, and how much fun can be had on the playground. Universal design, including accessibility for children with disabilities, should also be highlighted if these were major design factors for your equipment. Make sure that there are both audio and visual parts to your promotional material (poster, brochure, and script or storyboard).

You will also prepare a multimedia presentation for your board of directors on your design. Be sure to make your equipment sound exciting, yet safe. Your presentation should also describe your advertisement.

Assessment

You will be assessed on how well you

- meet the established criteria
- demonstrate an understanding of concepts, principles, and terminology
- show effective and safe use of materials
- understand the specific challenges
- make a plan to solve the problem
- carry out the plan, applying technical skills and procedures when necessary
- use critical/creative thinking processes to analyze the results
- prepare an appropriate presentation of the task that includes a clear expression and organization of ideas and information
- relate your finished product to society and how it could affect the lives of people
- assess the practical problems relating to the challenge and how they could affect the environment

Form and Function

Make a Summary

Word Summary

Review the vocabulary terms from this unit with a small group of classmates. Choose one vocabulary term from each chapter. Your teacher will keep a master list to make sure each group chooses different terms. For each vocabulary term, have each group member copy and complete the Vocabulary Terms Chart (Figure 1). Then, compare your charts. Were any of the other definitions different from yours? Update your Vocabulary Terms Charts with the new information.

Review the Vocabulary Terms Chart as a class. Create a Vocabulary Terms class book for the whole class to use as a reference.

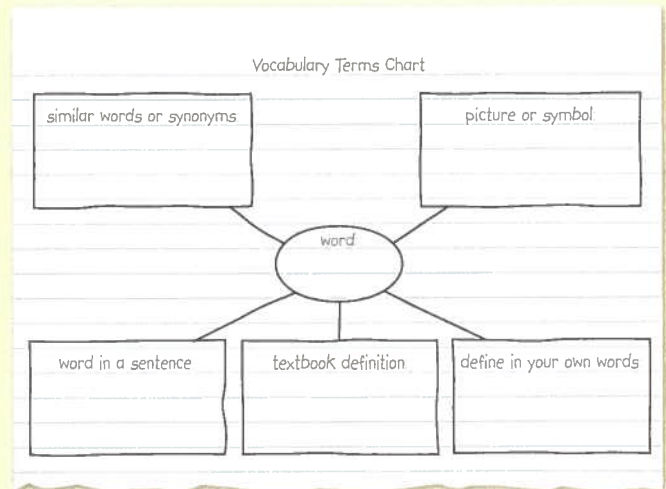


Figure 1

Unit Review Questions

What Do You Remember?

The following icons indicate the Achievement Chart categories:

K/U Knowledge/Understanding **T/I** Thinking/Investigation
C Communication **A** Application

1. In your notebook, complete each sentence by filling in the most appropriate word(s): **K/U**

truss	arch	stable	magnitude
rebar	centre of	shape	form
	gravity		

- (a) An object is _____ if it maintains its shape and position over an extended period of time.
- (b) The horizontal balance point of an object is very close to its _____.
- (c) A network of beams that form triangles is known as a(n) _____.
- (d) The strength of a beam can be changed by changing its _____.
- (e) The shape and outer physical appearance of a structure is known as its _____.
- (f) A(n) _____ supports a load by directing force downward along a curve.
- (g) Reinforcing steel rods in concrete are called _____.
- (h) The term _____ refers to the size of a force.

2. (a) Clearly distinguish between external and internal forces.
(b) List the four internal forces, and give a brief description of each. **K/U**
3. Identify and describe
 - (a) three factors that could determine the ability of a structure to support a load
 - (b) four factors that can cause a structure to fail **K/U**
4. Briefly list four ways that a beam can be strengthened. **K/U**
5. What is the main function of market research? **K/U**
6. Concrete is one of the basic materials used in modern structures.
 - (a) How does concrete react to compression and tension forces?
 - (b) How do engineers strengthen concrete? **K/U**

What Do You Understand?

7. Classify each of the structures in Figure 2 (a) to (d) as solid, frame, shell, or combination. Justify your choices. **K/U**



Figure 2

8. Why is symmetry such an important concept in how we design and build structures? **K/U**
9. Classify each of these examples as applications of the four internal forces:
 - (a) sitting on a cushion
 - (b) ripping a piece of paper in two
 - (c) stretching an elastic band
 - (d) a sweater twisted in a clothes dryer **K/U** **A**
10. (a) The International Space Station uses the truss as a framework for the entire station (Figure 3). Why is a truss such a useful structure in this situation?



Figure 3

- (b) Provide three examples of trusses in structures in your community. **K/U** **A**
11. You are seated at your desk in school writing in your notebook.
 - (a) Describe an external force that is acting on the desk.
 - (b) Describe some of the internal forces acting on the desk, and where these forces are located.
 - (c) What would happen to the desk if the internal forces acting on it became too large for the desk to support?

K/U **A** **T/I**

12. Apply the terms “point of application” and “plane of application” to
- pushing on a car that is stuck in the snow
 - pulling with both hands on a heavy garbage can to drag it out to the curb for pickup **K/U A T/I**
13. What is the relationship between an arch and a dome? Provide an example of an arch and an example of a dome. **K/U A**
14. Describe a dead load and a live load that acts on each of the following structures:
- a set of stairs at school
 - bleachers in the school gymnasium **K/U A**
15. Clearly state the difference between a fully supported beam and a cantilever, and provide two examples of each. **K/U A**
16. Identify the structures in Figure 4 (a) to (d) as cantilever, truss, fully supported beam, or arch. **K/U A**

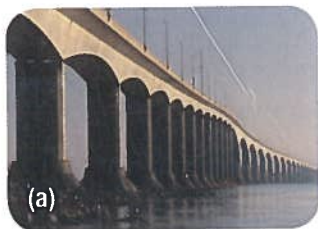


Figure 4

17. With a partner, brainstorm ergonomic reasons why a calculator and a computer numeric keypad have a different number placement than a telephone keypad. **T/I**

18. (a) What forces are acting on the diver in Figure 5?
- (b) What kind of force is acting on the top of the diving board? On the bottom?
- (c) What kind of beam is a diving board? **K/U**



Figure 5

19. (a) Research the Quebec Bridge collapse. Using a Venn diagram, compare the reasons for the collapse of the Quebec Bridge and the Tacoma Narrows Bridge.
- (b) Could these collapses have been prevented with the knowledge available at the time they were built? Explain. **K/U T/I**

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20. Why is ergonomics important in the design of products? **K/U**

Solve a Problem!

21. Ergonomics has had a major impact on the design of objects. Think of a structure that you use regularly (for example, TV remote, iPod, backpack).
- Describe ergonomic features that make this device comfortable to use.
 - Suggest a change in the structure or appearance of the device that may improve how comfortable it is to use.

K/U A T/I

Create and Evaluate!

22. Evaluate the following structures under the categories of function and form:

- (a) your home
- (b) your school building
- (c) a mall **T/I** **A**

23. (a) How would you classify the ancient structures in Figures 6 and 7? Why do you think they have lasted hundreds of years?

(b) Are there any modern structures that you think will last hundreds of years? Explain.

K/U **A**

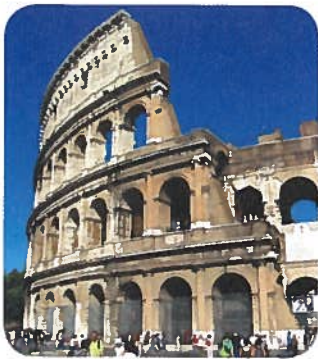


Figure 6



Figure 7

24. (a) Identify two disposable products, and suggest an alternative for each that people could use instead.

(b) Why might some people prefer the disposable product compared to your suggested alternative?

(c) What can you do to convince others to use your alternative product rather than the disposable product? **T/I**

25. (a) Large modern structures have deep foundations that are often drilled right into the rock that underlies the soil. Why is this done?

(b) Would the Leaning Tower of Pisa have benefited from this construction method when it was being built? Explain. Why do you think they did not do this? **A** **T/I**

26. You have been asked to create a new reading lamp that cannot be easily tipped over. What design factors would you use to make a stable lamp? **T/I** **A**

Reflect On Your Learning

27. Think about a structure in your community.

- (a) Reflect on how important function and form are for this structure.
- (b) Do you like the structure? Explain.
- (c) Is the structure well built? Explain.
- (d) Describe one improvement that could be made to the structure. Why would this change improve the structure?

28. Science classifies structures on the basis of how they are put together as solid, frame, shell, or combination structures. In everyday life, however, we usually do not classify structures in this way. How might people classify structures in everyday life?

29. (a) In what way has what you learned in this unit made you look at everyday structures differently?

(b) What was the most surprising idea you learned about in this unit? Explain.