UNIT 5

NEUROSCIENCE

Sensory Perception

In this unit, you will

- read about how the mind perceives odors and musical notes.
- review point of view.
- increase your understanding of the target academic words for this unit.

READING SKILLS Categorizing; Interpreting Charts, Tables, and Graphs

Self-Assessment

Think about how well you know each target word, and check (✓) the appropriate column. I have...

TARGET WORDS (AWL)	never seen the word before	seen the word but am not sure what it means	seen the word and understand what it means	used the word, but am not sure if correctly	used the word confidently in *either* speaking *or* writing	used the word confidently in *both* speaking *and* writing
🔑 category						
concurrent						
🔑 cycle						
dimension						
entity						
identical						
likewise						
🔑 minimum						
parameter						
🔑 philosophy						
🔑 plus						
🔑 principal						
🔑 stable						
unify						

🔑 Oxford 3000™ keywords

Outside the Reading What do you know about sensory perception? Watch the video on the student website to find out more.

Before You Read

Read these questions. Discuss your answers in small groups.

1. Does adding smell to movies and video games strike you as a useful improvement? What technical challenges would adding smell likely involve?
2. What other uses can you see for a machine that could reproduce odors? In businesses? In the home?
3. Odors can often trigger powerful memories. For example, the smell of bread baking may remind someone of their childhood home. What memories do you associate with certain odors?

MORE WORDS YOU'LL NEED

nontoxic: not poisonous; safe to eat, breathe, or touch
olfactory: connected with smell—*olfactory* nerves/cells/neurons/sense
simulate: to create an effect or situation that seems real but actually is not

Read

This magazine article discusses why, unlike sound, it is so difficult to add smell to movies.

VIRTUAL ODORS?

Movies have successfully captured sights and sounds on film since the 1920s. And today we can enjoy realistic and imaginary multimedia delights even on hand-held devices. But if such treats for the eye and ear are now commonplace, why is there no machine that can readily incorporate our sense of smell into the experience of a movie or a video game?

Actually, movie makers have tried to add this missing **dimension**. In 1959, a film called *Behind the Great Wall* piped odors through the air-conditioning system of a theater. The 1960 film *Scent of a Mystery*, featuring Smell-O-Vision, opened in a theater equipped to release smells in synch with the movie. Director John Waters gave "scratch-and-sniff" cards out to accompany his "Odorama" movie *Polyester* (1982). And Walt Disney World's Epcot theme park near Orlando, Florida uses odors to enhance its *Journey into the Imagination* attraction. So far, though, Smell-O-Vision-type devices are no more than gimmicks of only marginal interest. Why? No affordable machine can store enough odors to simulate more than a small fraction of what humans can smell.

Sound and color simulation do not face such limitations. Computer monitors, for example, can recreate millions of colors because it really only takes three colors to do so. A screen that can display tiny red, green, and blue pixels[1] can combine these colors to reproduce most colors that a human eye can see. Sound waves, though quite complex, can be defined mathematically, reproduced by a synthesizer[2], and amplified electronically.

Odors are different. They cannot be manipulated or defined mathematically. As Jaron Lanier explains in an article in *New Scientist*,

[1] *pixels:* minute areas of light on a computer screen, which together form an image
[2] *synthesizer:* a machine that produces different sounds electronically

odors "are not patterns of energy, like images or sounds. To smell an apple, you breathe hundreds or thousands of apple molecules into your nose." There is no way to amplify them other than adding more odor molecules. **Plus**, each molecule that triggers smell is unique. This means a machine cannot produce all possible odors by simply mixing three odors. It is true that odor-causing chemicals can be combined to produce millions of scents, but the **minimum** number of basic odors required would be in the many hundreds, perhaps thousands, to simulate all the scents that humans can sense.

Several odor **parameters** can be identified that might be useful. We can talk about the intensity of an odor or the persistence of an odor. We can label it as pleasant or unpleasant. Non-offensive odors can be grouped into seven general **categories**: medicinal, floral, chemical, fruity, vegetable, fishy, and earthy. They can also be **categorized** by how they feel in our nose: tingly, burning, warm, metallic, pungent, itching, sharp, and cool. But there are simply too many odors in each **category** to design a practical device that could reference and recreate all the scents we can smell. Jaron Lanier says, "Colors and sounds can be measured with rulers, but odors must be looked up in a dictionary."

That dictionary is in the brain. Odors are detected deep in the nasal passage when molecules come into contact with the olfactory epithelium—a patch of tissue covered with neurons. These neurons have receptors[3] that can detect a particular molecule. If a molecule fits into a matching receptor, the brain gets a signal. Apparently, the human nose has about one thousand different types of olfactory neurons.

The brain's "smell dictionary" **categorizes** odors, but not in a way that a chemistry book would. Instead the brain groups smells according to what they mean in the real world. Things that emit a rotting smell, for example, get very special handling. Interpreting smell also requires help from the other senses, and its meaning may derive from the context. Whether a smell is good or bad may depend on where you smell it and what you think is causing it. If a bowl of ice cream smells like hard-boiled eggs, you probably won't eat it even if you like hard-boiled eggs. In other words, smells function a bit like words do. We know thousands of different words, and the meaning of a word depends on the context in which it occurs. We define a word by pointing to the **entity** it refers to or by comparing its meaning to other words. With scents, we may say "it smells like a cucumber" or "it has a soapy smell."

If millions of visible colors can be produced from just three primary colors, is there any hope of finding smell "pixels" that will trigger the perception of smell in our brains? We, of course, see images on computer screens that look real to us even though the objects are not really there. They are optical illusions. **Likewise**, sound recordings and even your cell phone create an auditory illusion—the source of the original sound only seems to be present. Is it possible to design a mechanism that could somehow manipulate our brain to create the illusion of smell when no odor molecules are present—virtual odors?

In the near future, this achievement seems remote, but some progress is being made in research on machines that can mimic the sense of smell. These "electric noses" are equipped with olfactory sensors that detect specific odors. In order to design such a machine, scientists and engineers must be able to classify and identify an odor's distinctive "fingerprint" and design a mechanism that can electronically detect that fingerprint. The possible value of such a machine in food inspection, medicine, and law enforcement has prompted several dozen companies to develop and sell electronic nose units.

If a machine can digitally detect odors, perhaps the reverse is possible. The Tokyo Institute of Technology is reported to be working on an odor recorder and generator. The plan is to design a gadget that can be pointed at an object, record its odor through 15 electronic noses, and recreate the odor by mixing together and vaporizing odors from a set of 96 nontoxic chemicals. If this device succeeds, it will move well beyond current odor generators. These emit only a small number of odors and have failed commercially.

[3] *receptor:* a cell or device that reacts to changes such as temperature, light, or sound

If odor recorders and generators prove to be feasible and affordable, Smell-O-Vision may be primed for a comeback, adding a new **dimension** to the moviegoing experience. It may even require a new film rating system: "Warning: This movie is rated R for Rotten. Contains odors that some may find offensive." ■

Reading Comprehension

Mark each sentence as *T* (true) or *F* (false) according to the information in Reading 1. Use the dictionary to help you understand new words.

___ 1. A machine that can synthesize most smells would already exist if there were a market for it.

___ 2. At the present, the entertainment industry is using smell in limited ways.

___ 3. Virtually all colors that humans can see can be synthesized.

___ 4. Odors, like sounds, are created by energy waves coming from foods and other substances.

___ 5. A pleasurable smell will always remain so no matter where it occurs.

___ 6. At this time, electronic nose technology has more obvious practical applications than a smell generator does.

READING SKILL Categorizing

LEARN

When we group entities into categories that do not overlap, we say the categories are *mutually exclusive*. For example, musical instruments used in orchestras fall into mutually exclusive categories. There are wind instruments, string instruments, and percussion instruments.

APPLY

A. **These sentences are based on the readings in Units 4 and 5. For each sentence, answer the questions shown in the example. Write "not sure" if information is missing.**

1. Guitars can be classified into acoustic and electric guitars.

What entities are being categorized?	*Guitars.*
What is the basis for the categorization?	*The way the sound is amplified.*
Are the categories mutually exclusive?	*No. Some guitars are both acoustic and electric.*

2. There are two types of acoustic guitars: steel-stringed and nylon-stringed.
3. Non-offensive odors can be grouped into seven general categories: medicinal, floral, chemical, fruity, vegetable, fishy, and earthy.
4. Odors can also be classified by the way they feel in our nose: tingly, burning, warm, metallic, pungent, itching, sharp, and cool.
5. We can label odors as pleasant or unpleasant.

Categorizing may require us to draw a "dividing line" in order to create categories. Reading 1, for example, says odors can be identified by their intensity or their persistence. These two dimensions involve measurements for which there are many possibilities.

B. Examine these categories. Where would you draw the line? Why?

1. childhood and adulthood
2. middle age and old age
3. a short film and a feature film
4. a luxury car and other cars
5. the modern era and the "old days"
6. the poverty line (poor vs. non-poor)

C. This chart categorizes odors along two dimensions: how they smell and how they feel in the nose. Think of one item for at least five description squares. A banana, for example, could be categorized as smelling *fruity* and feeling *warm*.

	How odors feel in the nose								
How odors smell				banana					

Vocabulary Activities

Noun	Verb	Adjective	Adverb/Conjunction
category categorization	categorize	categorized categorical	categorically
dimension	___________	dimensional	dimensionally
entity	___________	___________	___________
___________	___________	___________	likewise
minimum	minimize	minimum/minimal	minimally
parameter	___________	___________	___________
___________	___________	___________	plus

A. Fill in the blanks with a target word from the chart that completes the sentence in a grammatical and meaningful way.

1. Guitars can be ________________ as either electric or acoustic.
2. Most people consider special effects to be part of the movie business, not a separate ________________ .
3. What's the ________________ number of colors you can use and still have a good image on the computer screen?
4. A standard movie screen provides a two-________________ viewing experience.
5. Even a ________________ amount of black paint will make white paint gray.
6. Coffee falls into the ________________ of bitter tastes, as opposed to sweet, salty, or sour.
7. Odors would add a whole new ________________ to the moviegoing experience.

B. The word *likewise* signals that the writer is giving another similar, but not identical, case. The word *plus* adds one more piece of supporting information. Fill in the blanks with *likewise* or *plus*. Compare answers with a partner.

1. The original 3-D movies ran into problems. It was difficult to keep the two projectors in sync. The glasses distorted color and caused headaches. ________________ , the effect did not work well throughout the entire theater.
2. With auditory perception, technically speaking, no sound gets past the ear. The sound waves are converted to a signal that is sent to the brain. ________________ , the human eye absorbs various wavelengths of light and sends information about that light to the brain.
3. The microphone limits a player's movements, and it often picks up other sounds, amplifying them along with the sound of the guitar. ________________ , it still does not make the guitar itself any louder.
4. The treatment is completely free, even for people who have no health insurance. ________________ , it has no side effects.

The reading contains three very abstract nouns: *dimension*, *entity*, and *parameter*.

Entity can refer to anything that can be identified as having a separate and independent existence.

A corporation is a legal ***entity.***

The Congress of the United States is a political ***entity.***

Since the two banks merged, First Bank no longer exists as a separate ***entity.***

Dimension can refer to the physical size and measurements of something. It can also refer to different aspects of things, like the different *dimensions* of a problem or new *dimensions* of sound technology. The word *dimensional* is used to describe space as *two-dimensional* (flat) or *three-dimensional*, as in a 3-D movie.

The ***dimensions*** *of the room are 10 × 12 feet.*

Smell would add a new ***dimension*** *to virtual reality games.*

The ***dimensions*** *of the problems they face are huge.*

Humans inhabit ***three-dimensional*** *space.*

Some people say that time is the fourth ***dimension.***

Parameter is mainly used in academic and technical discussions in fields such as statistics, computer science, mathematics, and engineering. In more common usage, it may refer to agreed-upon boundaries or limits for a particular activity.

The committee set the ***parameters*** *for awarding scholarships.*

Exploring the toxicity of these odors is outside the ***parameters*** *of this study.*

CORPUS

C. Fill in the blanks with *entity, dimension,* or *parameter.* Use plural forms when necessary.

1. By 1856, the Whig Party no longer existed as a functioning political ________________.
2. The birth of their first child added a new ________________ to their lives.
3. The committee, after a lengthy discussion, agreed to work within the ________________ that they had established earlier that year.
4. In "hyperdrive," the starship enters a separate ________________ where the speed of light is much faster and the distances between objects much less.
5. The business was penalized for working outside the ________________ set up by the government.
6. After the hurricane, the city began a cleanup and rebuilding effort of staggering ________________.
7. Before the reorganization, the two departments operated as separate ________________.

Before You Read

Read these questions. Discuss your answers in small groups.

1. A standard riddle of popular philosophy is this question: If a tree falls in a forest and there is nobody to hear it, does it make a sound? What do you think? To answer this question, start by discussing what is meant by the term "sound."
2. *Onomatopoeic* words imitate the sounds they describe. Here is a list of onomatopoeic words in English. What entity (object, force, or animal) do you think might be associated with each sound?

bang ________	ding dong ________	splash ________
caw ________	peep ________	tick ________
chirp ________	pop ________	thump ________
clang ________	quack ________	wheeze ________
click ________	roar ________	whirr ________
clunk ________	rumble ________	whoosh ________
crack ________	rustle ________	woof ________
crunch ________	slurp ________	zip ________

MORE WORDS YOU'LL NEED

eardrum: a membrane in the ear that is sensitive to air vibration. A membrane is a thin piece of tissue.

fluctuations: repeated increases and decreases in something

flux: a state of constant change

Read

This online article from a science magazine explains how sound is perceived as musical notes in the brain.

Pitch and Timbre

One **unifying** characteristic of human life is music. In fact, no known human culture lacks music. But what is there about human perception that allows us to hear sound as musical notes? Why do instruments playing an **identical** note sound different?

The answer to these questions requires some insight into how humans perceive pitch. When a musical instrument is played properly, it vibrates in a predictable way and pushes on the air in and around the instrument. This action creates waves or pulses that travel through the air. You might think of these waves as brief fluctuations in air pressure. Pitch relates to how close together these waves or pulses are. If the musical instrument vibrates 120 times a second, about the same as a typical adult male speaking voice, we say the sound has a frequency of 120 **cycles** per second, or in current terminology 120 Hz (pronounced *Hertz*, the name of a 19th century German physicist).

The typical female speaking voice has a vibration frequency of around 220 Hz. Notes with a low frequency of vibration are referred to as low notes and those with a high frequency as high notes.

Pitch is tied to the vibration of air, but it is ultimately a product of how our ear and brain interpret these vibrations. Vibrating air molecules push against our eardrums, causing them to vibrate at the same frequency. The vibration is then amplified by mechanisms in the middle ear. The amplified vibration stimulates nerve sensors that convert the vibrations into electrical signals that the brain can analyze. What we perceive as pitch is a mental image of those vibrations. Although the vibrating air molecules are quite real, pitch occurs only in the brain. So we may need to reconsider the **philosophical** question "If a tree falls in a forest and nobody is present to hear it, does it make a sound?" The air vibrates, of course, but can there be a sound without eardrums present to vibrate and a brain to interpret the vibrations?

The human ear and brain have limits and cannot assign a pitch to all frequencies of vibration. We cannot hear sounds below 20 Hz or so, and if a sound is below 30–35 Hz, we do not perceive it as a distinct musical note. It sounds toneless, like a rumble. The same is true at the high end. Human hearing tops out at about 20,000 Hz even though air can vibrate at frequencies many times higher. As with the very low frequencies, frequencies above about 4,000 Hz do not sound like musical notes. They begin to sound like snaps, hisses, clicks, and squeaks. You can test this aspect of human perception by playing the very lowest and highest notes on the 88-key piano. To most people, they seem a little musically "off" or lifeless.

The brain does interesting things with the arithmetic of pitch. If an instrument plays a note with a frequency of 220 Hz and another one at twice as many **cycles** per second at 440 Hz, we hear the same musical note (both an A in the C major scale). We say they are an octave[1] apart. **Likewise**, we hear an A if the frequency doubles again and vibrates at 880, 1760, and 3,520 Hz. At the lower end, we hear an A note at 110 Hz and 55 Hz. All told, we can hear between seven and eight octaves. Outside these ranges the notes become indistinct.

The fascinating arithmetic of musical notes allows the brain to play a trick on us that helps us distinguish sounds. Due to the physics of sound and the materials that make sound, there is no such thing as a pure tone. We may think a note is pure, but we are hearing much more. If a piano plays an A note with a frequency of 110 Hz, it actually plays a note at that frequency **plus** all the whole number multiples above it—220 (2 × 110), 330 (3 × 110), 440 (4 × 110), 550, 660, and so forth. The loudest frequency, the one with the most energy, is usually the lowest frequency (in this case 110 Hz). It is called the fundamental frequency, the frequency we identify as the pitch of the note. The higher frequencies are called overtones, or harmonics. You hear only one note, rather than dozens of evenly spaced notes, but that is because your brain works behind the scenes and uses the harmonics for other purposes.

You can experiment with harmonics using a guitar (or any string instrument). Pluck the thickest string on the guitar. If your guitar uses standard tuning, you will hear an E (about 82.4 Hz). Now very lightly rest your finger against the string at its exact midpoint (the 12th fret). Pluck the string again and you will hear a softer, rather pretty-sounding E note one octave higher. By lightly touching the string, your finger has absorbed the vibration produced by the fundamental frequency before it could reach the guitar body and be amplified. What's left are the higher harmonics.

Overtones and harmonics are also involved in shaping a musical instrument's tone or sound quality—its timbre (pronounced TAM-ber or TIM-ber). Timbre is the **principal** feature of sound we use to recognize each other's voices or distinguish a dog's bark from a

[1] *octave:* the distance between the highest and lowest notes on an eight-note scale

baby's cry. With musical instruments, timbre is partly determined by the way an instrument amplifies or dampens harmonics. A trumpet, for example, which is made of brass, amplifies the harmonics rather evenly. A clarinet, because it is shaped differently and made of different materials, amplifies some harmonics more than others.

You can see the effect that an instrument's shape has on tone by considering what your mouth does when you make vowel sounds. If you sing the words "tea" and "too" and use the same musical note, the fundamental frequency is the same for both words. But "tea" sounds different because you changed the shape of your mouth in such a way as to dampen the overtones between about 500 Hz and 2,000 Hz. To make the vowel in the word "too," your mouth amplifies the overtones between 500 and 1,000 Hz and dampens the higher ones. Confusing, for sure, but your brain is hard-wired[2] to handle such calculations automatically and adjust for the different fundamental frequencies of high and low voices.

Timbre is determined by more than just the loudness of overtones. All musical instruments make sounds when a musician commits some sort of controlled violence against the device. We strike keys, blow horns, pluck strings, scrape violins with a bow, beat drums. These actions all make noises that occur before a note can sound. This initial burst of sound, called the attack, is not particularly musical. It is the sound of clicks as keys are hit, hollow thumps as fingers cover holes, the friction of fingers rubbing against strings, hissing before a horn has enough energy to vibrate, tongues tapping and pulling away from mouthpieces. After the attack phase, there is a more **stable** phase when the note's fundamental frequency and overtone patterns emerge. Experiments show that if the attack phase is removed from a recording of an instrument, people have trouble identifying the instrument. Clearly, the way an instrument moves into a note is part of its distinctive sound.

The final **dimension** of timbre is the instrument's flux. Flux refers to the fluctuations that occur throughout the duration of a note, such as slight variations in pitch and volume. A trumpet, like many wind instruments, has very little flux. Its tone is fairly **stable** as the note proceeds. Percussive instruments tend to have a lot of flux. Think of the sound of a large gong struck with a lot of force. Its sound alters significantly as the gong returns to its nonvibrating state.

Other **dimensions** of sound contribute to a musical instrument's character—its volume, the duration of its notes, the speed at which it can be played, its register (the lowest and highest notes it can play), and the number of notes it can play **concurrently**. The workings of these elements may seem more intuitively obvious than the puzzling physics of pitch and timbre. But they too contribute to what we perceive as music by taking advantage of the way our brains process the subtle vibration patterns of air molecules. In the end, the only place these instruments make music is in our heads.

[2] *hard-wired:* computer terminology, a function that does not require software; here, something the brain does quickly and automatically without conscious learning

READING COMPREHENSION

Mark each sentence as *T* (true) or *F* (false) according to the information in Reading 2. Use the dictionary to help you understand new words.

___ 1. Humans are able to hear only a fraction of the possible frequencies of air vibration.

___ 2. The piano covers the whole range of sound that humans can hear.

___ 3. The number of octaves we can hear is only limited by the range of frequencies we can hear.

___ 4. The reading suggests that music and human language take advantage of some of the same properties of sound.

___ 5. A trumpet is an example of a percussive instrument.

___ 6. Musical instruments vary in how many notes they can play simultaneously.

REVIEW A SKILL **Point of View** (See p. 59)

In Unit 4 you saw how a technical process can be described from different points of view. Find the paragraph in the reading "Pitch and Timbre" that begins, "*You can experiment with harmonics....*" Describe the change in point of view.

READING SKILL Interpreting Charts, Tables, and Graphs

LEARN

Academic readings often include tables and charts to report data and statistics. When the numbers in a table are large and end with one or more zeroes, they are usually not exact figures. They are approximate or rounded. In this case, some tables leave out the zeroes and indicate how many zeroes are missing by saying "in thousands" or "in millions" beneath the table title. When reporting data or statistics, be sure to add the missing zeroes back to the number.

APPLY

iPod Sales

Year	iPods Sold
2002	376,000
2004	4,416,000
2006	39,409,000
2008	54,828,000
2010	50,315,000
Total 2002–2010	278,540,000

Source: Apple Inc.

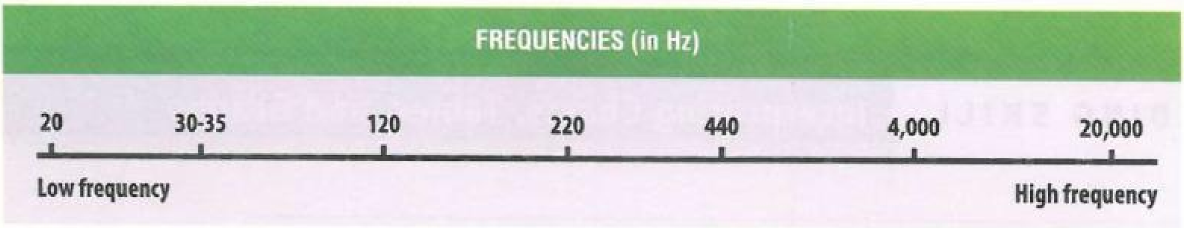
iPod Sales (in thousands)

Year	iPods Sold
2002	376
2004	4,416
2006	39,409
2008	54,828
2010	50,315
Total 2002–2010	278,540

A. Complete these sentences based on the information in the tables above. Then, write three more sentences giving more information from the tables. Use the sentence patterns from items 1 to 6 in your sentences.

1. In 2002, Apple sold ______________ iPods.
2. In 2004, ______________ iPods were sold.
3. Between 2002 and 2004, iPod sales increased by ______________.
4. In 2005, iPod sales reached ______________.
5. By 2008, Apple was selling more than ______________ million iPods a year.
6. From 2002 to 2010, iPod sales totaled just under ______________ million units.
7. ____
8. ____
9. ____

B. This chart lists frequencies of sound discussed in Reading 2. Match the label on the right to the frequency indicated.



____ Hz **1.** a man's speaking voice

____ Hz **2.** a woman's speaking voice

____ Hz **3.** the musical note A

____ Hz **4.** highest frequency humans can hear

____ Hz **5.** the lowest musical note

____ Hz **6.** the lowest frequency humans can hear

____ Hz **7.** the highest musical note

Vocabulary Activities

Noun	Verb	Adjective	Adverb
________	________	concurrent	concurrently
cycle	cycle recycle	cyclical	cyclically
________	________	identical	identically
philosophy philosopher	philosophize	philosophical	philosophically
principal	________	principal	principally
stability	stabilize	stable	________
unity unification	unify	unified unifying	________

A. Fill in the blank with a target word from the box that completes the sentence in a grammatical and meaningful way. Be sure to use the correct form.

cycle concurrent	identical principal	stable

One curious auditory phenomenon is the ability of many humans to hear a missing fundamental frequency. Sound waves are vibrations of air, measured in (1)________________ per second. A musical note is a particularly (2)________________ sound that always sends out the same number of vibrations per second. In reality, though, a musical note sends out several different sound waves (3)________________. The one with the lowest frequency is called the fundamental frequency. It is also the loudest. The other sound waves are called overtones. Curiously, their frequencies of vibration are exact multiples of the fundamental frequency. Middle C on the piano, for example, has a fundamental frequency of 261.63 Hz. But it sends out a weaker sound wave that vibrates approximately 523 times per second, another at 785, another at 1047, and so on.

Since the fundamental frequency is the loudest tone, shouldn't it be the (4)________________ component that we use to identify the pitch of a note? Maybe not. If we remove the fundamental frequency from a sound recording, many people still hear a note at the (5)________________ pitch. Our brain apparently measures the intervals between the overtones and figures out the original note. Due to this phenomenon, a small loudspeaker, such as in a telephone, can create the illusion that it is broadcasting a lower note than it is actually capable of producing. Deep voices still seem deep.

Can you hear missing fundamentals? Recent evidence from German researchers suggests that humans vary in what note they hear by as much as four octaves. Typing "missing fundamental" in a search engine will lead you to sites where you can test what you hear.

B. **Circle the word or phrase that best captures the meaning of the target word in each sentence.**

1. The coach was **philosophical** about the team's disappointing defeat.
   a. stoical and calm
   b. theoretical
2. Many of the bank's customers were nervous about risking their **principal.**
   a. money invested
   b. the school director
3. It takes about 30 minutes to complete the exercise **cycle.**
   a. bicycle
   b. a sequence of exercises
4. The patient's condition was **stable** after the surgery.
   a. not getting worse
   b. improving
5. They **cycled** around the town for several hours.
   a. rode their bikes
   b. rode around the same route
6. Their plan was **identical** to the one they used last time.
   a. similar to
   b. the same as

C. **Build sentences using a random generator: Your teacher or partner calls out a random two-digit number to identify two words from the lists below. You then use those words to write a grammatical and meaningful sentence.**

Teacher: "2-1." [The two words are "identical" (2) and "cycle" (1).]

Possible sentence: "The two species have nearly identical life cycles."

0. philosophical	0. concurrently
1. likewise	1. cycle
2. identical	2. cyclical
3. philosophy	3. dimensional
4. entity	4. identically
5. categorize	5. minimum
6. plus	6. principal
7. dimension	7. stabilize
8. stable	8. unified
9. category	9. unify

Collocations Chart			
Verb	**Adjective**	**Noun**	**Adverb**
escape, break, complete	life, billing, monthly, weekly, economic, business	(a) cycle	____________
____________	*cyclical*	pattern, trend	____________
run, do, operate	____________	____________	*concurrently*
____________	*minimum*	number, requirements, age, standards, sentence, wage, balance	____________
____________	*principal*	areas, concerns, means, source, reasons	____________
remain	*stable*	economy, condition, prices, rates, currency, relationship	____________
____________	*unified*	country, system, theory, approach, community	____________

D. **The chart above shows some common collocations, or word partners, for selected target vocabulary. Refer to the chart and complete these sentences. Compare work with a partner.**

1. The committee outlined the ________________ areas of concern to be discussed at the annual meeting.
2. Despite the unusually cold weather, fuel prices remained ________________ in January.
3. A student must meet the ________________ requirements to be admitted to the program.
4. The conference discussed the need to find a ________________ approach to combating email spam.
5. An economic or business ________________ is the regular fluctuations in economic activity over a period of time.
6. The study reported in *New Scientist* collected data suggesting that hurricane activity follows a ________________ pattern that lasts several decades.
7. By switching quickly between tasks, computers can have two or more programs running ________________ .
8. You must maintain a ________________ balance of $500 in your account to avoid a service charge.