Саратовский государственный университет им. Н. Г. Чернышевского

Е.В. Тиден

THE PRIVATE LIFE OF PLANTS

Учебно-методическое пособие по биологии

2015

Составитель - Е.В. Тиден

The Private Life of Plants: Учебно-методическое пособие по работе с видеоматериалами для студентов биологического факультета. /Сост. Е.В. Тиден. — Саратов, 2015. —61с.

Предлагаемое учебное пособие по работе с видеоматериалами предназначено для студентов биологического факультета. Система упражнений каждого урока направлена на развитие навыков аудирования и овладения новой лексикой по специальности. Аутентичный учебный материал позволяет решать учебно-методические проблемы на современном уровне.

Пособие основано на документальном сериале Дэвида Аттенборо «Невидимая жизнь растений» и включает фильмы о размножении и росте растений с разработанной к ним системой упражнений.

Рецензент:

Кандидат филологических наук, доцент, Н.Ю.Смирнова

Содержание

ВВЕДЕНИЕ

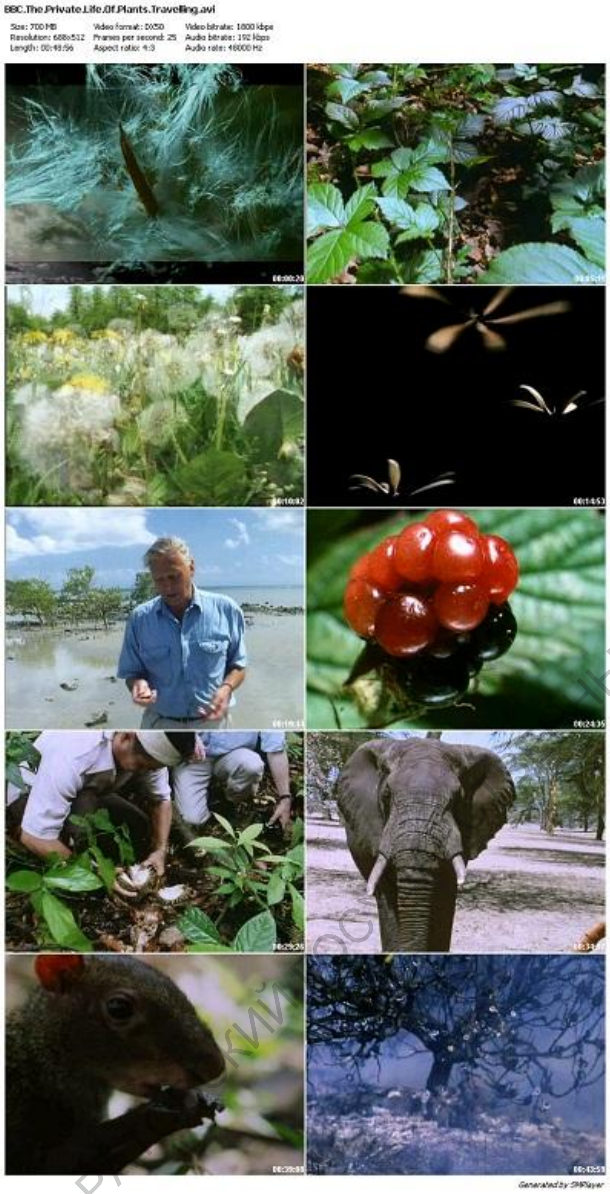
Предлагаемое пособие основано на документальном сериале Дэвида Аттенборо «Невидимая жизнь растений» и включает фильмы о размножении и росте растений с разработанной к ним системой упражнений, направленной на развитие навыков аудирования и овладения новой лексикой по специальности.

Пособие состоит из 6 уроков. Каждый урок включает предсмотровые упражнения(Previewing), показывающие насколько студенты знакомы с темой, упражнения после просмотра и повторного просмотра эпизода(Viewing), помогающие понять основные и второстепенные идеи фильма. В разделе (Postviewing) предлагаются упражнения на перевод с русского языка на английский и другие задания для закрепления полученных знаний.

Раздел “Supplementary reading“ служит материалом для расширения словарного запаса и дальнейшего закрепления навыков работы с текстами по специальности.

Данное пособие помогает подготовить студентов к самостоятельной работе со специальной литературой, обучить устным формам общения по научной тематике на предложенном видеоматериале.

Пособие предназначено как для аудиторных занятий, так и для внеаудиторной практики для студентов биологического факультета, изучающих английский язык.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Lesson 1

to unfurl	распускаться
wood anemone	ветреница
hazel	лещина обыкновенная
dock	щавель туполистый

Previewing

1. Check these words in a dictionary.

lifeless, dramatic, woodland, mate, plant, living organism, to unfurl, dock, move, shoot

Viewing

1. (00:00:34- 00:03:08) Watch and listen to the video and fill in the blanks with these words: **lifeless, dramatic, woodland, mate, plant, living organism, to unfurl, dock, move, shoot.**

a) On the countryside is so still it seems almost---------------.

b) But these trees, bushes and grasses around me are---------------just like animals.

c) They have to fight one another, they have to compete for---------------, they have to invade new territories.

d) But the reason we seldom aware these dramas is ---------------of course live on a different timescale.

e) And then you can see how ---------------the life of plants can be.

f) Speed a week into a minute and you can sense the urgency with which the ground living plant raise to----------------their flowers.

g) The broad leaves of-----------------are rising from the ground.

h) Strange though as it may seem some can -------------not just their flowers and leaves but they can travel from place to place.

i) Of all the ---------------plants this is the one of the most aggressive.

j) It waves its --------------and agitative leaves side to side as if feeling for the best way forward.

Postviewing

1. Choose English equivalents for the given Russian word combinations.

midwinter	щавель
dock	стебель-захватчик
to face very much the same sort of problems as	завоевывать новые территории
to compete for mate	бороться друг с другом
to fight one another	зрительно ускорить
to invade new territories	редко осознавать
to live on a different timescale	вырасти на 8 см в день
to speed things visually	распускать цветы

seldom aware	середина зимы
to condense 3 months into 20 seconds	бороться за возможность размножения
raid of spring	наступление весны
to speed a week into a minute	сталкиваться с похожими проблемами
to sence the urgency with which the ground living plants raise	происходить медленно
to unfurl flower	уместить неделю жизни в минуту
almost alarminly	преодолеть все барьеры
to invite insects to collect pollen	всем своим видом
invading stem	привлечь внимание насекомых
to climb over anything that stands on its way	уплотнить экранное время

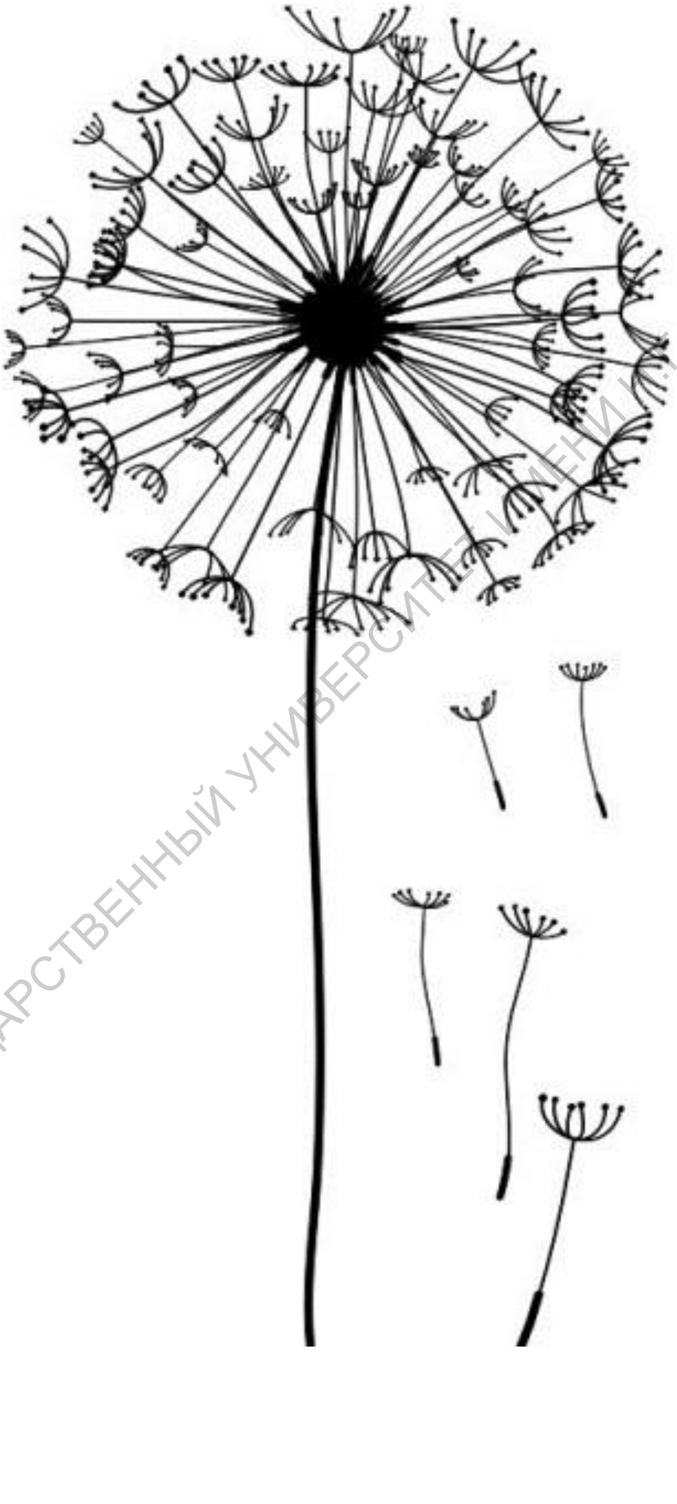
2. Translate from Russian into English:

a. Середина зимы. Вокруг так тихо, что, кажется, жизнь остановилась.
b. Но все деревья, кустарники, трава вокруг меня – такие же живые организмы, как и представители фауны.
c. Им приходиться на протяжении всей жизни прикладывать почти те же усилия, что и животным.
d. Они должны сражаться друг с другом, бороться за возможность размножения и завоевывать новые территории для жизни.
e. Но эти драматические события в жизни растений редко видны глазу, потому что происходят очень медленно.

f. Но сейчас мы можем зрительно ускорить происходящие процессы и показать, какой захватывающей может быть жизнь растений.
g. Уместите неделю жизни в минуту, и вы будете наблюдать за тем, как быстро распускаются цветы.
h. У земли разворачивает свои листья щавель туполистый.
i. Некоторые растения умеют не только шевелить листьями и распускать цветы, но и путешествовать.
j. Взгляните, к примеру, на этот куст ежевики.
k. Это одно из самых агрессивных лесных растений.
l. Шевеля своими побегами из стороны в сторону, ежевика пытается ухватиться за что-нибудь.
m. За день побег вырастает почти на 8 см.

3. Answer the following questions:

1. What problems do plants face?
2. Why do people seldom aware plants problems?
3. What helps people to understand this difference?
4. What are the reasons of moving?



Lesson 2

fox glove	наперстянка
pollen	пыльца
bramble	ежевика неская
shoot	побег
stem	стебель
spine	шип
root	корень
desert dunes	песчаные дюны
particle	частица
genetic instruction	генетическая информация
grain	зерно
fungus	гриб
seed	семя
spore	спора

puffball	дождевик
earth star	земляная звездочка
dandelion	одуванчик
petal	лепесток
cottonwood tree	трехгранный тополь
fluff	пух
to germinate	прорастать
canopy	лесной массив
humid air	влажный воздух
liane	лиана
sycamore	явор
blade	лопасть

Previewing

1. Choose the better definition for each of the following words.

tiny
a. very big
b. very small
emerge
a. to come out in view
b. disappear from view
genetics
a. the study of how characteristics are passed from one generation to another
b. the study of life
particle
a. element
b. a single whole
sheltered
a. discovered
b. covered
generation
a. all the people of a different age
b. all the people of a similar age
device

a. a small piece of equipment that does a particular job
b. to make a plan of how to do something

efficient

a. is one that works well and does what you want it to do
b. well organized and does not waste any time or energy

advantage

a. the bad things about something, which make it less good than others of the same type
b. the good things about something, which make it better than others of the same type

particular

a. exclusive
b. general

Viewing

1. (00:03:28-00:15:03) Watch and listen to the video and complete the following chart.

fungus	flower	tree

2. (00:03:28-00:15:03) Watch and listen to the video again. Then put the following sentences into sequence.

1. The smallest of all belong to fungi.
2. In autumn other smaller fungi appear on the woodland.
3. These grains are so small that it is in this form that most plants do most of their travelling.
4. Flowers also use the wind to transform their seeds.
5. But the particles they produce called spores are in many ways similar to seeds.
6. And few do it more successfully than dandelion.
7. Trees have a particular advantage – their height.
8. Plants preceded humanity in building not only gliders.
9. The longer it takes to reach the ground the further it can travel.
10. They created helicopters too.

3. (00:03:28-00:15:03) Watch and listen to the video again and say if the following sentences are true (T) or false (F). Correct the false ones.

1. These big particles are the next generation.
2. Fungi are plants.
3. The seeds are much lighter than the spores of fungi.
4. For seeds to fly special apparatus is needed.
5. Many seeds of cottonwood trees will germinate.
6. There is much more wind in a tropical forest.
7. Aircraft designers had to try to build a wing as efficient as this one but failed.
8. The balance between the weight of the seed and the length of the wing is exact and perfect.
9. A slightly heavier seed or a shorter and narrower wing and a whole thing would fall like a stone.
10. Plant produces a revolving seed with eight blades.

Postviewing

1. Give Russian equivalents to the following words and expressions.

to become exposed, to rebuild an adult plant, grow to an adult, 800 times the volume of the Earth, be carried by the wind, drip, damp air, globe, distant shore, the loss is of no consequences.

2. Give English equivalents to the following words and expressions.

в этом ему нет равных, специальный аппарат, снабженный парашютом, противоположный берег, производить в достаточном количестве, влажный воздух, продлить полет, легкое прикосновение, длинная дистанция

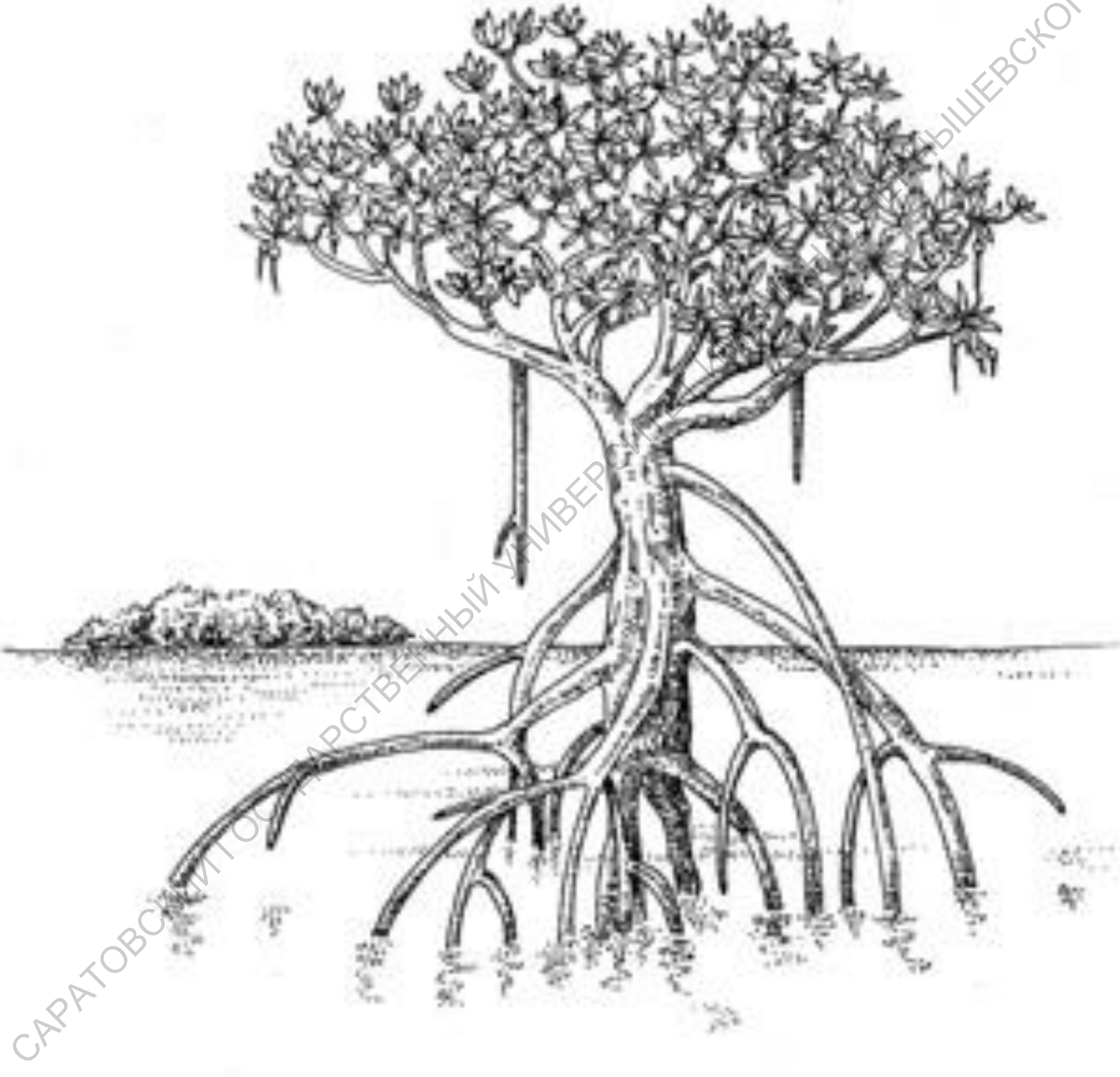
3. Translate from Russian into English.

a. Другие растения путешествуют еще быстрее.
b. Это растение погибло.
c. Но здесь, в этих частичках есть жизнь.

d. Некоторые из таких спор видно только в микроскоп.
e. Они образуют отдельное царство.
f. Сначала он немного напоминает взрослого представителя своего царства.
g. Но как только подует влажный ветер, земляная звездочка начнет преображаться.
h. В это время года земляная звездочка раскрывается навстречу дождю.
i. Это приспособление настолько действенно, что даже легкий ветерок уносит семена высоко в небо.
j. Семян так много , что популяция тополей не пострадает.

4. Answer the following questions .

1. What part of plant contains genetic instruction?
2. What part of fungi is similar to plants seeds?
3. What will happen if 2 generations of every spore grow to an adult?
4. What helps fungi to make long distances?
5. In what season do earthstars appear?
6. Why do earthstars open this season?
7. What flower is the most successful in transforming seeds with the help of the wind?
8. In what period do petals and flower heads of dandelion transform into globes?
9. Why do seeds of dandelion need special apparatus?
10. What advantage do trees have?



Lesson 3

jet propulsion	реактивная тяга
Himalayan balsam	недотрога гималайская
mesembryanthemum	хрустальная травка
pod	стручок
sea bean	морская фасоль
mangrove	мангровый лес
burdock	лопух
hook	колючка
spike	шип
thorn	шип
cleft	трещина
hoof	копыто
pad	подушечка на лапе
scaly	чешуйчатый
ostrich	страус
ripen	созревать
rowan	рябина
yew	тис
strawberry	земляника
cherry	черемуха
hawthorn	боярышник
fig	фиговое дерево

Previewing

1. The *italicized* words in the sentences below are used in the video. Read the sentences, and then match the words with the meaning.

1. Water *provides* many plants the power they need.
2. Many doubtless are lost at sea, but some *eventually* will reach another and may be a distant coast.
3. As well as fruit-eating birds they *attract* all kinds of mammals, monkeys, squirrels and gibbons.
4. One by one the sea beans start on their *voyages*.
5. It is not a *disaster* for the seed is able to flout by itself.
6. This one has *landed* on Tropical beach in Northern Australia.
7. To *survive* it must get bellow ground.
8. The seed has now *reached* the safe place and an ideal position to germinate just bellow the surface of the ground.
9. They *force* to fit with their timetable.
10. The scaly feet of ostrich are *particularly* tough.

1. *provide*	a. to stay alive in a dangerous situation
2. *eventually*	b. a long journey
3. *attract*	c. to arrive somewhere after a journey
4. *voyage*	d. to come down to the ground after being in the air
5. *disaster*	e. to give or make available something that someone needs or wants
6. *land*	f. to make someone or something go to a place because they want to find out what is happening there
7. *survive*	g. in the end, after some time has passed
8. *reach*	h. a very serious accident, especially one that causes a lot of damage
9. *force*	i. to make someone do something that they do not want to do
10.*particularly*	j. especially, more than others

Viewing

1. (00:15:03-00:26:07) Watch and listen to the video and complete the following chart.

Plants that send their seeds by sea	Plants that use living couriers

2. (00:15:03-00:26:07) Guess the meaning of these words in context: **absorption, flout, leak off, tread on, naked, relatively, vivid, groove, mouth, tough.**

3. (00:15:03-00:26:07) Watch and listen to the video again and fill in the blanks.

1. Plants also use ……………jet propulsion.
2. This is a squirting …………….
3. And this ……………balsam.
4. …………….seed heads are opened by rain.
5. There is a groove across the ………….between its seeds.
6. The seed makes its way through the ………… to the sea.
7. The burdock uses …………. .
8. These things are called by local people “devil ………….”
9. These berries do not …………….simultaneously.
10. Tropical …………. produce much smaller fruits.

Postviewing

1. Match the words to make phrases.

set	with
shake	hiker
tempting	for
entice	off
to be	reward

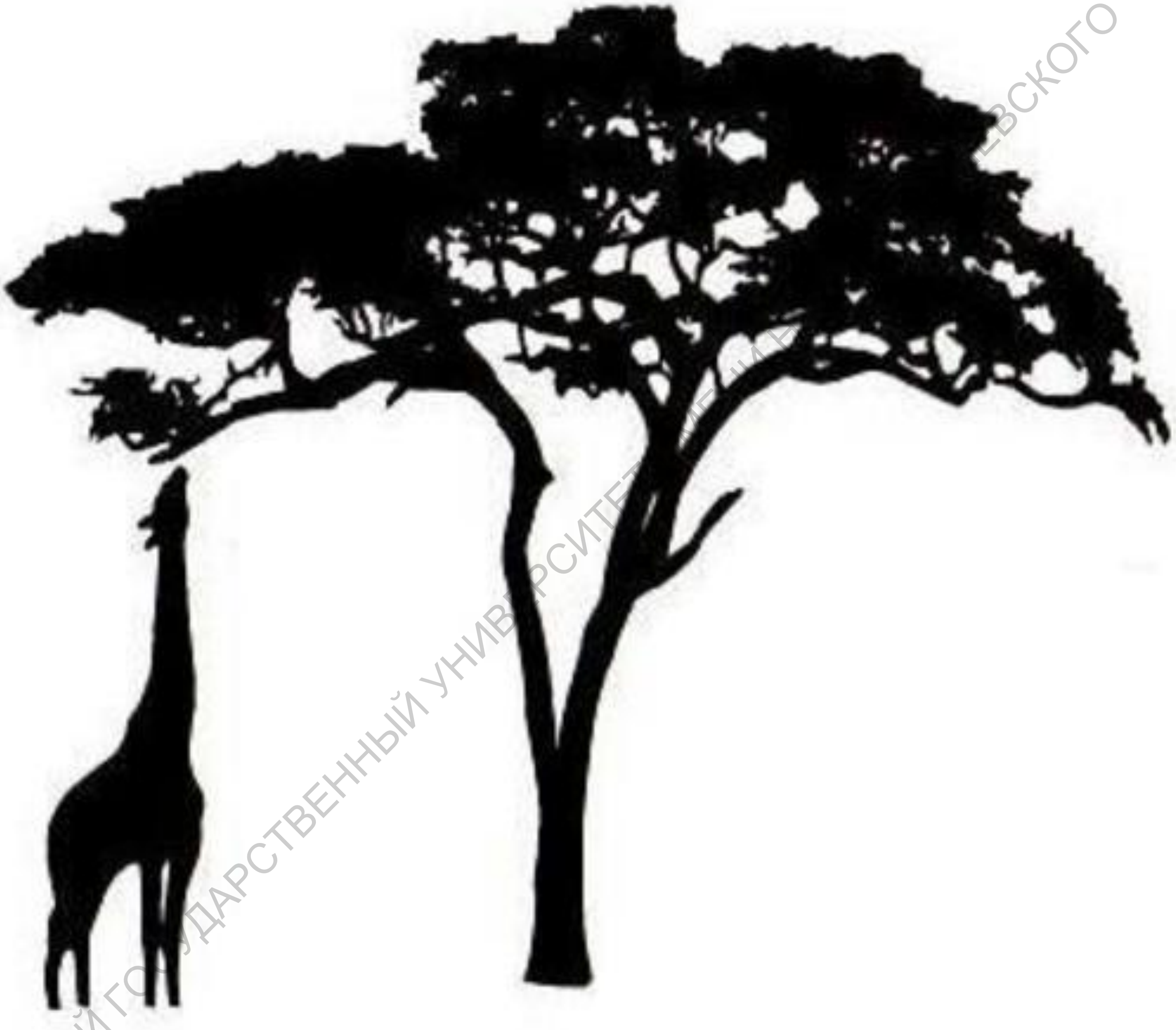
vicious	effect
ill	of no interest
fit	packaging
protective	with one’s timetable
start	on

2. Translate from Russian into English.

1. По берегам тропических рек растет самое крупное из стручковых – морская фасоль.
2. Ее семена – один из самых успешных путешественников.
3. Такое семечко в течение года может проплыть мимо островов, выйти в открытое море, преодолеть океанские течения и все равно не погибнуть.
4. Это семечко доплыло до северной Австралии, но неизвестно, откуда оно приплыло.
5. Его родиной может быть дерево неподалеку но, возможно, оно с другого континента.
6. Итак, растения отправляют семена по воздуху и по морю, но многие привлекают для этих целей курьеров.
7. Брюки и ботинки хорошо служат для переноски семян.
8. Здесь на юге Африки есть растения, которое использует шипы, и ждет пока кто - нибудь наступит на него.
9. Если на них наступит разутый человек или животное, ему будет очень больно.
10. Птицы различают цвета почти также хорошо, как и люди.

3. Answer the following questions.

1. What plant is the most successful of all vegetable travelers?
2. Why do sea bean seed fall independently?
3. How long does it take sea bean to sail across the sea?
4. What do plants use to force us to fit with their timetable?



Lesson 4

rhinoceros hornbill	пегий носорог
to digest	переваривать
indigestable	непериваримаемый
crop	зоб
cassowary	казуар
wattle	бородка
pungent	резкий
durian	дориан
Indian rhinoceros	индийский носорог
monsoon flood	муссон
acacia	акация
species	вид
beetle grub	личинка жука
to hatch	вылупляться

Previewing

1. Read the sentences, and then match the *italicized* words with the synonyms.

1. Both male and female cassowaries have vividly colored wattle and a similarity between them and fruits which birds make food may not be merely *coincidence.*
2. The *wattle* serves as social signals between the birds.
3. *Visual* signals however have limitations in advertisement.
4. There is another message- *smell*.
5. The smell is very *disgusting*.
6. Animals may carry seeds for long distances in their stomachs but most of them get rid of them more or less at *random.*
7. Their seeds can not grow and germinate in *deep* shade.
8. It's so fond of these fruits that they are called locally "rhino apples".
9. Without elephants some species of acacia would *barely* survive.
10. Inside the pods the seeds are *threatened* by serious enemies.

coincidence	disorder
wattle	like
visual	dense
disgusting	hardly
random	jowl
deep	optical
to be fond of	to be in danger
barely	abominable
to be threatened	odour
smell	concurrence

Viewing

1. (00:26:07- 00:34:11)Watch and listen to the video and fill in the blanks below:

1. Types of messages:

a. --------------------------------
b. ----------------------------

2. Disadvantages of visual signals and smell:

a. ---------------------------------
b. ---------------------------------

3. Advantages of visual signals and smell:

a. -----------------------------------
b. -----------------------------------

2. (00:26:07- 00:34:11)Watch and listen to the video again and circle the correct word in the sentences below.

1. The (**rhinoceros hornbill** / **cassowary**) in order to eat such small fruit with such a huge beak has to be a bit of a juggler.
2. Dozens of fruit, containing hundreds of seeds are carried away in hornbill's (**beak/crop)** for miles.
3. The **(flesh/indigestible bits)** will be digested.
4. Some people like the **(taste/smell)** of this fruit.
5. The grasslands are created by **(hurricanes/monsoon floods).**
6. Once more they **(trust/rely on)** rhino to solve it.
7. Without elephants some species of (**acacia/durian)** would barely survive.
8. Little **(beetle grubs/fly maggots)** are hatched from eggs.
9. **(Monkeys/elephants)** eat pods, seeds and grubs.
10. The acacia (**gets little benefit from/take advantage of)** providing them with meal.

3. (00:26:07- 00:34:11)Watch and listen again and match nouns with adjectives.

rich	duties
social	risk
pungent	enemy
deep	animal
Indian	signals
daily	shade
great	variety
serious	trouble
considerable	smell
magnificent	rhinoceros

Postviewing

1. Translate from Russian into English.

1.На острове Новая Гвинея почти нет млекопитающих, и почти не водятся обезьяны.

2.На острове самый крупный представитель фауны – это птица.

3.Она называется казуар.

4.Определенно можно сказать, что казуары с легкостью находят ярко окрашенные плоды.

5. Зрительные сигналы не всегда служат для передачи информации .

6.В густом лесу на большом расстоянии они не различимы.

7.Некоторым жителям так пришелся по вкусу этот плод, что они готовы много времени потратить на его поиски.

8.Вот он знаменитый дориан.

9.В Африке в симбиозе живут слоны и кусты акации.

10.Каждый год у акации созревает большое количество семян, которые дают пищу многим животным.

2. Answer the following questions.

1. In what part of body do rhinoceros hornbills carry seeds?
2. Which place has the richest variety of fruit eaters' messages?
3. Are there many mammals in New Guinea?

4. What color attracts cassowary?
5 What is the taste of durian?
6. What is the purpose of visual signals?
7. Why do some plants need living couriers?
8. What mammals used as living couriers have been mentioned in the video?
9. Is it possible for acacia to survive without elephants?
10. Why does acacia get little benefit from providing monkeys with meal?

Lesson 5

digestive juice	желудочный сок
dung	помет
Brazil nut tree	бразильский орех
agouti	агути
to gnaw	прогрызать
to sprout	пускать ростки
alpine nutcracker	поползень
pine	сосна
cone	шишка
ivy	плющ
protea	протея

Previewing

1. Read the sentences, and then match the *italicized* words with the antonyms.

1. These acacia seeds have spent at least 24 hours *inside* an elephant stomach.
2. So acacia seeds eaten by an elephant have been saved from *death*.
3. Some seeds however are so well *protected* that it seems nothing could eat them.
4. The agouti has as sharp *front* teeth as a chisel.
5. It doesn’t have a *perfect* memory.
6. It *looses* tracks of what it buried and the significant proportion of the nuts survived to sprout.
7. The bird knows exactly how to *open* a cone.
8. But *unlike* the agouti it carries the seed away from the forest.
9. It buries them at *right* depth.
10. Yet some plants *succeed* in reaching inaccessible sites.

inside	threatened
death	bad
protected	find
front	like
perfect	lock
loose	outside
open	fail
unlike	wrong
right	back
succeed	survival

Viewing

1. (00:34:26 -00:47:57)Watch and listen to the video and complete the following chart.

living beings	**seeds which living beings can eat**

2. (00:34:26 -00:47:57)Watch and listen to the video again and fill in the blanks.

1. 90 % of acacia seeds in elephant…………… germinate.
2. Only one animal has the equipment to open them- the…………
3. They enable to …………… a hole.
4. And the agouti has a habit which exactly suit the …………. .
5. It looses tracks of what it buried and the significant proportion of the nuts survived to………….. .
6. The ……………..is a kind of a crow.
7. The bird knows exactly how to open a …………. .
8. Some of these places …………the young trees very well.
9. There are several species of ………….growing here and they all depend on the arrival of seasonal fires.
10. In fact it is the only time the protea seeds can …... because these seed heads have to be burnt before they release their seeds.

3. (00:34:26 -00:47:57)Watch and listen again and match nouns with adjectives.

digestive	agouti
certain	time
front	tree
individual	site
significant	ash
hard	juice
young	depth
right	proportion
inaccessible	death
rich	teeth

Postviewing

1. Translate from Russian into English.

1.Даже упав с высоты 30 метров, они не разбиваются.
2. Бразильский орех сумел защитить себя от вторжения агути.
3. Внутри каждого шара 15-20 орехов. Это больше, чем может съесть зверек.
4. Зверек закапывает про запас все, что не может съесть.
5. Птица проглотит их, но отправит их не в желудок.
6. Затем поползень поступает также, как агути.

7. Поползень одно за другим извлекает из зоба семена и закапывает свои сокровища.
8. После того, как лепестки опали, начинается рост и развитие семян.
9. Растение находит ближайшую к нему щель в стене и само высаживает свои семена.
10. Растения добиваются, чтобы их семена оказались в наилучших для развития условиях.

2. Answer the following questions.
1. Who saves acacia seeds from death?
2. What habit does the agouti have?
3. What helps the significant proportion of the nuts to be survived?
4. Who knows how to *open* a cone?
5. When the protea seed heads can release their seeds?

Lesson 6

trunk	ствол
bark	кора
chest nut	каштан
larch	лиственница
transparent	прозрачный
pore	пора
tangle	плетение
infant	молодой
manufacture	изобретать
fern	папоротник
raw	сырье
chlorophyll	хлорофилл
dawn	рассвет
rootlet	корешок
moisture	влага
reflect	отражать

dim	тусклый
alocasia	алоказия
begonia	бегония
hydrogen	водород

Previewing

1. Read the sentences, and then match the *italicized* words with the synonyms.

1. Now it will *rot* and release a thousand seeds.
a) extinct b) decay
2. The shoot that comes from a seed like all shoots can *sense* the light.
a) understand b) feel
3. Each *sprouts* upwards.
a) shoot b)breed
4. That is enough *to enable* to travel about 6 feet.
a) be able b) be unable
5. If it doesn't find what it looking for within that distance it will die of *starvation*.
a) abundant b) hunger
6. They *reach* a vertical surface – a tree trunk.
a) achieve b) fail to achieve
7. As soon as one touches it its behavior changes *dramatically*.
a) a little b) much
8. It starts growing upwards and as it does it *puts out* its first leaves.
a) sprout b) let out
9. With each additional leaf the young plant increases a *strength*.
a) power b) weakness
10. Come the *dawn* the sun reappears and the process starts again.
a) sun rise b) sun set

Viewing

1. (00:01:25-00:16:26) Watch and listen to the video and complete the following chart.

raw material which plants need to grow	**the source of the raw material**

2. (00:01:25-00:16:26) Watch and listen to the video again and fill in the blanks.

1. But this ………….plant behaves very strangely.
2. They reach a vertical surface – a tree………….
3. Now for the first time it ……………food for itself.
4. They are powered by the sunshine and they use the simplest of ……materials- air, water and a few minerals.
5. The process is a ………..talent of plants.
6. This a very …………..of life.
7. It circulate within them and reach the tiny granules which contain a green substance…………...
8. That means light falling on the surface of the leaf is going through it is not lost but …………it back into the body of the leaf.

9. Having found water they put out thin …………….. .
10. The soil in woodland is a …………of rootlets from many different kinds of plants.

3. Choose the correct English equivalents for the given word combinations.

to be powered by the sunshine	фокусировать свет
to grow hardly	молодой побег
to release light	выпускать корешки
to reflect back	погибнуть от голода.
to put out rootlets	подпитываться энергией солнца
to release seeds.	пропускать свет
to sprout upwards	дать жизнь семянам
to die of starvation.	почти не растет

infant plant	отражается
to gather light	тянуться вверх.

Postviewing

1. Translate from Russian into English.

1. Как только растение коснулось его, оно начинает расти вверх.
2. На первое время растение нашло себе пищу.
3. Маленькие круглые листочки прижимаются к стволу дерева.
4. А сырное дерево достигло своей цели- кроны леса.
5. А вот листья уже взрослого растения.
6. Листья - фабрика пищи для растений.
7. Ни одно животное на это не способно.
8. Так что, все они зависят от пищи, которая производится здесь.
9. Вот основа жизни.
10. В густом лесу все гораздо сложнее.

2. Answer the following questions.

1. How long can an infant plant go?
2. What difficulty do plants have?
3. What raw material do plants need?
4. How do canopy trees loose a lot of water?
5. What facilities do tropical plants have to carry water away?

Supplementary reading:

Introduction

Wherever there is sunlight, air, and soil, plants can be found. On the northernmost coast of Greenland the Arctic poppy peeps out from beneath the ice. Mosses and tussock grasses grow in Antarctica. Flowers of vivid color and great variety force their way up through the snow on mountainsides. Many shrubs and cacti thrive in deserts that go without rain for years at a time, and rivers, lakes, and swamps are filled with water plants.

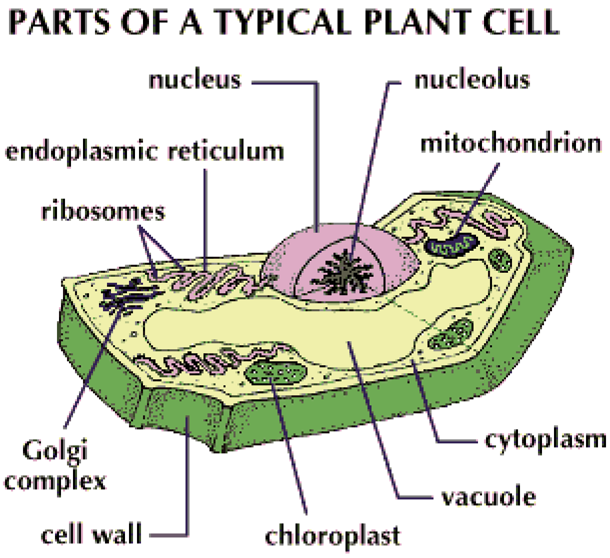
The scientists who study plants—botanists—have named and described approximately 270,000 different kinds of plants. They estimate that another 30,000 unidentified species exist in less explored ecosystems such as tropical forests.

Parts of Plants

A plant is actually more complex than it might appear. Its various parts, composed of specialized cells and tissues, work together to carry on the plant's life functions. The leaves gather sunlight and help the plant make its food; the stems support the plant; the roots anchor the plant and draw water and minerals from the soil; the flowers, fruits, and seeds allow the plant to reproduce.

Plant Cells and Tissues

The tissues that make up the parts of a plant are groups of cells that perform a particular function. Plant tissues are said to be simple if they are composed of a single type of cell and complex if they are composed of two or more cell types.



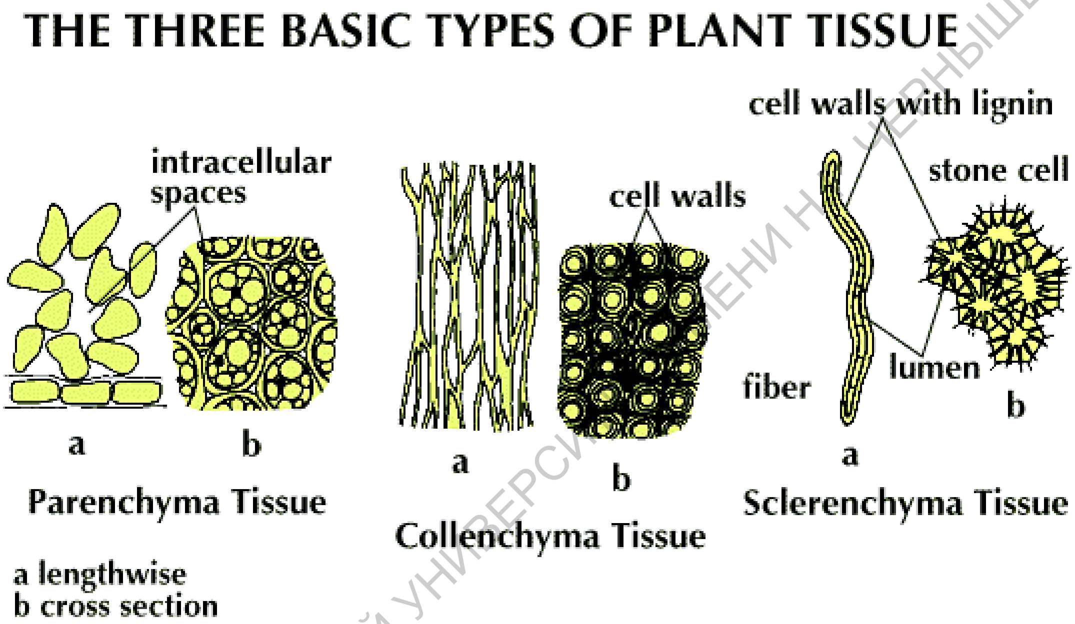
Simple tissues

Also referred to as ground tissues, simple tissues include the tissues known as parenchyma, collenchyma, and sclerenchyma. Parenchyma tissue is composed of parenchyma cells, which are found throughout the plant. They are particularly abundant in the stems and roots. The leaf cells that carry out photosynthesis are also parenchyma cells. Unlike many other plant cells, parenchyma cells are alive at maturity and retain the ability to divide. They perform many functions. Some are specialized for photosynthesis, others for storage, and still others for secretion and transport. An important class of parenchyma cells makes growth tissues called meristem and cambium. These tissues give rise to all other tissues in the plant body.

Like parenchyma cells, collenchyma cells are alive at maturity. They differ from parenchyma cells in that they have thick cell walls. Collenchyma tissue is most often found in the form of strands or cylinders of cells in stems and leaves. The thick cell walls of collenchyma cells provide support to these plant structures. The strands of tissue in celery are collenchyma tissues.

Sclerenchyma tissue is found throughout the plant. The cells of this tissue also have thick cell walls. These walls are often composed of the chemical lignin, which gives the walls a great deal of strength. Cells with lignin in their cell walls lack protoplasts at maturity—that is, they are dead. Sclerenchyma cells give plant parts strength and support.

The most common kinds of sclerenchyma cells are fibers—long slender cells that often occur in bundles or strands. These cells are interwoven so that the tissue is very strong. Manila hemp, used for making rope, is derived mainly from these fibers. Other sclerenchyma cells, called stone cells, form the shells and husks of seeds and nuts. Stone cells are scattered throughout certain fruits. They give fruits such as pears a gritty texture.



Complex tissues

The complex tissues include the dermal and vascular tissues of plants. The epidermis is the outermost layer of cells on the plant body. It covers the leaves, stems, and roots, as well as the flower parts and seeds. In most plants the epidermis is only one cell-layer thick. The epidermal cells are closely packed. When viewed through a microscope, they resemble a stone pavement. The outer cell wall of the epidermis is very thick. It contains a waxy chemical known as cutin and is called the cuticle. Because water does not easily move through the cuticle, this layer protects the plant from water loss. The cuticle also protects the delicate tissues underneath from damage.

The epidermis of leaves and of some stems has small openings that allow gases to move in and out. These openings are called stomata (a single opening is called a stoma). Each stoma is opened and closed by two specialized cells called guard cells. Unlike other dermal cells, guard cells have chlorophyll and carry out photosynthesis. These cells swell during the day, causing the stoma to open. During the night they lose pressure, and the stoma closes.

In older stems and roots the epidermis may be replaced by periderm tissue. It is periderm that produces the tough bark that protects tree trunks. It consists mainly of cork tissue rich in sclerenchyma cells. Periderm also includes specialized parenchyma cells that produce cork tissue by means of cell division.

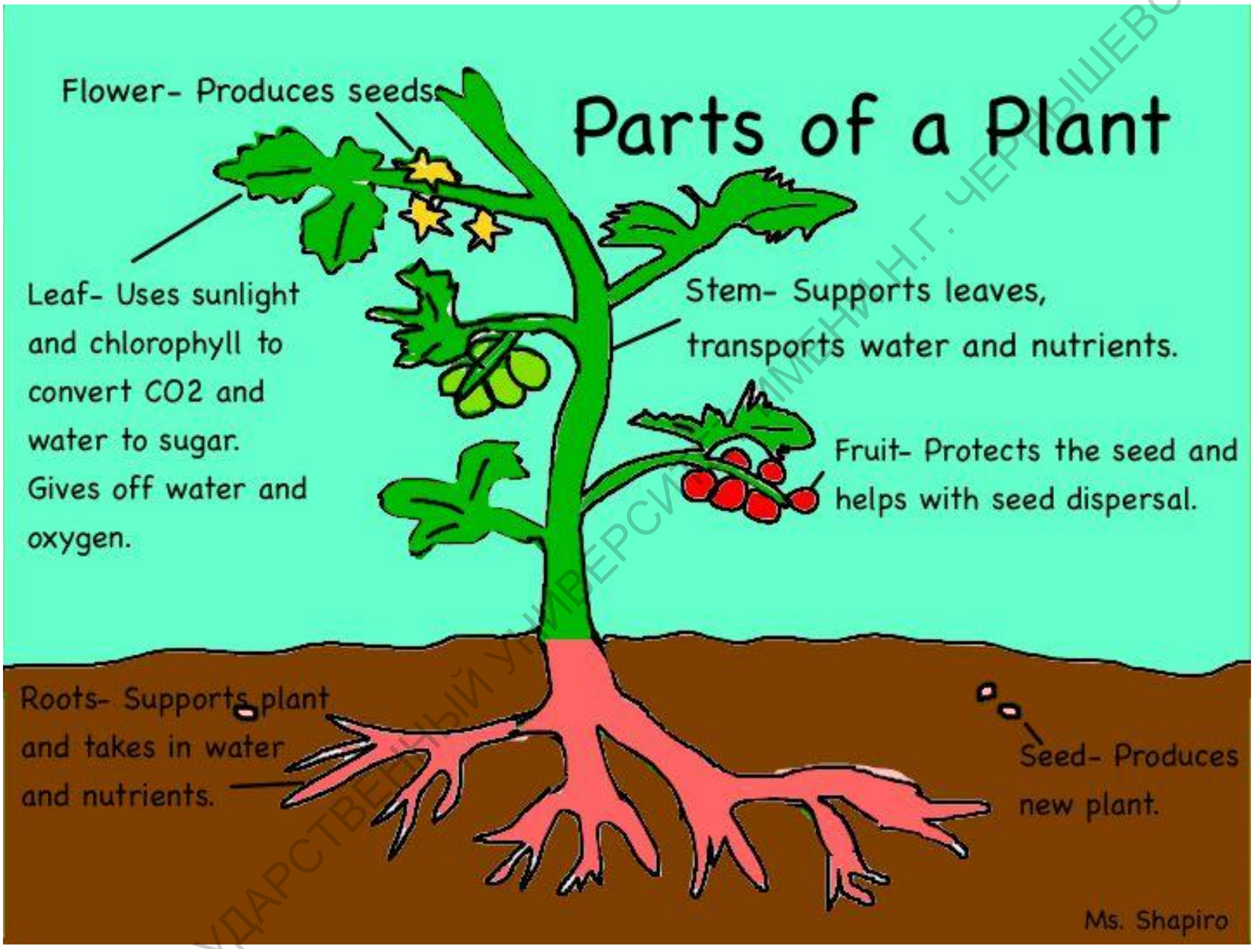
Unlike dermal tissues, vascular tissues are specialized for the transport of water, minerals, and food throughout the plant body. Vascular tissues include two types of complex tissue: xylem and phloem. These complex tissues are arranged either in strands or in units called vascular bundles. The strands form a continuous transport system that extends from the roots, up the stems, to the leaves. The leaf veins are composed of vascular bundles.

Xylem is the principal material in wood. It includes four types of cells: parenchyma, fibers, tracheids, and vessel members. Parenchyma cells are the only living cells in xylem. They form rays through the xylem and transport materials across it. Parenchyma cells also produce other xylem cells. The thick cell walls of fibers provide support to the xylem.

Tracheids are long cigar-shaped cells. They have thick cell walls that contain lignin. Like fibers, they are dead at maturity. The cell walls of tracheids contain many pores, which allow water to flow easily from one tracheid to the next. Tracheids also provide support to the xylem. Tracheids are the only type of water-conducting cells found in such primitive vascular plants as ferns and conifers.

The cells called vessel members form vessels that run up and down the xylem of flowering plants. Like those of tracheid cells, the cell walls of vessel members contain lignin. As vessel members mature, the cell wall at each end of the cell dissolves and the protoplast dies, leaving a continuous “pipe” through which water can move.

Like xylem, phloem includes parenchyma and sclerenchyma cells. The type of cell primarily responsible for transporting food through the plant body is the sieve cell. These are elongated cells joined together end to end to form a sieve tube. A vascular bundle may contain hundreds of sieve tubes. Sieve cells are alive at maturity (the transport of food materials requires the activity of living cells). The walls at the ends of sieve cells have large pores through which food materials can be readily moved. The sieve cells of flowering plants lack a nucleus; adjacent to each sieve cell are several companion cells that function in place of the missing nucleus.



Leaves

Plants may well be thought of as food factories. The most important part of the plant factory is the chemical laboratory—the leaves. In the presence of sunlight, the chloroplasts, which contain the pigment chlorophyll, carry out photosynthesis. All life on Earth depends on photosynthesis. Without it there would be no green plants, and without green plants there would be no animal life. Moreover, the green plants of the past that were locked up in the Earth have become the major fuels of today—coal, gas, and oil.

Any plant that contains chloroplasts can make its own food. Some plants conduct photosynthesis in the green tissues of stems, and some very simple plants have chlorophyll in single cells. Green leaves, however, are the chief laboratories in which photosynthesis takes place.

The epidermis of the leaf usually consists of a single layer of cells covering both the top and bottom of the leaf. Most epidermal cells do not contain chloroplasts. The tiny openings called stomata usually occur on the lower surface of the leaf. Stomata permit gases to enter the leaf and permit gases and water to leave the leaf. If the stomata were on the side of the leaf exposed to the sun, the leaf would lose too much water and would die. Some leaves have chloroplasts and stomata on both sides and turn their edges to the sun.

Between the upper and lower epidermis of the leaf is a layer of cells called the mesophyll. The mesophyll is composed of parenchyma cells that have chloroplasts—it is in the mesophyll that most photosynthesis takes place. Mesophyll cells form a loose network with many air spaces, allowing such gases as carbon dioxide and water vapor to move freely between the cells. A single square inch (6.5 square centimeters) of an elm leaf may have 250 million chloroplasts, and a mature elm tree may have 100,000 leaves.

The veins of the leaves contain the transport tissues—xylem and phloem. Xylem brings water and mineral nutrients such as nitrogen to the mesophyll cells. Phloem transports sugars and organic matter from the mesophyll cells to other parts of the plant.

The colorless plants that lack chlorophyll are either parasites, which live on other plants, or saprophytes, which live on decaying animal or vegetable matter. Dodder and mistletoe are parasites. Indian pipe is a saprophyte.

Stems

A crucial part of higher plants is the stem. (The simplest plants have none.) Stems give the plant support. The xylem and phloem within the stem distribute the water and sap throughout the plant. Leaves, flowers, and branches develop from buds on the stem.

Stems have many different forms. The woody upright trunk of a tree is a stem. Shrubs have many woody stems. Large species of vines called lianas are climbing stems with roots in the ground. Grapevines are woody lianas. The stems of such plants may also have curly tendrils—modified branches that cling to a tree or other support. In tropical forests there are many kinds of woody lianas that climb up the trunks of trees into the sunlight.

The stems of herbs have very little woody tissue. The banana tree is not a tree at all but an herb because its trunk, or stem, is not woody. There are several kinds of herbaceous stems. Most of the familiar flowers have upright stems. The stems of cucumber and pumpkin plants lie prostrate on the ground. Morning-glory and bindweed stems twine upward with the help of tendrils.

A horizontal stem growing below the surface of the ground is called a rhizome. The common iris, for example, grows from an underground rhizome. Short, fleshy underground stems are called tubers. The potato is a tuber. Its “eyes” are actually buds from which the aboveground potato stems sprout. Upright underground stems enlarged with stored food, such as those produced by the gladiolus, are called corms. A stem that grows erect and then curves over, touching the ground at its tip, is called a stolon. Certain roses and raspberries have stoloniferous, or stolon-bearing, stems. A stem that runs along the ground, often far from the point where the plant has its roots, is called a runner. Strawberry plants have such stems.

Flowering plants may be divided into monocotyledons and dicotyledons not only on the basis of the formation of their embryonic leaves, but also on the basis of the arrangement of the vascular bundles within their stems. In dicotyledons (often shortened to “dicots”), or plants with two seed leaves, the bundles are arranged in a circle around the central portion of the stem, called the pith. Beans and most trees and shrubs are dicots. One way to recognize dicots is by the veining of their leaves: the veins of most dicots are arranged in the form of a network.

A tree trunk is a typical dicot stem. The stump of a tree reveals the same kind of rings as those in the stem of a violet viewed under a microscope. Immediately beneath the outer layer, or epidermis, of the dicot stem is a layer called the cortex. The cortex is composed of parenchyma cells that primarily store food. Inside the cortex are the vascular bundles. The phloem, which conducts food through the plant body, is located within the vascular bundles toward the outside of the stem. The xylem, toward the inside of the stem, conducts water upward from the roots. Between the xylem and the phloem is the third tissue, the cambium. This is a layer of parenchyma cells; the cells toward the outside produce phloem cells, and those toward the inside produce xylem cells. The growth in the diameter of a stem takes place in the cambium layer. The center of the stem, the pith, serves as a storage place for reserve food.

In woody dicots, such as shrubs and trees, the cambium forms a continuous ring around the stem and produces a continuous ring of phloem to the outside and xylem to the inside. As a result, the xylem forms a solid core—the wood. As the stem matures, the pith and cortex may disappear. The cell walls of the tracheid cells and vessel members of the xylem that are produced in the springtime are thinner than those produced in the summer. This variation results in the formation of distinct rings in the wood that indicate the growth pattern of the tree over the period of a year. These rings are called annual rings.

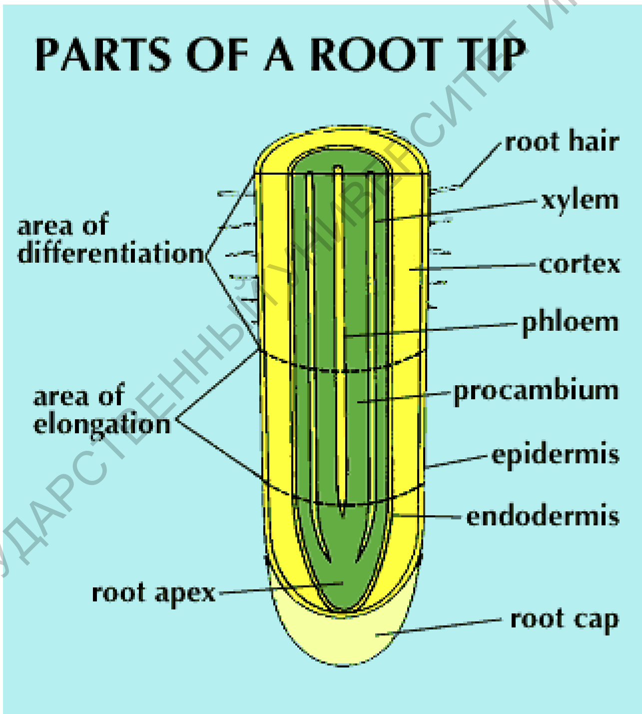
Plants with one embryonic leaf have vascular bundles in the form of strands scattered throughout the stem. Such plants are called monocotyledons, or monocots. The veins in their leaves generally run parallel to one another. Grasses, corn (maize), bananas, palms, and lilies are among the monocots. Monocot stems have a cortex and vascular bundles with xylem and phloem. Their vascular bundles do not have a cambium layer and the stems have no central pith. Because they lack cambium, monocots grow in height but, with the exception of palms, the diameter of their stems does not increase.

Vascular bundles divide into smaller bundles as they enter branches, twigs, leafstalks, and finally leaves. Food moves not only up and down but also sideways into all parts of the plant. Vascular rays and pith rays carry sap horizontally through the cell walls.

Stems are distinguished from roots in that stems have buds. Buds called terminal buds occur at the tip of the stem and lateral buds grow on the sides of the stem. The buds develop into leaves, side branches, and flowers or cones. Annuals, most biennials, and a few perennials have naked buds that are covered only by the flower parts or elementary leaves. Perennials, which must survive the hardships of winter, have protected buds that are covered with waterproof waxy bud scales. When the buds begin to swell in the spring, the bud scales fall off, leaving scars. The amount of annual growth of a plant can be measured by the distance between these scars.

Active buds are those that are growing and producing new plant parts. Most buds are latent—that is, they do not grow unless the plant suffers injury, as from fire, insects, or frost. Latent buds lie in reserve and are stimulated to growth only when necessary to restore the plant to good health.

Roots



The roots may be called the receiving rooms of the plant factory, for one of their chief functions is to draw water and minerals from the soil. As rainwater filters into the ground, it dissolves the minerals in the soil. The plant uses this solution for its work in making food. Roots also anchor the plant in the soil and serve as places to store food.

When a seed sprouts, the first thing to break out of the coat is the root (called the radicle at this early stage). No matter what the position of the seed is when it is planted—whether upright, sideways, or upside down—the root always turns downward.

The most important part of a root is its tip, where the actively dividing cells in the meristem tissues are found. Just above the very end of the root, called the root cap, root hairs extend from the cells of the epidermis. These root hairs increase the surface area in contact with the soil and increase the plant's ability to draw water and minerals. The root hairs are seldom seen because when a plant is pulled up they are broken off. This is why flowers and trees that are to be transplanted must be carefully dug up, with a ball of earth to which the roots are fastened remaining at the base.

Roots take in enormous quantities of water. It has been estimated that one alfalfa plant requires about 900 pounds (408 kilograms) of water; a potato plant, 636 pounds (288 kilograms); wheat, 500 pounds (227 kilograms); and cactus, 40 pounds (18 kilograms). A small amount of this water is used for photosynthesis or is retained in the plant's cells; most passes into the air through the leaves in a process called transpiration. Because all this water must enter the plant through its roots, a plant must have a vast root network. After four months, a single rye plant, for example, has about 13,800,000 roots. If the epidermis of those roots was spread out flat, it would cover a football field.

Flowers and Fruits

Flowers are the primary reproductive organs of those plants belonging to the division Anthophyta. In flowers the seeds are produced that will give rise to the next generation. The primary parts of the flower are the sepals, petals, stamens, and pistil.

The leaflike sepals form the protective covering for the flower bud before it opens. All of the petals together are called the corolla. The petals are often brightly colored to attract insects or other animals that might pollinate the flower. Some flowers have glands at the base of the petals or sepals that produce nectar—an additional attraction to pollinators.

The stamens produce pollen grains. The lowermost portion of the pistil is swollen to form the ovary, within which the ovules are found. Ovules develop into seeds after they are fertilized—that is, after pollen is transferred from the stamen to the pistil.

The arrangement of flower parts varies from one plant species to another. Often the color and shape of the corolla is such that only particular insects or hummingbirds are attracted to the flower. For example, only insects with long “tongues” can reach the nectar produced at the base of the corolla of certain orchids. Some flowers lack sepals, petals, or both. This is true, for example, of many forest trees that depend on wind, rather than insects, to carry pollen from flower to flower. In some plants, flowers may be specialized: some have stamens and others have pistils. The common persimmon of temperate forests, for example, has “male” trees, which produce flowers that have only stamens, and “female” trees, which produce flowers that have only pistils.

After the ovules in the ovary have been fertilized, the ovary may begin to enlarge into a fruit. A fruit is a matured ovary that contains seeds. In some plants the ovary wall may separate into two layers. The inner layer forms a hard shell, called the stone, or pit, that encloses the seed. The outer layer may be fleshy and succulent. The peach, cherry, and apricot are examples of such fruits. In the fruits called berries, the seeds are embedded entirely in fleshy tissue. Dry fruits, such as nuts and acorns, are those in which the ovary wall forms a hard outer covering.

Seeds

Embryonic plants, called seeds, vary considerably in size. Orchids, for example, produce seeds as small as dust particles. The coconut is one of the largest seeds in the plant kingdom. In many seeds, the protective outer seed coat is composed of sclerenchyma cells, which make the coat resistant to physical damage and which may also contain waxes and oils that help prevent water loss.

The embryo within the seed begins as a single cell, the zygote. The basic organs of the plant body can be found in the embryo. In some seeds the embryonic leaves, or cotyledons, are quite large, filling most of the volume of the seed. Such cotyledons are major sources of stored food for the embryo. Beans are examples of plants with large cotyledons. In many other plants the cotyledons are relatively small, and the embryo is nourished by a tissue called endosperm.

Plant Classification

Plants may be organized according to the forms in which they grow. Or flowering plants can be classified according to the length of their life cycles. Or all plants can be classified in terms of their complexity and evolutionary ancestry.

Classification by Growth Form

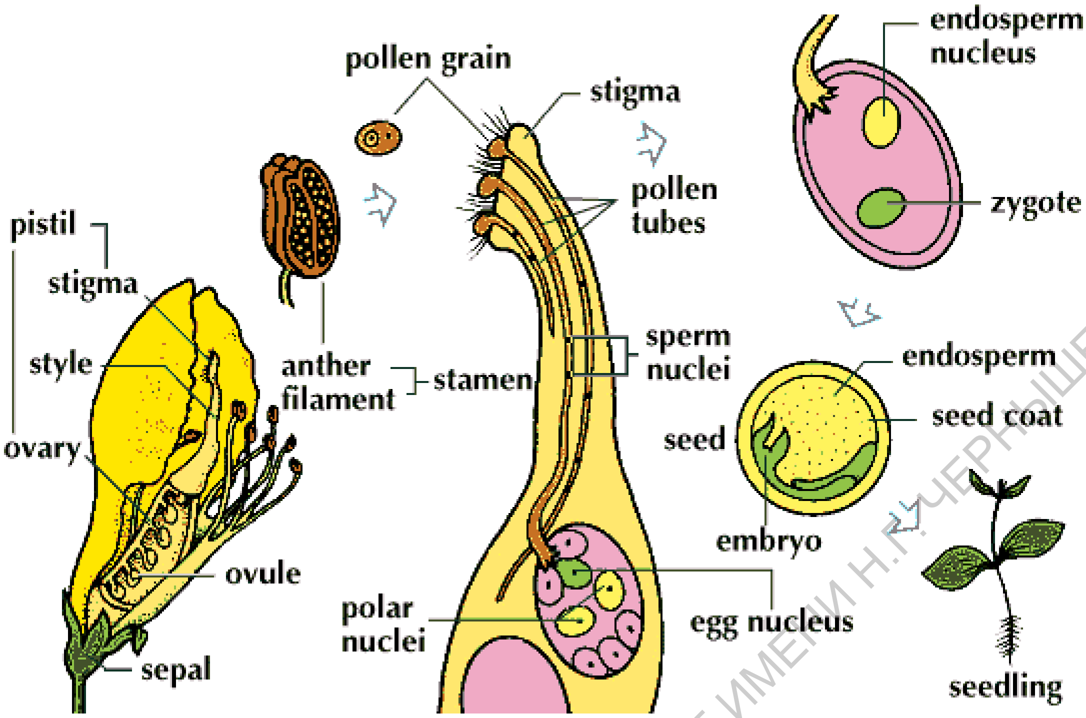
A common classification scheme is based on growth form. Plants are called trees if they have tall, woody stems, or trunks, and are generally 8 feet (2.4 meters) or more in height. Shrubs are low, woody plants, usually with many stems branching off close to the ground.

Herbs have tender, juicy stems in which the woody tissue is much less developed than it is in shrubs and trees.

Within each of these groups there is a great deal of variety. For example, some trees, such as the giant sequoia, grow to heights of more than 300 feet (90 meters), while others, such as the flowering dogwood, rarely grow to more than 30 feet (9 meters) in height.

Plant Reproduction and Growth

HOW FLOWERING PLANTS REPRODUCE



Plants continue to live on Earth by producing new plants. This process, called reproduction, may be asexual, or without the union of two different sex cells; vegetative—from roots, stems, or leaves; or sexual—involving the union of two different sex cells.

Asexual Reproduction

Some higher plants may reproduce asexually. Mosses and liverworts, for example, often have cuplike structures on their leaves or stems that contain plant fragments called gemmae. Gemmae break loose and can germinate to establish a new plant, which is genetically identical to its parent.

Vegetative Reproduction

Most vascular plants can reproduce either asexually or vegetatively. Under the proper conditions, pieces of leaf or stem broken from a plant may produce roots and establish a new individual. This process is known as vegetative reproduction. Plants that produce runners and stolons often reproduce vegetatively. The strawberry produces runners that may establish a new plant. The runners can then be broken without disturbing the parent or the new plant.

Many cultivated garden plants reproduce more efficiently from roots, stems, and leaves than from seeds. Such vegetative reproduction has the advantage of producing larger plants more rapidly. The potato seed, for example, is very small and develops into a small, weak plant. The tuber, however, contains a reserve supply of starch and produces a strong, fast-growing plant. Vegetative reproduction enables plants to spread quickly over the area surrounding the parent plant. Many weeds are difficult to control because they grow quickly using vegetative reproduction. Bulbs, corms, rhizomes (also called rootstocks), runners, and tubers are all types of stems from which new plants may grow.

Cuttings, also called slips, are twigs, branches, or leaves cut from the parent plant and placed in soil, sand, or water. In time, new roots, stems, and leaves grow from the cuttings. The willow tree, geranium, begonia, and African violet are examples of plants that may be produced in this way. A process called layering is used with certain trees and shrubs. When a branch is bent down to touch the soil, it sends roots into the ground and a new plant results. Gooseberries, blackberries, grapevines, and forsythia may be reproduced in this way.

Improved varieties of fruit are obtained by grafting. In this process the stem of a plant that has produced superior fruit is made to grow on the stem of another plant, called the stock, of hardy but inferior quality. The stems are cut so that the cambium layers of the two are in contact and grow together. The cuts are then tied together and covered with cloth or with a special wax. Budding is the process of removing a bud from one plant and setting it into the bark of another, usually a young seedling.

Sexual Reproduction

In sexual reproduction male and female cells, called gametes, unite to form a single cell, called a zygote. This zygote then undergoes cell division, ultimately giving rise to a new plant body. Offspring produced by asexual reproduction are identical to their parent. Offspring produced sexually, however, have two parents and so, though they certainly resemble the parents, the offspring are not necessarily identical to them.

Consequently, sexual reproduction is a process that increases variation among offspring.

Mosses and ferns have a peculiar habit of reproducing by spores in one generation and by sex cells in the next generation. This reproductive pattern is called alternation of generations. The common ferns growing along stream banks produce spores in special structures called sori, which are often found on the underside of the plant's leaves.

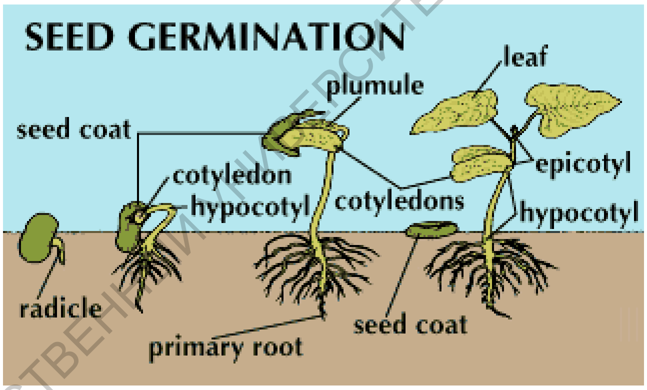
A plant that produces spores is the sporophyte. Spores are single cells that, like the gametes of animals, are produced by meiosis. If the spore lands in a favorable location, it will germinate. By means of many cell divisions, the spore produces a heart-shaped leaf that is less than 0.25 inch (0.6 centimeter) across. This leaf produces gametes and is called the gametophyte. Male gametes unite with female gametes and form a zygote, which then begins to divide by normal cell division. The gametophyte grows into a young fern plant—another sporophyte. Ferns and mosses most often grow in moist habitats, such as along streams, because the male gametes require moisture in order to move to the location of the female gametes.

The most highly developed plants are those that produce new plants by means of seeds. Seeds develop from the union of a male and a female cell. It took millions of years for plants to develop the process of seed making, but the evolution of the seed allowed plants to reproduce in many different habitats. For example, unlike mosses and ferns, seed plants can reproduce even in very dry locations.

The earliest seed plants were seed ferns, which are now extinct. They produced their seeds on special leaves. Then the conifers and their relatives evolved. These plants produce sex cells on the scales of cones. The male sex cells are formed from pollen, which is produced in small male cones, or microstroboli. During pollination, billions of pollen grains are released from these cones into the wind. Most of this pollen falls to the ground and is wasted, but a small amount of the pollen produced lodges on the ovules of the female cones. The ovules contain the female sex cell, the egg. The pollen grains germinate and produce a pollen tube that carries the male gamete, or sperm, to the egg. The egg and sperm unite to form a zygote. The zygote then divides by normal cell division to produce an embryonic plant. The embryo and the ovule that surround it together form the seed.

Pollination in the flowering plants is far more efficient. The brilliant colors, delicate perfumes, and sweet nectar of many flowering plants attract insect visitors to the flowers. Pollen from the flower's stamen is picked up by the hairs on the insects' bodies and carried to another flower. Some of these pollen grains then rub off the insect and onto the top of the flower's pistil, called the stigma. These pollen grains then germinate, producing a pollen tube that carries sperm cells to the egg within the ovules in the ovary. The sperm cells and egg fuse to form a zygote, and the zygote divides to produce an embryo. The embryo and ovule develop to form the seed and the ovary becomes the fruit.

Seed Germination



The embryo has all of the basic plant parts. Its epicotyl or plumule will form the plant shoot as the seed begins to grow. The cotyledons quickly unfold into leaves and begin producing food. The radicle gives rise to the root system. The region that connects the radicle and plumule is called the hypocotyl.

In most plants, the nutritive tissue in the seed is endosperm, formed during the fertilization process. Seeds with large amounts of endosperm include those of corn (maize), castor beans, and pumpkins. The “milk” contained in coconuts is actually endosperm. The seeds of other plants, such as beans and peas, contain very little endosperm. In these plants the cotyledons of the embryo are quite large and provide nourishment to the embryo during germination.

Seed germination requires moisture, oxygen, and a suitable temperature, but there are sufficient food and minerals stored in the seed so that these factors are not necessarily essential during the very early stages of germination. Many seeds germinate best in the dark. Initially they can grow using food reserves from the endosperm or cotyledons. Within a few days of germination, however, the developing seedling must have light in order to manufacture its own food.

Seed germination begins when the seed absorbs water. This causes the inner tissue layers to swell enough to rupture the seed coat. Water also hastens chemical reactions that occur very slowly in dormant dry seeds. These chemical reactions provide food directly to the embryo, causing it to begin its growth.

The rapid growth of the embryo results in very high rates of respiration. This is why oxygen is so important for the germination of most seeds. Seeds that are deprived of oxygen once they begin to germinate soon die. This sometimes happens when planted seeds receive too much water—oxygen cannot diffuse easily into very wet soil.

Once germination of the seed begins, the radicle usually emerges first. The radicle grows rapidly downward through the soil to establish the root system. In some plants, the tissues that make up the hypocotyl stretch, pushing the cotyledons above the soil. The cotyledons can then unfold and begin producing food. In plants with cotyledons that store food, the cotyledons may remain in the soil. Once the root system is established, the epicotyl rapidly develops into a system of shoots and leaves.

Before germination, dry seeds are very resistant to environmental stresses such as drought or unfavorable temperatures. This portion of the plant's life cycle allows the plant to survive during periods when plant growth is impossible. In order to prevent seeds from germinating when conditions are unfavorable, many seeds are dormant when they are produced. This means that they will not germinate even if there is sufficient moisture and oxygen and suitable temperatures. Such seeds are nevertheless alive. If allowed to “afterripen” for a period of weeks or months, they will germinate normally. Many plants that grow in cold winter regions produce dormant seeds. Such seeds germinate in the spring, often only after they have been exposed to cold, moist conditions.

Some seeds require special conditions in order to germinate. Such requirements often guarantee that the seed will germinate only when conditions are most favorable for seedling growth. Seeds of the pin cherry, for example, may remain dormant in forest soils for decades. When the soil is disturbed and the seeds are exposed to light, they will germinate. It is only under these conditions that a pin cherry seedling is likely to survive to become a tree. In desert regions the seeds of many plant species germinate only following very heavy rains, when sufficient moisture will be available for the plants to complete their life cycles. The seed coats of many such plants contain chemical inhibitors that prevent normal germination. Heavy rains remove these inhibitors, permitting germination. Some plants germinate and grow best in areas that have recently been burned by wildfire. The heat of the fire is the stimulus that breaks the seed's dormancy.

Water Movement

Most plants require large quantities of water in order to grow and reproduce. Water is crucial for photosynthesis; it is the liquid in which all other molecules, including food and minerals, are transported through the plant. In addition, water pressure in plant cells, called turgor, is necessary for maintaining cell growth and plant structure.

Large quantities of water move through a plant each day. In plants there is no "pump" comparable to the heart in many animals that serves to move liquids. Instead, plants depend on other processes to move water through their bodies.

Diffusion is the movement of water molecules from areas of high concentration, or areas with many water molecules, to areas of low concentration, or areas with few water molecules. When diffusion occurs across a living membrane, it is called osmosis. Cell membranes are semipermeable—that is, some molecules, such as water, pass through them easily, while other molecules, such as sugars and some salts, do not. The cell's cytoplasm contains large amounts of sugars and salts. When cells come in contact with water, the concentration of water is greater on the outside of the cell than it is on the inside. The difference in concentrations causes water to diffuse into the cell. This is how water moves from the soil into the cells of plant roots.

As more and more water diffuses into the cell, the turgor of the cell increases. Cell turgor is very important to plant growth and structure. Turgor causes expansion of the cell wall and stimulates cell growth. It also keeps cells rigid and so enables the plant to remain upright. Loss of water, and consequently of turgor, from plant cells causes the entire plant to wilt. This can happen when the soil becomes too dry. It can also happen when too much fertilizer is added to soil, because fertilizer increases the concentration of minerals in the soil. This decreases the concentration of water molecules. When this happens, even though the soil feels moist, water diffuses out of the plant cells and the plant wilts.

How is water transported from the roots to other plant tissues? In the process known as transpiration, water is constantly evaporating from leaf cells—through the stomata of the leaves—and into the atmosphere. This is particularly true during the daytime when the stomata are open and the air is warm. It is estimated that a single oak tree gives off 90 to 100 gallons (341 to 379 liters) of water each day. Transpiration from the leaf cells lowers the concentration of water in these cells. This causes water to diffuse into the leaf cells from the cells of the xylem in the leaf veins. The loss of water from the xylem in the leaf veins lowers the concentration of water in the xylem tissues of the leaf. This causes water to move from the xylem of the stem into the leaves. Movement of water up the stem lowers the concentration of water molecules in the xylem of the root, causing water to be drawn from the root cells and so from the soil. Thus, water is pulled up the plant as a result of the transpiration from leaf surfaces.

Many plants that grow in hot, dry habitats have adaptations that decrease the rate of transpiration and so decrease the amount of water needed by the plants. For example, the cuticle, or outer layer, of the leaves of some plants is very thick. This waxy layer prevents excessive water loss from the leaves. Many succulent plants, such as the many species of cacti, are able to take up and store large quantities of water when it is abundant. They can then survive on this stored water during dry periods.

Photosynthesis

In the process of photosynthesis, green plants use sunlight to produce food and oxygen, without which humans and animals could not live. Photosynthesis is carried out in specialized structures in the cytoplasm called chloroplasts. Chloroplasts contain chlorophyll and a vast array of proteins called enzymes. These enzymes are essential to the many reactions involved in photosynthesis.

Light energy is initially trapped by one of several chlorophyll pigments. Chlorophyll a is the most abundant of these pigments; its chemical formula is $C_{55}H_{72}O_5N_4Mg$. Chlorophyll b is also found in most green tissues; its formula is $C_{55}H_{70}O_6N_4Mg$.

Carbon dioxide (CO_2) from the air enters the leaf through the stomata. Water (H_2O) travels to the leaf cells from the soil through the xylem in the roots and stems. The captured light energy is then used to break down the water into oxygen molecules (O_2) and hydrogen atoms (H) and to join these hydrogen atoms to the carbon dioxide molecules to make sugar molecules ($C_6H_{12}O_6$). Six molecules of oxygen are produced as a waste product and are released into the air through the stomata.

The sugar molecule formed in this process is glucose, a simple sugar. Enormous numbers of such molecules are produced in every chloroplast during each second of sunlight. Some of the glucose produced during photosynthesis is used by the plant in the process of respiration to generate other forms of energy.

Much of the glucose, however, is converted into other molecules. Some is converted into the sugar sucrose, which is refined from sugarcane and sugar beets to make table sugar.

By combining glucose molecules into long chains, or polymers, plant cells form starch and cellulose. Much of the stored food in plants is in the form of starch, and cellulose is the main component of plant cell walls. Sugars, starch, and cellulose belong to a general class of organic molecules called carbohydrates. In many plants, food is stored in the form of lipids, or fats—high-energy molecules that contain less oxygen than do carbohydrates.

Plants also need proteins and nucleic acids in order to survive. These compounds are made by combining carbohydrates with other elements, such as nitrogen, sulfur, phosphorus, potassium, iron, calcium, and magnesium. The plant roots obtain these essential elements from the soil.

Respiration

To make cellulose, to build new cells, to store a reserve food supply, and to carry on all other activities necessary for living and growing, a plant needs energy. Energy is obtained by "burning" some of the glucose produced during photosynthesis. Just as coal releases energy when it burns in the presence of oxygen, so glucose and oxygen combine to release energy. The glucose is not burned in a fire, as is the case in a coal furnace, but the chemical process is the same in both cases. This process, known as respiration, goes on day and night in every cell in a plant.

The chemical reactions involved in respiration are the reverse of those involved in photosynthesis. Oxygen combines with glucose to produce carbon dioxide and water and to release energy. Oxygen enters the plant through the stomata of the leaves, through the roots (either from air spaces in the soil or in solution in water), and through the air openings in the stems. Glucose combines with the oxygen to form carbon dioxide and water. The glucose is thus turned back into the same two substances from which it was made during photosynthesis, and the carbon dioxide and water vapor are released back into the air through the stomata. During the daytime, photosynthesis proceeds more rapidly than does respiration. As a result, plants release more oxygen than carbon dioxide and water vapor. At night, when photosynthesis stops (because of the absence of light), only oxygen is taken in, and carbon dioxide is given off as a waste product.

Factors Influencing Plant Growth

Plant growth and development are consequences of three processes: cell division (the process called mitosis), cell enlargement, and cell differentiation. Cell division in the meristem tissues at the tips of roots, leaves, and stems is primarily responsible for increases in the length of these plant parts. Cell division in the cambium tissues of the roots and stems causes these plant parts to increase in diameter. Much plant growth also results from cell enlargement.

Plant cells can increase in size because their walls are elastic. As cells mature, they may then differentiate into specialized types of cells, such as fibers, tracheids, or sclerenchyma. The speed with which these processes of cell division, enlargement, and differentiation proceed is influenced by a number of factors, including environmental conditions, the presence of substances known as growth regulators, and heredity factors.

Environment and nutrients

The rate of growth of a plant is directly related to the amount of food that the plant is able to produce. Consequently, plants grow best in environments that are favorable for photosynthesis. The availability of water also affects plant growth because water pressure inside the plant's cells provides the force necessary for cell enlargement. Plants grow more slowly when water is in short supply. If the environment becomes too dry, the pressure in the plant's cells may become so low that the plant wilts. Plant growth is also influenced by other environmental factors, including temperature and the availability of mineral nutrients such as nitrogen and phosphorus.

Growth regulators

In addition to light, carbon dioxide, water, and minerals, plants need certain chemicals in order to grow. These substances are called growth regulators, or hormones. They are produced in plants in very small quantities.

The first growth regulators to become known were the auxins. The term comes from a Greek word meaning “to increase.” The role that auxins play in the growth of plants was first demonstrated between 1926 and

1928 by the Dutch plant physiologist Frits W. Went. They play a key role in the growth of roots, stems, and buds, in the development of fruit, and in the falling of fruits and leaves.

Auxins are produced at the tips of stems and roots. They diffuse back to the growing cells of leaves, stems, and roots and stimulate these cells to grow longer. This function of auxins was proved when botanists stopped the growth of oat seedlings by cutting off the tips of the plants. Growth started again when juice from the tips was rubbed into the cut ends of the plant.

Auxins play a central role in plant-growth patterns called tropisms. Phototropism (meaning "light turning") is the growth of plants toward light. If a plant is exposed to light coming from a certain direction, the plant will bend in the direction of the light. This response is the result of the diffusion of auxins to the unlighted side of the plant, speeding up growth on that side and slowing down growth on the lighted side.

Geotropism (meaning "earth turning") is the growth of plant parts toward or away from a source of gravity—stems grow up and roots grow down. If a stem is laying sidewise, the force of gravity causes more auxins to accumulate on the lower surface of the stem. This accelerates the growth of the cells on the lower surface, causing the stem to bend upward. In plant roots, the accumulation of auxins on the lower surfaces causes the roots to grow down.

Gardeners have long known that if they remove the terminal bud of a plant, the side buds develop and the plant becomes shorter and shrubbier. The reason is that the loss of the terminal bud stops the downward diffusion of auxins. As soon as the side buds develop enough auxins, they begin to grow and take over the task of checking the growth of the plant's lower buds. As long as the upper foliage and buds exposed to light are growing, the lower, shaded buds are arrested in their growth. The advantage to the plant is that if the upper buds and leaves are destroyed by frost, insects, or disease, the lower ones can then develop and take over the work of photosynthesis.

Heredity

Some plants grow faster than others because of genetic differences. Such hereditary differences may be caused by many factors. In some plant species, hereditary differences in growth are due to differences in the rate of production of hormones called gibberellins. Gibberellins, like auxins, are growth-regulating chemicals. Dwarf varieties of cultivated plants produce very little of these hormones. Gibberellins also play a role in flowering, fruit production, and the breaking of dormancy in seeds and buds.

Photoperiodism

The rates of plant growth and cell differentiation vary from one season to the next. Plants seem somehow to know when the seasons are changing. Actually, plants are sensitive to the relative lengths of alternating periods of darkness and light. Their reaction is called photoperiodism. Photoperiodism accounts for the fact that plants grow better in certain latitudes, because the seasonal lengths of day and night better meet their needs. Thus plants are divided into spring-, summer-, and fall-blossoming groups. Skunk cabbage, for example, is one of the earliest blooming spring plants in the northern United States. It requires longer nights than does the wild rose, which blooms three months later. Barley, wheat, and many other small grains blossom in early summer when the nights are relatively short, whereas corn (maize), soybeans, and chrysanthemums bloom later, in midsummer and fall, when the nights are longer.

Plants actually “measure” the duration of darkness rather than of light. The photoperiodism of plants is caused by changes in a pigment called phytochrome (from two Greek words: *phyton*, meaning “plant,” and *chroma*, meaning “color”). Phytochrome is a light-sensitive, blue-green pigment. It occurs in plant tissues in minute quantities—about one part in 10 million. The pigment acts as an enzyme—that is, it activates certain life processes without itself being used up. Phytochrome exists in two forms. In daylight the chemical is converted to its active form, and in darkness it is converted to its inactive form. When the pigment's active form reaches a certain level of concentration in the plant, it spurs changes in the plant's rate of growth.

Photoperiodism controls many plant growth processes other than flowering. Germination of many seeds depends upon the amount and duration of light. In the winter, when the nights are long, the buds of trees and shrubs become dormant. In the laboratory, dormancy can be broken by giving the plant short nights. The buds then begin to develop. (Britannica Student Library. Encyclopædia Britannica. Chicago: Encyclopædia Britannica, 2015).