Flowering Plants
[Angiosperms]

dominant plants in world today

→90% of all living plant species

235,000 known species

flowering plants were the last of the 4 main groups to appear in the fossil record

1st appeared ~130 MY ago

→ quickly spread and diversified

have dominated the landscape for the last 100 Million years

Characteristics of Flowering Plants:

1. **highly adaptable vegetative organs**

vegetative Organs of flowering plants generally perform the typical functions as described earlier

but in many cases they are often modified to enhance certain properties in the plant:

→ extra support
→ gas exchange
→ food gathering

→ food or water storage
→ protection
→ asexual reproduction

much more so than in any other plant group

A. Extra Support

prop roots & buttress roots

roots that help support plant

eg prop roots: corn, sorghum, red mangrove, banyon tree

eg. buttress roots: tropical figs

vining stems

weak stems - use other plants or objects for support

but can grow rapidly

→ don't need to expend lots of energy on strength

may grow away from sunlight rather than toward it

→ more likely to encounter a tree to grow on

some vines are **twiners**

stems grow spirally for support

others have other modifications to attach to support

vines are most numerous in tropical forests

eg. lianas

= woody vines with adhesive suckers
connect tops of trees
provide walkways for animals

adhesive roots

vines often produce special adventitious roots from above ground stem with **adhesive pads** that stick to bark

tendrils

some tendrils are modified leaves rather than stems

→sometimes hard to tell the difference) that grasp and hold onto other structures

tendril may be whole leaf or only part of the leaf

eg. peas

aerial roots

on **epiphytes** → plants that grow on other plants

eg. ball moss, spanish moss, bromeliads, orchids

their roots are for anchoring only, not to absorb water or nutrients

B. Gas Exchange

pneumatophores

aerial "breathing" roots

act like siphon to get oxygen to root cells

produced by plants growing in swamps or waterlogged soils

have well developed system of internal air spaces that take oxygen to interior of root system

eg. black mangrove, white mangrove, bald cypress

aquatic leaves

floating leaves of many aquatic plants:

→have **stomata on upper surface**

→**long petioles** to allow blade to float

→petioles and submerged parts of plant have internal system of **air ducts** to take O_2 to underwater roots and stems

C. Food Gathering

window leaves (=fenestraria)

transparent windows on the tips of succulent leaves allow light to penetrate into the leaf for improved photosynthesis

parasitic roots (=haustoria)

all parasitic plants are flowering plants (dicots only, not monocots)

some parasitic plants use roots to penetrate host and absorb nutrients

eg. mistletoe, dodder, broomrapes, pinedrops

insectivorous leaves

leaves for catching bugs → extra nitrogen

some able to close quickly, some hold water, some produce sticky secretions

eg. venus fly trap, pitcher plants, sundews

D. Food & Water Storage

succulent stems

used to store water

eg. cacti, euphorbs

succulent leaves

some leaves (rather than stem) are adapted for storing water

thick, fleshy leaves

eg. jade plant, aloe vera

tuberous roots & Storage taproots

portions of some roots are enlarged for food storage

eg. sweet potatoes,

tuberous stems

some rhizomes produce greatly thickened ends

= fleshy underground stems enlarged for food

storage

eg white potatoes, elephant ears

the "eyes" of a potato are axillary buds

bulbs & heads

in both the stem is almost nonexistent

→ very short internodes

bulbs are surrounded by fleshy nonphotosynthetic, storage leaves

usually partly underground

covered by paper-like scales (=modified leaves)

frequenty form smaller "daughter bulbs"

eg. lilies, onions, garlic, tulips, etc

head has whorled leaves surrounding very short stem

some outer leaves are green and photosynthetic

no paper-like scales

often biennials in 1st yr before "bolting"

rhizomes

rhizomes are underground stems

in some plants they are enlarged to store food

eg. irises

E. Protection

spines

stems or leaves modified for protection against herbivores

some spines arising from the axils of leaves are modified stems = **thorns**

eg. large thorns of locust and mesquite trees

most spines are modified leaves

spines can be formed from whole leaf

eg. cacti

or just portion of leaf;

eg. holly, young live oak leaves

prickles

some stems produce surface **prickles** but they are not an integral part of the stem

they are outgrowths of the epidermis or ground tissue just beneath epidermis

→ they break off easily

eg roses

F. Asexual Reproduction

runners (=stolons)

horizontal above ground stems that grow along surface of ground

have long internodes

buds develop along stolon giving rise to new plants

eg strawberry, bermuda grass, airplane plants

rhizomes

horizontal underground stems

resemble roots but have nodes, buds etc,

each piece can become a separate new plant

eg irises, bamboo, ginger, many grasses, etc

2. **complex symbioses** with fungi, bacteria and animals enhance survival and efficiency

eg. fungi → mycorrhizae

eg. bacteria → root nodules

eg. ants in tropics

[more later]

3. much **more efficient transport tissues**

structure of both xylem and phloem are more efficient than in gymnosperms

4. no asexual reproductive organs or spores produced

5. sexual reproductive organ is the **flower**

mostly hermaphrodite

→ with male and female parts

some are dioecious with separate male or female flowers

great diversity in flower structure
→greatly enhances reproductive success

6. **seeds protected within a fruit**

produce resistant seed as in conifers
but better protection inside fruit

gymnosperm cones produced 'naked seeds'

angiosperms surround seed with fruit

also offers much greater variety of dispersal

Flower Structure

in flowering plants, sexual reproduction occurs in flowers

are temporary structures

are extremely variable in size and shape

eg. *Rafflesia* flower is up to 3 ft across

most (not all) flowers have both male and female parts

= most flowering plants are hermaphrodites

a typical flower has 4 main parts:

a. sepals
b. petals
c. stamens (male) **= filament + anther**
d. pistils (female) **= stigma + style + ovary**

a. sepals

lowermost whorl
leaflike
covers and protects flower bud

all sepals together = **calyx**

b. petals

whorl just above (inside) sepals

great variation in size, shape and color

sometimes fused to form tube

all petals together = **corolla**

c. stamens

just inside petals

consist of **filament** and **anthers**

anther = sac like structure that produces **pollen grains**

c. pistil

female reproductive organs

sometimes there are many pistils

each **pistil** consists of:

stigma →on which pollen lands

style →neck like structure

ovary →sac like, contains one or more **ovules**

each **ovule** contains an **egg**

many variations in flower structure

in some species the flowers are unisexual

→ separate male and female flowers

esp in wind pollinated plants, esp trees and shrubs

a. sometimes on different plants → **dioecious**

eg. willows, poplars

b. or male and female flowers on the same plant
→ **monoecious** (hermaphrodite)

eg. sedges, maize, oaks, hickories

and a few of these can apparently switch their sex

→ transsexuals; males produce female flowers and females producing male flowers

a flower with all four different parts = **complete flower**

lacking one or more = **incomplete flower**

some of these variations are due to the way flowers are pollinated

pollen grains must travel from anther of one flower to stigma of another

self pollination → pollen travels to stigma of same flower

only a few flowers are self pollinating

cross pollination → pollen travels to stigma of different plant

the **flower** evolved to facilitate **fertilization** of the egg

in most conifers, pollen is carried by wind to female cone
a relatively random process

a large part of the success of flowering plants is due to the variety of pollenation

→ provides much better mixing of genes

flowering plants have coevolved with many kinds of animals through most of their history

the **color**, **smell** and **nectar** of most flowers is to attract the appropriate pollenator

this close relationship between plants and pollinators has resulted in **coevolution**

→ mutual adaptations for mutual benefits

plant: petals, scent, nectaries

animal: special body parts and behaviors

We like to think of animals as the most 'evolved' lifeforms
→ but plants lack brains, muscles, speech yet they don't need them
- they borrow animals to do their bidding

In some instances the relationships have become **very specialized** such that only a single species of animal can pollinate a particular species of plant.

1. wind pollinated

often grow in **dense** populations

many small **inconspicuous** flowers

petals reduced

pistils and stamens exposed

numerous stamens and conspicuous

large amounts of pollen produced

eg. oak, willow, grasses; including some of our most important crops – wheat, corn and rice

2. insect pollinators

petals colorful and large

often with **nectaries**

much less pollen produced

insects can be attracted by showy flowers, smell &/or nectar

a. bee & wasp pollinated

pollenate more flowers than any other group

20,000 different species of bees are important pollinators for many plants

bees have very **good vision**

bees pollenate mainly spring flowers

flowers generally **shallow** (short mouthparts)

honeybees are attracted to **nectar**

they also gather pollen

flowers often **delicately sweet** and **fragrant**

flowers are generally **brightly colored**

predominately **blue or violet markings**

rarely pure red (pure red appears black to them)

flowers often have lines or distinctive

markings that function as "**honey guides**"

→ lead bees to nectar

some of these markings are only seen in **UV** light

→ invisible to us, not bees

b. beetle pollinated

flowers generally **large** and open

usually **white** or dull in color

(beetles cant see as well as bees)

flowers tend to have a **strong** yeasty, spicy or fruity **odor**, sometimes unpleasant to us

secrete no nectar but may supply food as pollen or in special storage cells in petals

most eat parts of the flower

eg. magnolias, lotus

c. carrion flies

tend to be **dull red** or brown or white

often have **foul odors** resembling rotting meat

eg. skunk cabbage

eg. carrion flower = *Rafflesia*

a parasitic flowering plant of SE Asia

early botanists thought it might be a fungus

parasitic plant with no true roots or leaves

now known to be in pointsettia family

parasitic on vines in genus *Tetrastigma* (Vitaceae)

produces a huge speckled flower on little stem with no leaves

largest known flower:

flower bud size of basketball

flower up to 1 m across; weighs up to 10 kg

smells like rotting meat

fruit is eaten by three shrews and other mammals

d. butterflies

sweet fragrance and provide **nectar**

fused petals force insect to crawl into flower for nectar

nectaries are usually at bases of deep spur that only butterflies and moths can reach with their mouthparts

some butterflies can detect red flowers

eg. daisy family: butterfly bush= *Buddelias*, goldenrods, blazing star

eg. monarchs → pollenate milkweeds

e. moth pollinated

white or yellow **large tubular flowers**

heavy fragrance

open at night, closed in daylight

eg. yuccas, night blooming jasmine, night blooming cereus

f. ants

dense **clusters of small flowers** near ground

sticky pollen

with **nectar**

eg. some composites

h. wasps

wasps have very **good vision**

flower preferences similar to bees

but wasps pollenate mainly in summer

wasps are much less "hairy" so not very good pollenators

flowers are generally **brightly colored**

predominately **blue or violet markings**

flowers generally **shallow** (short mouthparts)

flowers often **delicately sweet** and fragrant with **nectar** or fruit juices

eg. fig wasps exclusively pollenate almost 1000 species of tropical fig trees

eg. some species of orchids resemble certain wasp females that attract only one species of wasps

in some plants slight electric fields that form around flowers may lure pollinators, such as bees, much as color and fragrance do

3. bat pollinated

mainly in tropics

large bell or disk shaped **flower** with long stems to put flowers away from rest of plant

dull color; **open at night**

strong **musky smell** (fermentation products)

produce large quantities of pollen and nectar

eg. saguaro cactus, organpipe cactus, some century plants

4. other mammals

especially in tropics

some flowers are pollenated by
lemurs
rodents
marsupials
giraffe→ acacia

5. geckos

certain flowers produce colored nectars that are preferred by geckoes

6. hummingbirds

have poor sense of smell, but excellent vision

hummingbirds eyes are sensitive to red which insects generally don't see

frequently bright red or yellow flowers

little if any odor

fused petals with nectary deeply hidden

produce copious quantities of nectar

long floral tubes prevent most insects from reaching the nectar

eg. fuschias, petunias, morning glories, salvias, cardinal flowers, trumpet creepers, columbines, penstemons

7. Ballistic Pollenation

A few plants have anthers with filaments that are spring loaded and are able to launch pollen up into the air or onto nearby insects for dispersal

eg. a bunchberry dogwood has tiny flowers opens in less than half a millisecond flinging pollen upwards

→ the fastest plant motion of any kind on record

8. water pollenation

eg. in species of *Vallisneria* the male flower develops underwater

when mature it breaks off and floats to the surface

the flower of the female plant floats on the surface and is attached by a long stalk to the rest of the plant

the male flower floats over and onto the female flower to pollenate it

eg. in some sea grasses pollen is released into the water forming small floating rafts which float to the flower of another plant

Role of Pollinators in Modern World

without pollinators many plants cannot be fertilized to produce seeds

90% of worlds flowering plants are animal pollinated

→including 80% of world's 1330 cultivated crop species

→ 1/3rd of US agricultural crops are insect pollinated

[grains, eg wheat, corn, rice are wind pollenated]

120,000 – 200,000 animal species are pollinators

→ including >1000 sp of birds and mammals

honeybee pollination services are 60-100x's more valuable than the honey they produce

in US ~1/2 of honeybee colonies have been lost in last 50 years → 25% in last 5 yrs alone

threats:
habitat loss & fragmentation
loss of nesting and overwintering sites
intense exposure to pesticides and herbicides
introduction of exotic species

Fertilization:

the processes above just get the pollen to the stigma of another plants pistil

if the pollen grain is of the correct species it will begin to grow a **pollen tube** down through the **style** to the **ovary** which contains the eggs

the pollent tube is attracted by specific chemicals to "find" the egg in the ovary

a single pollen grain can fertilize one egg.

in flowers with many eggs, need many pollen grains

each pollen grain contains a **sperm cell** that "swims" down the fluid filled pollen tube and fertilizes an egg

the time from pollenation to fertilization varies from **hours** to **years**

The Seed:

seed = plant embryo with stored nutrients in a protective shell

mature seed consists of:

1. **plant embryo**

complete with embryonic root, stem and leaves

2. **food**

the nutrients are used by the germinating seed until true leaves can begin photosynthesis

3. **seed coat**

tough, for protection

→ most seeds will survive 5-10 yrs

some with very tough outer coats have sprouted after 100's or 1000's years

eg. 365 yr old "beggars tick" seeds from the Atocha ($130 M in gold, silver and emeralds-Mel Fisher) were brought up from the ship and placed in freshwater to clean and preserve them. A couple germinated and one grew into an adult plant

eg. seeds of water lotus have survived more than 1000 years

eg. a date palm (*Phoenix dactylifera*) seed was discovered during excavation of King Herod's palace and sprouted after 2000 years

eg. seeds from the Arctic flower *Lupines arcticus* sprouted after 10,000 years in frozen silt

seed size varies from:

eg. dustlike → orchids

eg. 60lbs → double coconut

The Fruit

seeds are not naked as in most gymnosperms

As the **ovule** develops into a **seed**; the **ovary** portion of the pistil increases greatly in size and becomes a **fruit**

→ **fruit** = a ripened ovary containing seeds

eg. pea pod = fruit; peas = seeds

peach, bean and watermelon all develop from ovaries only 1/8th to 1/4th inch in diameter

causes great drain on food supply

→ vegetative growth often ceases when fruits are developing

pinching off some flower buds results in larger fruits that are left

The tissues of fruit and seed enhance survival and may aid in dispersal

→ can provide food for germinating seed

→ protects seed from desiccation

→ distributes new plants to areas away from parent plant

Seed Dispersal Mechanisms:

1. **wind**

one of most important

a. small, light seeds

eg. orchids → seeds resemble dust

b. hairlike appendages

eg. dandelions, milkweeds

c. winged seeds

eg. maple, bigonia

d. whole plant dispersal

eg. tumbleweed (=Russian thistle)

e. automobiles

small seeds and fruits hitch hiking on vehicles or swept along in the traffic wind vortices contribute significantly to dispersal along highways

this method is particularly effective for invasive plant species

2. **edible fruits**

attracts birds or mammals

may eat whole fruit or spit out pits

if swallowed seeds resistant to digestive juices

squirrels and birds bury fruits and seeds

nuts stored underground are forgotten

3. passively carried by animals

hooks or spines to catch in fur or on skin

in mud on feet of birds, etc.

burs, beggars ticks, devils claw, etc.

4. water dispersal

aquatic plants

rainfall

some contain airsacs to float

eg. mangroves, coconuts, willow, sea bean, waterlily, mangrove

5. mechanical dispersal

=explosive dehiscence

seeds are forcibly ejected from fruit

many cast seeds several feet away from parent plant

eg. violets

Seed Germination

numerous factors affect whether and when a seed germinates; for example:

temperature

each species has an optimal temperature at which the largest number of seeds germinate

→most ~ 25-30º C (77-86º F)

eg. some seeds, eg apple, require long exposure to cold before seeds will germinate

water: seeds generally need plenty of water to germinate

rainfall washes out the abscissic acid to allow seed to germinate

eg. many desert plants often contain high levels of abscissic acid which ensures they will not germinate until they are exposed to significant rainfall

eg. soaking seeds in water makes them germinate quicker

oxygen gas: seeds usually need adequate oxygen to germinate

germination requires a great deal of energy to convert stored food to ATP by aerobic respiration

→therefore needs oxygen for germination

seeds in saturated soil or buried too deeply usually will not germinate

some plants, eg rice, can begin growth without oxygen → flooded soil

light: some plants, especially those with tiny seeds require light for germination

eg. lettuce seeds will germinate only if very close to surface of soil

otherwise it may not have enough food reserves to grow to surface to begin photosynthesis

physical abrasion

eg. legumes (beans, peas) have extremely hard thick seed coats that prevent water and oxygen from entering

sometimes require a trip through the digestive tract of an animal before they will germinate

eg. most "dodo trees" (***Sideroxylon grandiflorum***) on the island of Mauritius are >300 years old.

Seeds produced by the tree rarely germinate.

One explanation is that the hard seeds had to pass through the gut of the now extinct dodo bird before they would germinate.

Once the bird went extinct (~300 yrs ago) there were no animals left that would adequately "prepare" the seeds for germination

So today, very few seed germinate at all

eg. some garden plants germinate more successfully if rubbed with sandpaper or scratched with a knife before planting

Asexual Reproduction
in Flowering Plants

like conifers, flowering plants have given up the production of spores as a major means of asexual reproduction

energy is put into a much more effective form of sexual reproduction

some plants reproduce regularly asexually by **budding** or **fragmentation**

eg. jumping cholla

eg. maternity plant

but most flowering plants can reproduce asexually in nature due to some of the modifications of vegetative structures mentioned previously

→ adventitious roots
→ tuberous roots
→ runners (=stolons)
→ rhizomes
→ suckers
→ bulbs

many flowering plants grow in large interconnected **colonies** in this way

eg. some creosote bush , eucalyptus, aspen

eg. quaking aspen (*Pando* sp.). one grove may contain 47,000 trees, cover 43 ha and weighs 6,000,000 kg)

plants also have great powers of **regeneration**
→ if a branch, bud, limb or root breaks off it will sometimes take root and germinate into a new plant

artificially, plants are cloned by grafting and rooting

Grafting
freshly cut surfaces of 2 stems are bound together firmly so that two cambial layers are in contact

callus forms of undifferentiated cells

differentiation in callus cells forms cambium uniting the two stems

most successful grafts are between members of same species (ie varieties)

navel (seedless) oranges are propagated only by grafting

Stem Cuttings
of some plants (eg coleus, willow, roses) placed in moist soil produce adventitious roots

Economic Value of Flowering Plants

1. perhaps our greatest direct dependence on plants is as food crops

nearly 70% of all the food we eat are flowering plants

plants were some of the first organisms to be **genetically modified** successfully by human selection over 1000's of years

today genetic modification continues at the cellular level and is even more fruitful and has much more immediate results

however today's version is much more controversial, and for some, a cause for concern; for others just a modern version of ancient practices

research is now showing that the food we eat has been directly altering the behavior of **our** genes all along

cabbage, rise, broccoli, possibly all plants we eat contain micro RNA's that get absorbed and circulate in our bodies

eg. can alter genes that control cholesterol levels

eg. cosmetic researchers found that a pill containing a mix of food extracts can cause our genes to boost collagen levels to reduce wrinkles

virtually all **crop plants** are flowering plants

eg. monocots: grains, corn, millet, sugarcane, etc
eg. dicots: carrots, lettuce, beans, tomatoes, potatoes

most crops come from a single family: The grasses (Gramineae)

including the 3 main food plants:

wheat → 54% of world population (3.1 Bil)
rice → 34% (2 Bil)
corn → 12% (0.7 Bil)

some agricultural plants have developed such a high degree if interdependence with humans that they no longer can survive in the wild

eg. *Zea mays*

evolved from teosinte - an American grass

unless removed and individually husked; corn can no longer reproduce on its own

eg. root crops
many are biennial: sugar beets, turnips, rutabagas, parsnips, horse radishes, carrots, sweet potato, yams, cassava

eg. leaf crops
cabbage, parsley, lettuce, spinach, chard, celery & rhubarb (petioles only)

2. **caffeine beverages**: teas, coffee, cocoa

caffeine – a plant alkaloid

common additive in coffee, teas, soft drinks,
stimulate CNS, speeds heartbeat, increases blood pressure,
stimulates breathing constricts blood vessels

used to alleviate fatigue and drowsiness

improves athletic performance

like many drugs caffeine is addictive and can cause withdrawal symptoms

a. coffee

made from the seeds of *Coffea arabica*, native to mountains of Ethiopia

used for 1000's of years
at first beans were eaten whole

later were crushed and mixed with fat and eaten

roasting the seeds and producing a drink similar to our coffee didn't begin until 13th century in Yemen

today coffee trees are cultivated in tropical climates

worlds most expensive coffee: Kopi Luwak coffee

"produced" in SE Asia when a palm civet (a catlike mammal) eats ripe coffee beans off the vine
the ripest reddest beans are the most preferred for coffee and the preferred beans of this animal
the animal eats and digests the outer covering of the bean
the rest of the bean is "flavor enhanced" as it passes through the civets digestive tract and is excreted whole
is sold for up to $75 for a quarter pound of coffee

b. teas

according to the Chinese, tea was discovered by the Emperor Shen Nung in 2737 BC when a tea leaf fell into a pot of water being boiled for drinking.

today, tea is the world's most popular beverage, next to water

tea is made from dried leaves of *Camellia sinensis*, a small tree or shrub native to China, Tibet, India and burma

each plant is pruned to ensure shrubby growth

the best tea is made from the terminal bud and top two leaves of each branch

harvested tea is:
dried
rolled to break up cells
fermented

fired to stop the fermentation process and further reduce moisture content leaves
→turn dark black =black tea

green teas are not fermented and dried as much
→ leaves remain green

or oolong tea are partially fermented and dried to light greenish brown color

the aroma & flavor of tea is created mainly by the **oils** and **tannins** in the leaves

green tea seems to have cancer preventative properties

stimulating effects of some teas due to caffeine

c. chocolate:

used for beverages and foods.

Extracted from the seed of the cacao tree (*Theobroma cacao*) which is native to tropical Central and South America.

(not same as coca plant the source of cocaine)

the small tree grows as understory plant in tropical forests, requires wet warm climate

processing:
begins with roasting to develop the rich color and full flavor

the seeds are then cracked open and crushed to produce a dark brown oily paste

this paste can be solidified into squares of baking chocolate

or the cocoa butter can be removed from the paste with heat and pressure leaving behind cocoa powder

cocoa butter has many uses:
mainly to produce chocolate

used to produce confectionery chocolate or white chocolate

also used in suntan lotions, soaps and cosmetics

3. cooking oils

eg. corn, canola, peanut, sesame, olive, etc

4. spices and seasonings

ancient peoples were probably first attracted to

spices by their scents

ancient Egyptians used herbs and spices extensively in medicine, cooking , embalming and as perfumes and incense

during the time of the ancient Greeks, the spice trade was flourishing between the Mediterranean region and the Far East

eg. cinnamon, cassia, black pepper, ginger

many were lost then rediscovered by Marco Polo in 1200's

eg. black pepper

one of the earliest spices known

the most widely used spice today

black pepper is obtained from the dried berries of *Piper nigrum*, a climbing vine native to India and the East Indies

the berries are picked green just before they ripen

they are allowed to dry for a few days causing them to blacken and shrivel

begin to lose their flavor after grinding
→ fresh ground are preferred

whole=peppercorns, or ground

eg. Cinnamon

one of the oldest and most valuable spices known

use has been documented from ancient times by Egyptians, Greeks, Romans and Chinese

was one of the main spices sought in the early explorations

comes from the bark of an evergreen tree *Cinnamomum zeylanicum* native to India and Sri Lanka, other varieties are from SE Asia

grows best under wet, tropical conditions

outer layer of bark is scraped away and inner bark curls into "quills"(=cinnamon sticks)

sticks can be ground into powder

in addition to its use as a food spice it has been used in medicines, perfumes and other scents

eg. Cloves

cloves are the unopened flower buds of *Eugenia caryophyllata*, an evergreen tree

valued in ancient China where used to sweeten the breath of court officials

buds must be picked with care since once opened they are useless as a spice

after picking, buds are dried and marketed as whole cloves or ground and used in desserts, beverages, meats, pickling, sauces and gravies

in Indonesia, cloves are mixed with tobacco for cigars and cigarettes

clove oil has also been used in medicines, disinfectants, mouthwashes, toothpaste, soaps and perfumes

eg Nutmeg

obtained from the nutmeg tree, *Myristica fragrans*, native to the Spice Islands

the pit of the fruit of this tree is cured until the seed is freed from the pit

the nutmeg seed is sold whole or ground

nutmeg has received some notoriety as a potential hallucinogen

however need *very* large quantities

such quantities would cause nausea, vomiting, dizziness and headaches

eg. Saffron

world's most expensive spice

obtained from the stigmas of the flower of the autumn crocus, *Crocus sativus*, in the Iris family

plant is native to eastern Mediterranean and Asia Minor

was much desired by many ancient civilizations

today most (70%) Saffron comes from Spain

purple flowers appear in autumn, short blooming period (2 wks)

flowers must be picked in full bloom before wilting
→ often the critical time for the harvest is just a few hrs

once picked, flowers are carefully stripped of their stigmas; must be done before the flower wilts

stigmas are dried and roasted

retail US (1998): $240.00/oz

eg. Chili Peppers

a new world spice, cultivated for >9000 yrs

these peppers are fruit of the pepper plant, *Capsicum* sp., which includes 5 cultivated species and 100's of varieties

includes mild sweet bell peppers & many varieties of hot peppers such as cayenne, tabasco, habanero

a member of the tomato family

the biting taste is due to several alkaloids, esp capsaicin

mainly found in seeds and placental area

bell pepper has almost no capsaicin; in others, even handling can irritate the skin

has also been used in pepper spray

and by physicians in creams that are applied to relieve pain of arthritis, shingles and cluster headaches

eg. vanilla

also a new world spice

the only spice obtained from an orchid, *Vanilla planifolia*, a perennial vine native to tropical rainforests of Central America and Mexico

today also cultivated in Madagascar and islands of Indian Ocean

produces elongated pods that are processed into the vanilla beans

flowers are hand pollinated

pods are picked while green and are cured for several months by heating and fermenting, then dried

uncured beans lack the characteristic vanilla flavor which is due to vanillin, a chemical synthesized during the curing process

today, vanillin can be synthesized chemically from clove oil, lignin from wood plp or coal tar to produce imitation vanilla extract

extracts of tonka beans, *Dipteryx odorata*, are sometimes passed off as vanilla extract. A dangerous substitute since these beans contain coumarin, a blood thinner that could cause internal hemorrhaging

eg. licorice plant (Glycyrrhiza glabra)

ancient Chines and Greeks used licorice as a cold remedy, digestive aid, wound healer and asthma treatment

>400 biologically active chemicals have been found in plant

flavor comes from anethole, an essential oil also found in fennel and anise

also contains glycyrrhizin which may interfere with steroid hormones and cause imbalances in body chemistry and high blood pressure and heart problems in susceptible people

eg. sasparilla → roots of greenbriar, *Smilax*

eg. sassafras → bark of sassafras tree

eg. root spices:

sassafras, sarsaparillo, licorice, angelica

eg. stem spices:

cinnamon

eg. leaf spices:

bay leaves, sage, thyme, marjoram, oregano, taqrragon, peppermint, basil, dill, cilantro, parsley

5. lumber: the lumber from flowering plants (eg. oaks, walnuts, hickories, maple, etc) are referred to as **hardwoods**

wood is generally much denser than softwoods of conifers

eg. lumber from ironwoods doesn't float, its denser than water

a. **oaks**

wood is heavy and strong, about twice as dense as white pine, resilient, durable, impermeable to liquids

eg. makes good barrels, flooring, cabinets, furniture

eg. 1 100-gun wooden sailing ship (mid-late 1700's) took 80 acres of oak forest to build

b. **walnut**

harder than oak, shock resistant, beauty of grain, good machining properties,
eg. choice hardwood for fine furniture and interior paneling

c. **ash**

resilient, straight grained, stiffness, strength, good bending abilities, remains smooth as it wears
eg. used for baseball bats, tennis racquets, oars, skis, long tool handles

d. **maple**

smooth, hard, strong
eg. Romans used for spears and lances
eg. bowling pins and bowling alleys, dance floors, toys
eg. spools, bobbins, cue sticks, croquet balls

e. **birch**

light and soft
eg. clothespins, toothpicks, thread spools

f**. elm**

eg. wood paneling, hockey sticks, church pews

g. **teak**

eg. furniture, shipbuilding

h. **yew**

eg. English longbows were made from this

i. **hickory**

hardwood; hardness, strength, toughness, resiliency
eg. in horse and buggy days was widely used for wheel spokes and rims
eg. handles of impact tools like axes and hammers, skis

6. cut flowers & ornamentals

the market for ornamental flowers and cut plants totals over $70 Billion/yr in sales

is also a huge area of research to develop new varieties

7. commercial products:

wood alcohol: esp from oaks and hickories
latex/rubber, adhesives
maple syrup
sugar
tanning materials from oak

8. Dyes

vegetable dyes

not used as much today

eg. indigo → stems and leaves of Indian legume
eg. saffron → stigmas of crocus
eg. black dyes → logwood from tropical Americas

eg. madder → roots of herbaceous plant

9. Perfumes & Incense

the art of perfumery has been practiced for at least 4000 years

based on the plant chemicals used to attract pollenators

two of the longest used scents, frankincense and myrr come from the resin of two species of flowering trees

10. pharmaceutical extracts

are secondary plant products, especially **alkaloids**

100's of plant extracts (alkaloids) are known to have pharmaceutical applications

eg. **atropine**; active ingredient in belladonna from roots and leaves of nightshade
nightshade → belladonna → atropine
eg. **aspirin**
eg. **quinine** extracted from bark of *Cinchona* tree for treatment of malaria
eg. jimsonweed → scopolamine → hallucinogenic native Americans used for puberty rights and rituals
eg. **aloe** used to treat burns and rashes
eg. **digitalis**→leaves of foxglove
eg. **morphine** → alkaloid of opium poppy
eg. **strychnine** → from seed of asian tree, *Nux vomica*
eg. **ipecac**
eg. **eucalyptus oil**
eg. **castor oil** → from seeds of castor bean
eg. **camphor** → distilled from wood of Asiatic tree

many additional plants and herbs are thought to have medicinal properties but many/most have not yet been scientifically evaluated

drug companies regularly screen unusual plants

and animals for chemicals that might have clinical applications

The Pseudoscience of Neutriceuticals

nutraceutical industry is multibillion dollar industry

makes sometimes fantastic claims that have never been verified by scientific evaluation

Americans spend $14 B/yr on health related therapies that have not been scientifically validated

there is no law that regulates the claims that can be made on these products

only a few have been tested recently

eg. Houston health food stores & herbal remedies
→ all those contacted said they had herbs that would treat or cure HIV/AIDS

11. Psychoactive Plants & Illegal Drugs

a. Caffeine

stimulant:
75-150 mg/cup of coffee
30-60 mg/cup of tea
30-70 mg/12oz soft drink
30-70 mg/OTC pain releivers
100-200mg used as OTC stimulants
80mg mg/4oz bar of chocolate

low to moderate doses increased alertness and better ability to concentrate

higher doses cause nervousness and agitation

overdose poisoning: tremors, nausea, vomiting, irregular or rapid heart beat; confusion, panic attacks

extreme: delirious or seizures

fatalities extremely rare but possible

can interfere with other drugs that raise blood pressure

b. Nicotine

extracted from the tobacco plant

powerful stimulant to heart

taken with cocaine puts far more stress on heart than either alone

stimulates Ach receptors in brain
→ excites nerve cells
→ may improve memory

may cause dizziness, weakness or nausea

dangerous OD rare but possible

→ would cause tremors and convulsions and resp failure

reaches fetus in pregnant women and can cause permanent damage to fetus

is addictive yet lacks mind altering effects of alcohol, other stimulants and opiates

toxicity

nicotine increases heart beat, irregular beat, increased blood pressure

tobacco is the leading cause of preventable deaths in US (18% of population smokes$_{2014}$)

for each 1000 tons of tobacco produced 1000 people will die from tobacco related illnesses

causes cancer, heart disease, strokes

teens, esp women, more likely to develop osteoporosis, vertebral fracture and hip fracture

abt 1 Billion people worldwide smoke daily

worldwide tobacco related illnesses are estimated to cost $200 B/yr direct and indirect costs

c. Marijuana (hash)

active ingredients: various forms of THC cannabinoids; 1-8% of marijuana products

brain has cannabinoid receptors
→ stimulates pleasure centers in brain

History

may have been cultivated up to 10,000 years ago

native to central Asia

staple crop of ancient China:
used for food, fiber, oil, paper, medicine

in US 1940's it was patriotic duty of American farmers to grow it for hemp

early 1900's 1st American conference on medicinal uses of marijuana

was used to successfully treat:
- stomach pain
- childbirth psychosis
- chronic cough
- gonorrhea
- as an analgesic
- antiinflammatory

India, late 1800's used therapeutically for:

cramps	spasms	convulsions	headache
asthma	piles	delerium	diuretics
hysteria	neuralgia	sciatica	tetanus
bronchitis	flatulence	impotence	tonic
ague	cholera	hydrophobia	dysentery
catarrha	dyspepsia	sedative	disinfectant
leprosy	brain fever	gonorrhea	hay fever
TB	diabetes	toothache	aphrdesiac

not that it was actually effective against all these

but it was the most important drug in Indian medicine

by 1930's Eli Lilly and Parke-Davis were marketing cannabis extracts and tinctures

medical use declined from 30's as it was replaced by synthetic drugs

in 1994, US Distr Court of Appeals (under heavy pressure from FDA) judged cannabis had no medicinal value

Current medicinal uses:

a. Glaucoma
- >2M Americans have glaucoma
- 80,000 Americans go blind due to glaucoma
- leading cause of preventable blindness in US
- 8x's more common in nonwhites
- successful drug therapy deals with most cases
- if ineffective can undergo risky surgical treatments
- canasol = sterile opthalmic preparation of cannabis
  - → effectively lowers IOP and prevents further damage to optic nerve

b. To treat symptoms of chemotherapy
- chemotherapy for cancer often causes violent uncontrolled nausea and vomiting
- conventional medicines don't work for this
- people who smoked MJ before chemotherapy reported enormous help
  - → stopped vomiting and even made them hungry

c. to treat anorexia associated with weight loss

in AIDS patients
- also untreatable by any other drug
- stimulates appetite
- reduces intense nausea of disease and the AZT therapy

d. other potential treatments
- → spasticity due to spinal injury >1M in US
- → as treatment for pain and headaches

toxicities:

marijuana smokers are at higher risk of lung damage than tobacco smokers

even though they usually smoke less often

damages lungs, chronic bronchitis and probably lung cancer

→ 3-4 joints/day ~ 1 pk cigarettes/day

impairs judgement and coordination

→ users ~2x's more likely to have a car accident

continuous use
- lower sperm count
- irregular menstrual cycle
- may decrease fertility
- may suppress immune system
- cannabis smoking is linked to a 41% increase risk of developing psychotic illnesses such as schizophrenia (lancet, 2007)
- those who start a habit in their teens have significantly lower IQ than non users by the time they reach middle age

Overuse:

estimates are that abt 9% of marijuana users become addicted

in 5000 years no reported cases of fatal overdose

lethal dose is virtually impossible

in small children → may cause coma in large doses

combined with cocaine may be dangerous to heart

people with heart disease and high blood pressure may be at risk
- → extra load on heart

d. Cocaine

effects similar to amphetamines: alertness, pleasure, sense of well-being, lower anxiety and social inhibitions and heighten energy, self esteem , sexuality and emotions of interpersonal experiences

acts by increasing actions of GABA in brain

most users do not become dependent

of 30 M americans who have tried it, 80% have not become regular users, 90% are not addicted to the drug

smoking (free basing) allows the drug to reach

brain quicker and increases liklihood of abuse

symptoms of stimulant abuse:

acute: esp in high dose, binge users:
impaired judgement
impulsiveness
hypersexuality
extreme psychomotor activation

abstinence after binging:

crash → exhaustion, intense depression, anxiety

withdrawal→ decreased energy and reduced interest and ability to experience pleasure, drug craving

extinction→ diminshing episodic drug craving

used as anesthesia and as sedatives in over 2500 kinds of medicines

→ almost all are used illegally, recreationally

also reduces anxiety

though made for medical purposes the main difference is in potency

overdose:

lethal → esp if heart problems

creates social problems: depression, paranoia, addiction

anxiety, nightmares, hostility, rage

impaired learning and memory

combined with other sedatives can cause fatal repression of breathing and heart failure

e. Belladonna

alkaloid from jimsonweed

only major group of hallucinogens used medicinally

used for 1000's of years:

used during middle ages to dilate pupils for enhancement of beauty: word means "beautiful woman"

works differently than other hallucinogens

→blocks 1 group of acetylcholine receptors that slows heartbeat and helps form memories

depresses parasympathetic system

at low doses is effective treatment for asthma and some stomach problems

has other effects on:

body temperature→ can rise to dangerous levels

affects memory → amnesia

f. Opium & Heroin

extracted from poppies

by 1900 >50,000 different brands of opiated formulas

affects the release of many neurotransmitters

opiate receptors in brain react to endorphins & enkephalins, related to:

pain reduction
well being/euphoria
suppressed breathing
drowsiness

drugs generally stimulate all receptors at once instead of individual activation

can be lethal anytime

but especially when injecting

especially dangerous when used with alcohol, barbiturates and Valium-like drugs

long term problems:

impotence, reproductive problems

is addictive

→ neglect health, risky behavior (eg. shared needles)

12. Commercical uses:

a. cork from bark of cork tree

eg. *Quercus suber* = cork tree

grows on >30 M acres in Spain and Portugal
renewable resource
→ harvesters carefuly strip away outer bark without damaging cork cambium

harvested about every 9 - 10 years

cork used for: stoppers, gaskets, life preservers, fishing floats, flooring, insulation

wildlife has flourished in these cork oak forests

use of plastic corks may force cork farmers to turn to other crops – may destroy balanced ecosystem

b. fiber

for clothing, rope, baskets etc

cotton→ #1 fiber: clothing, furniture, rope, paper

flax → linen, very fine fibers: clothing, cloth, paper

hemp
jute
abaca
} coarse fibers: mostly string and rope

c. paper

most paper is made from conifer wood

but finer papers come from flowering plants:

cotton
linen
papayrus

d. nanocrystalline cellulose

made of tightly packed, needle-like, microscopic crystals

extremely cheap to produce

transparent & 8 times the tensile strength of steel

produced from processing wood pulp

→ "natural renewable version of carbon nanotubes at a fraction of the price"

being haled as the latest "wonder material"

flexible electronic displays

computer components

replace plastic and some metal car parts

lightweight body armor

ballistic glass

13. energy

wood burning

alternative energy sources

eg. ethanol fuel from corn & agricultural wastes

switchgrass and forest residues are considerably more efficient and less polluting that corn or other crops for alcohol production

eg. creosote bush

14. Paleobotany & Forensic Botany

a. **Dendrochronology**

counting tree rings

can accurately date back to 50,000 years using wood found in archaeological sites

b. **Plant Remains**

archaeologists have made extensive use of plant remains in reconstructing the lifestyle of ancient peoples

not all parts of a plant are equally well

preserved

→lignified wood and fibers are most resistant to decay

eg. seeds, wood, pollen phytoliths and fibers are the most informative

phytoliths are plant crystals that are formed in the vacuoles of epidermal cells in the stems and leaves of some herbaceous plants

they are usually composed of calcium salts or silica and can remain intact for 1000's of years

the same principles of plant identification are used in modern forensic science

eg. the 1st use of plant forensics was the famous 1935 Lindberg kidnapping case.

Bruno Hauptmann was convicted of kidnapping and murdering the son of Charles and Anne Lindberg.

a homemade wooden ladder used during the kidnapping and left at the scene was shown to be made of wooden planks from Hauptmann's attic floor

In modern forensics, even herbaceous plant parts can be useful:

eg. fragments of tree leaves and bark in the cuff of an

accused rapist indicated that he had climbed a tree to get into a window of the victims home rather than being invited through the front door as he had claimed

since plant materials are not digested well by our stomachs, stomach analysis can determine foods eaten and time since meal with great accuracy

eg. in cases of suspected plant poisoning ID can be made from leaves or fruits of intact plants

eg. analysis of stomach contents:
investigation of a salad eaten by victim allowed investigators to identify the specific restaurant where the victim had eaten; his companion at the time of the meal was identified and eventually charged

15. Phytoremediation

some plants tend to accumulate various toxic metals from the soil they live in:

zinc, lead, chromium, nickel, selenium, copper, etc

sometimes at levels that are toxic to most other life forms

eg. some can absorb up to 4% of their body weight

may protect the plant from herbivores

eg. some trees can accumulate zinc to levels that inhibit insect attacks

we can use this knowledge to remove specific elements from contaminated soils

eg. being used at Chernobyl to help remove radioactive isotopes from soil

16. Diseases of Plants

plants can be parasitized by 100's of species of bacteria, fungi, viruses, worms, insects

cause billions of dollars in crop damage, ornamentals, tree farms, etc

plant diseases, primarily fungal and bacteria, cost US alone over $4 Billion/yr (2000)

eg. bacteria cause diseases in pears, potatoes, tomatoes, squash, melons carrots , citrus, cabbage and cotton