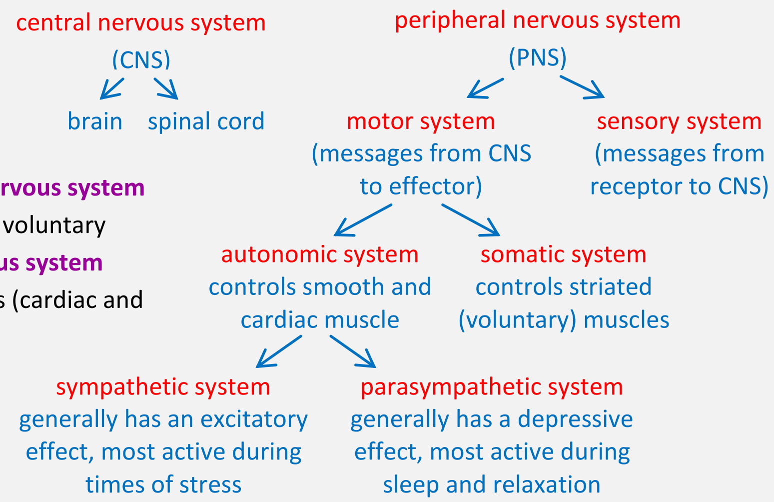
F215 Control, genomes and environment

Unit 8: Responding to the environment

The Nervous System

The nervous system can be divided into the **central nervous system** (CNS) which comprises the brain and spinal cord, and is made of white and grey matter. The **peripheral nervous system** (PNS) is made up of all the neurones which transmit messages into and out of the central nervous system

The PNS has the *sensory system* which takes messages from the receptors to the CNS, and the *motor system* which takes messages from the CNS to the effector



This motor system consists of the **somatic nervous system** which is responsible for sending messages to voluntary (skeletal) muscles, and the **autonomic nervous system** which sends messages to involuntary muscles (cardiac and smooth muscle)

The autonomic system can further be broken down into the **sympathetic nervous system** which is excitatory, and the **parasympathetic nervous system** which is inhibitory (depressive)

In the autonomic system, two neurones run to each effector, meeting at a **ganglion**. The sympathetic branch has ganglions at the target organs (long *pre-ganglionic* neurones) and the parasympathetic branch has ganglions much closer to the spinal cord (long *post-ganglionic* neurones). The other major difference is that the sympathetic system uses the transmitter **noradrenaline**, and the parasympathetic system uses **acetylcholine**

Human Brain

The largest part of the brain is the **cerebrum**, divided into four lobes (temporal, occipital, frontal and parietal) in two *hemispheres*. Each lobe contains many areas, which can be **sensory areas** (those which receive indirect impulses from receptors), **association areas** (which use what has been learnt from past experiences to decide on an appropriate response to a stimulus), and **motor areas** (those which send impulses to effectors – muscles and glands)

The cerebrum is involved in muscular movement and coordination, but *fine motor control* is coordinated in motor areas in the **cerebellum**, which lies beneath the cerebrum

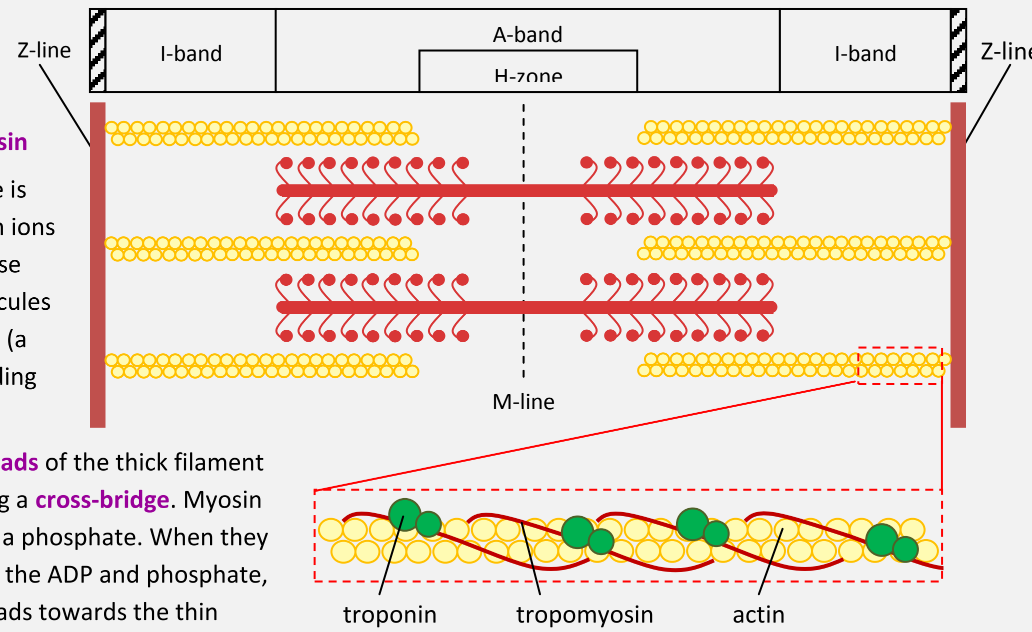
cerebrum (cortex)	Involved in a wide range of 'higher functions', this four-lobed part of the brain is enlarged in humans. It has been associated with personality, emotions, language, reasoning, visual processing and also possibly consciousness
cerebellum	Responsible for **fine motor control** (for example, gripping objects and playing the piano), as well as posture, balance and walking (movement). It has also been connected with memory
medulla oblongata	Responsible for the control of basic vital functions, such as breathing and heart rate; the medulla is something we have in common with all vertebrates, and is also involved in producing the 'fight-or-flight' response
hypothalamus	Involved in various homeostatic mechanisms, and contains different receptors (for example, for water potential – osmoreceptors – and temperature – thermoreceptors), and is connected with the **pituitary gland** (for example, in *osmoregulation*)
corpus callosum	Connects the two hemispheres of the brain, this is bigger in human females who use each side equally, and smaller in males who have *lateralised brains*, using the right hemisphere more effectively

Sliding Filament Model

Muscle action is controlled by the **neuromuscular junction**, which is similar to a synapse. An **action potential** arrives at the synaptic knob of the motor neurone which contains vesicles of **acetylcholine**, and the impulse causes the vesicles to move and fuse with the cell surface membrane, releasing ACh into the gap by exocytosis, where it diffuses across and binds to receptors on muscle fibres, causing a **depolarisation** of the muscular membrane, which travels down **T-tubules** in the muscle, triggering the **sarcoplasmic reticulum** to release calcium ions from its stores

Similarities to the synapse	Differences from the synapse
both use acetylcholine as the neurotransmitter (provided the synapse in question is the cholinergic synapse)	T-tubules carry the electrical signal quickly into the inside of the muscle cell, whereas at a synaptic junction the message is passed on by the movement of sodium ions
the enzyme acetylcholinesterase is involved in both for breaking down acetylcholine to maintain a concentration gradient and prevent constant impulses being transmitted	the neuromuscular junction is only ever excitatory, whereas synapses can be either excitatory or inhibitory
both are triggered by the arrival of an action potential on the pre-synaptic/motor neurone membrane	the synapse sends a message from neurone-to-neurone, whereas the neuromuscular junction transmits a signal from neurone-to-muscle

Fibres of skeletal muscle are contained by a muscular membrane (**sarcolemma**) and contain cytoplasm (**sarcoplasm**), which are rich in mitochondria to supply the energy for contraction. The fibres are made up of muscular subunits called **sarcomeres** which give skeletal muscle its striated bands. They comprise *thick filaments* made of **myosin**, and *thin filaments* made up of **actin**, **troponin** and **tropomyosin**



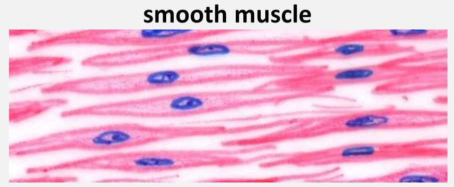
When our muscles need to contract, a nerve impulse is sent across the motor neurone which causes calcium ions to be released from the sarcoplasmic reticulum. These ions enter the sarcomere and bind to troponin molecules on the thin filaments, which causes the tropomyosin (a protein which is long and at rest covers up actin binding sites) to move, revealing the actin binding sites

With the actin binding sites now free, the **myosin heads** of the thick filament are able to move and bind to actin filaments, forming a **cross-bridge**. Myosin heads at rest are attached to a molecule of ADP and a phosphate. When they form a cross-bridge with the actin sites, they release the ADP and phosphate, which releases energy, which is used to bend the heads towards the thin filaments, which pulls the thin filaments inwards (the **power stroke**)

Once this has occurred, a molecule of ATP binds to the each myosin head, which causes them to dissociate from the actin, so there is no more cross-bridge. This allows a very brief resting period, called the **recovery stroke**. The ATP is then immediately hydrolysed to form ADP and phosphate, and the myosin is reset for another power stroke. As long as calcium ions remain present in the sarcomere, power strokes will continue. Calcium ions will have to be removed by *active transport* when they are no longer needed, as it will be against the concentration gradient, a further use of ATP

Types of Muscle

There are three types of muscle: **skeletal muscle** (*voluntary muscle* or *striated muscle*), **smooth muscle** (*involuntary muscle*) and **cardiac muscle**

	skeletal muscle	smooth muscle	cardiac muscle
			
structure	many mitochondria, multinucleated, extensive sarcoplasmic reticulum, striated (striped/banded)	non-striated, spindle-shaped cells, single nucleus in cells	striated, cells form connecting platforms with each other called **intercalated discs**, single nucleus in cells
function	leads to the movement of the skeleton at joints, leading to the movement of limbs, contracts as described above	involved in **peristalsis** (moving food along intestine) and temperature regulation (vasoconstriction)	the **myogenic** muscle is part of the cardiovascular system, keeps the blood stream flowing, supplies organs with blood

Innate Behaviour

An **innate behaviour** is one which an animal is born with and naturally occurs. It is genetically predetermined, and all members of the species share such behaviours. There are four main types:

- a **reflex action** is a non-conscious response which is fast and automatic, such as the *escape reflex* seen in fish and shrimp whereby a detection of change in pressure causes them to flick their tails (involuntarily), darting them away
- a **taxis** behaviour is a *directional* movement response, such as positive **chemotaxis** in ants, where chemical responses in their antennae cause them to move towards a sweet substance, or negative **phototaxis** in maggots, where maggots detecting light from a certain direction are caused to move away from the light
- a **kinesis** behaviour is a *non-directional* movement response, where there is no particular direction indicated, but the aim is simply to *change direction*, such as with woodlice, who prefer damp and dark conditions, and so in response to being in a bright or warm environment will randomly move about until they find more favourable conditions
- a **fixed action pattern** is a more complex animal behaviour which always follows the same set of rules, but is a response to a *non-immediate stimulus*, and probably the best known example is the **waggle dance** of bees (whereby a bee indicates to other bees the direction and distance to a food source, based on the angle and duration of its waggle)

All of these innate behaviours are described as **stereotyped**, because they are the same in all individuals of the species and always follow the same set of rules

Learned Behaviour

Learned behaviours are those which are developed and learned through interaction with the environment. These are not genetically passed onto offspring, but may be taught to offspring. It shows adaptation in response to experience:

- **habituation** – learning to ignore certain stimuli as they pose no threat or offer no benefit
  e.g. birds learning to ignore scarecrows as they do not harm them
- **classical conditioning** – associating two stimuli so that they both trigger the same response
  e.g. a cat running into the kitchen when it hears a can opener opening a tin of cat food
- **operant conditioning** – learning behaviours through reinforcement, whereby past experiences teach animals how to respond
  e.g. humans learning to avoid foods which make them ill
- **imprinting** – some newborn precocial species learn to follow an organism, and will only learn from that organism
  e.g. young ducks learning how to swim and fly by following their parents
- **insight learning** – problem-solving, animals use knowledge and experience to find a solution to a situation and learn it
  e.g. chimpanzees can assemble a stack of boxes to climb upon in order to reach bananas hung from the ceiling
- **latent learning** – (exploratory learning) animals learn information by exploring which may be called upon at a later date
  e.g. young rabbits learn the layout of their burrows which may help them avoid predation in the future

Social Behaviour in Gorillas

Mountain gorillas live in **troops** which usually consist of around ten individuals (one **dominant** male, a number of adult females and their offspring). The dominant male protects the group and leads them in search of food and shelter. When the young males reach sexual maturity, they leave the group and live on their own until they are old enough to attract their own females. Females can continue to live in the same troop or move out and find a new troop when they reach sexual maturity

As with most primates, these gorillas pick parasites off of each other's fur. This is called **allogrooming**. This occurs between all individuals within the troop and reinforces their relationships. The mothers in the troop protect the offspring when young, remaining in constant contact for the first five months of a young gorilla's life, and close contact for the next twelve, protecting its children until it is ready to fend for itself and explore its own environment

Learning also takes place after the age of two, as young gorillas learn by exploration and playing together. They also imitate the adults in the troop by foraging for food. The adult gorillas are not only important in the sense of providing protection and a source of food, but also in teaching the juvenile gorillas important life skills

Advantages of this social behaviour include:

- ✓ communication systems, such as grunting and displays, are used to warn other gorillas of danger in the area
- ✓ females only give birth to one (or a small number of) individual at a time, so early maternal care is extensive and successful
- ✓ knowledge and protection of food sources is shared with group members, they do not compete with each other
- ✓ the young gorillas learn through exploration and playing with each other, and this learning is important to their later survival

Dopamine and the DRD4 Gene

Dopamine is a molecule which acts as both a *hormone* in the bloodstream, and a *neurotransmitter* in the nervous system. It has a variety of effects, and different **dopamine receptors** elicit different responses. There are five types of dopamine receptor, each with a different structure: DRD1 to DRD 5. There are a number of versions of the **DRD4** (dopamine receptor D4) gene, containing 20 alleles, which differ at a specific base sequence called the **variable number tandem repeat**

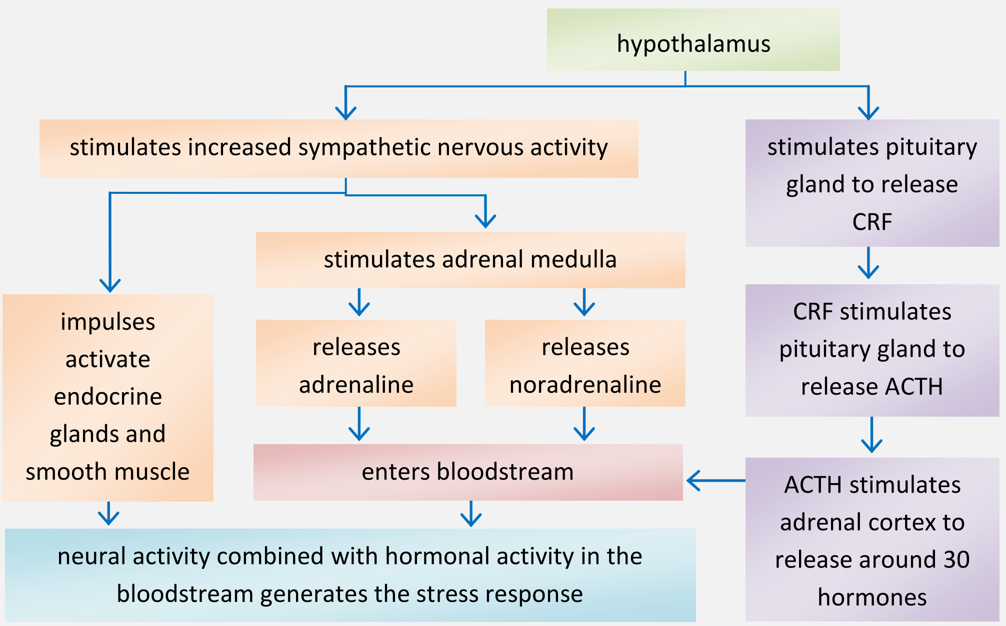
Evidence for the role of dopamine has come about from research into sufferers of **ADHD** (attention deficit hyperactivity disorder). A drug called Ritalin can be given to people with ADHD, which affects the levels of dopamine in the brain, and treats the symptoms of the disorder. Also, a particular version of the DRD4 gene has been noticed as more frequent amongst those with ADHD

The DRD4 gene has also been linked with **addiction**, and as such has been associated with disorders such as *anorexia nervosa* and *bulimia nervosa*, as well as smoking and gambling disorders. Recent research has showed that particular variants of the DRD4 gene can genetically-predispose someone to addictive characteristics such as these

Such research has led to the investigation of the role of other neurotransmitters in behavioural conditions, such as the chemical **serotonin** (another neurotransmitter belonging to the *monoamine* group, with dopamine and noradrenaline), which has been associated with **OCD** (obsessive-compulsive disorder), more specifically a lack thereof

Fight or Flight Response

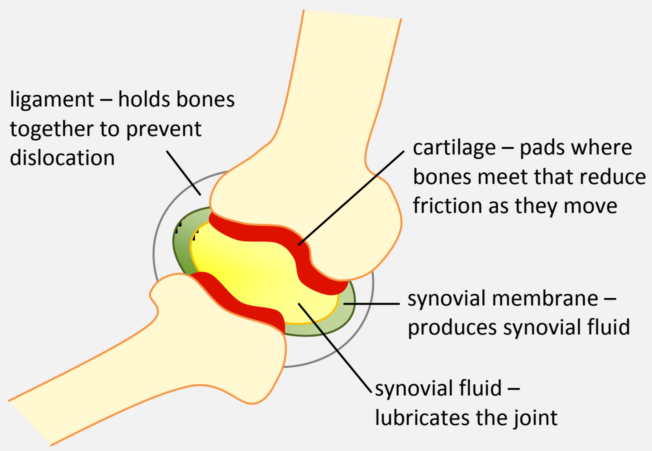
When a mammal detects a potential threat in its environment, the **fight or flight response** causes a number of physiological changes which prepare the mammal for either fighting its way out or escaping the danger. The **hypothalamus** is stimulated, which causes the release of **corticosteroid releasing factor** (CRF) from the **pituitary gland**, which in turn stimulates release of **adreno corticotropic hormone** (ACTH) which arrives at the **adrenal cortex**, causing it to produce and release approximately thirty other hormones into the bloodstream. The hypothalamus when stimulated also stimulates nervous activity, sending impulses around smooth muscle, causing *involuntary* contraction, as well as sending impulses to the endocrine glands, stimulating the **adrenal medulla** to release **adrenaline** and **noradrenaline** (norepinephrine), which also enter the bloodstream. The combined nervous and hormonal activity stimulates the fight or flight response. Physiological changes include pupil dilation, increase in heart rate, increase in breathing rate and restriction of blood flow to areas of the body such as the gut ('butterflies in the stomach')



Muscles, Joints and Bones

Muscles work in **antagonistic pairs**. Muscles can only produce a force creating movement by *contracting*, so movement at a **joint** is made possible by the contraction of one of the antagonistic pair whilst the other is *relaxing*. The elbow is a **synovial joint** where a lot of movement occurs, and movement is made possible by the antagonistic action of the muscles which surround the joint

Synovial joints produce **synovial fluid** (from the synovial membrane) which acts as a lubricant for the joint. This is there to east the movement of the bones at the joint. At the end of each bone is **cartilage** to reduce friction caused by the movement of the bones, and a protective **ligament** casing keeps them together when they move



Plant Growth Substances and How Plants Grow

Like animals, plants respond to their environment, both to **biotic** and **abiotic** factors. Those responses which are *directional* responses are called **tropisms** (tropic movements), and *non-directional* responses are called **nasties** (nastic movements). Examples include:

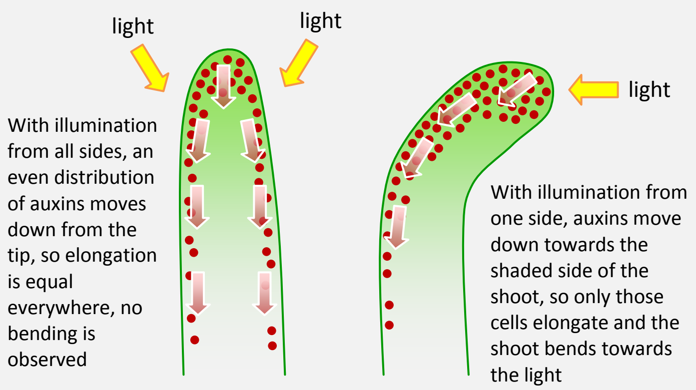
- **phototropism** / **photonasty** – responding to light
- **chemotropism** / **chemonasty** – responding to substances or molecules
- **thermotropism** / **thermonasty** – responding to temperature
- **thigmotropism** / **thigmonasty** – responding to tactile touch

Plant responses are controlled by **plant hormones** (or *plant growth substances*). The table below compares plant and animal hormones

Plant growth substances	Animal hormones
• site of production: interestingly, effectively any cell in the plant is able to produce any plant hormone • method of transport: multiple methods (e.g. diffusion, gaseous transport, in the phloem, etc) • modes of action: receptors on target tissues bind to the chemicals • effects: different growth substances have multiple, unpredictable effects	• site of production: specialised endocrine glands in the body produce specific hormones • method of transport: hormones are secreted into the bloodstream and travel in the blood • modes of action: receptors on target tissues bind to the chemicals • effects: one-specific effect or more per hormone (some have multiple effects, e.g. adrenaline)

Due to their cellulose cell walls, plants cells are limited in how they can expand and divide, unlike animals. For this reason, plant growth only occurs at areas of plants called **meristems**. These include **apical meristems** (at the roots and shoots), **lateral bud meristems** (on buds or nodes where shoots can grow) and around the **cambium strip**. At meristem sites, cell division occurs, but **cell elongation** also contributes towards plant growth. Certain plant hormones trigger cell elongation, whilst others stimulate cell division

Phototropisms



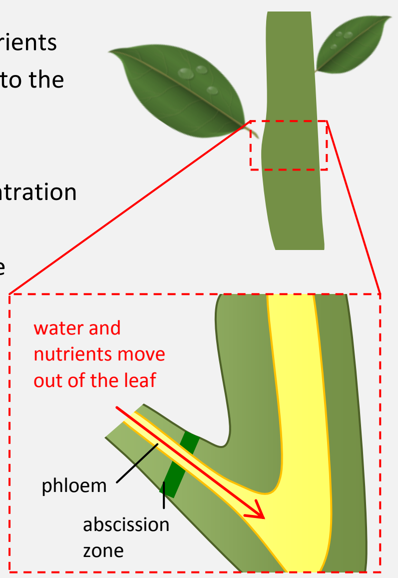
Phototropisms are directional responses to light. During a phototropic response, a shoot of a plant bends *towards* the light. This happens because cell elongation occurs more on the *shaded* side of the plant, which pushes the shoot in the direction of the light

When a **coleoptile** is exposed to light from only one direction, it causes the auxins inside the coleoptile to redistribute along the shaded side of the shoot. This is believed to be caused by two enzymes (*phototropic I* and *phototropic II*) but why the light causes this movement of auxins is still unclear. The reason for the bending is because the auxins stimulate cell elongation on the shaded side, which elongates much more than the side exposed to light

Leaf Abscission

Abscission occurs in **deciduous** trees, caused by a change in the levels of certain plant hormones. Abscission is also called *leaf drop*

1. The levels of **cytokinin** drop as a result of lower availability of nutrients and changing day lengths
2. The plant withdraws nutrients from the leaf – since it is about to drop, the plant will not want to waste nutrients by sending them to the leaf about to drop – in terms of phloem transport, the nutrients simply flow back into the main body of the plant (the stem)
3. As cytokinin levels drop, the level of **auxins** decrease also
4. In response to the drop in auxins, another hormone antagonistic to auxin called **ethene** increases in concentration as ethene production is stimulated
5. High levels of ethene in the leaf stimulate the production of **cellulase** enzymes in the **abscission zone** of the **petiole** (the small stem connecting the leaf to the main stem) which digests the petiole and the leaf drops



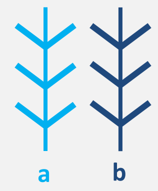
Cytokinin is a plant hormone which prevents plant **senescence** (the removal of nutrients – this is what causes deciduous trees to get their autumn leaf colour), which explains why when the levels of cytokinin drop, the nutrients withdraw from the leaf back into the main phloem

Auxins have a variety of effects on plants, but in this case their function is to inhibit the production of ethene, so that unless the plant needs the leaf to drop, cellulase enzymes are not produced to digest the cells in the abscission zone

Gibberellins

Hormones called **gibberellins** affect plant growth by both cell elongation and cell division. Although involved in a number of processes, they are mainly involved in **stem elongation**. An experiment like the one below could be used to show the action of gibberellins:

This represents a normal, healthy pea plant at its regular adult height



Two mutant varieties of the pea plant are taken, both of which lack gibberellins:

- **a** lacks gibberellins because it lacks the precursor molecule which becomes gibberellin
- **b** lacks gibberellins because it lacks the enzyme which converts the precursor into gibberellin

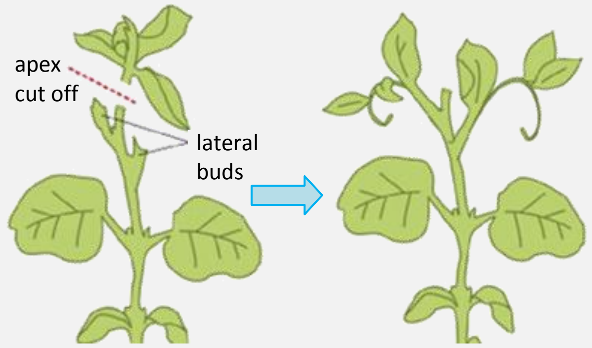
When both varieties were grafted together they grew to a normal height

The importance of this experiment is that it proves natural production of gibberellins and natural processes caused the plant growth. Had gibberellins been artificially inserted, the results would have been less convincing

Apical Dominance

If you cut the **apex** (shoot tip) of a plant off, the plant begins to grow side branches from **lateral buds** which were previously dormant. Research has suggested that this is due to auxins in the lateral buds preventing them from growing due to **apical dominance**. This is the theory that apical growth has priority over lateral shoot growth

To test this, researchers took a plant and cut its apex off. This encouraged growth of the side (lateral) shoots. Further experiments involved cutting off the apex and then applying a paste with auxins to the cut end of the plant – where they found that this actually meant side shoots did not grow. This further supported the theory, as it shows auxins give dominance to apical growth over lateral. However, further experiments have shown that apical dominance is not likely to be a simple cause and effect relationship, so further testing is needed



Commercial Uses for Plant Hormones

Auxins	• artificial auxins can be used to prevent leaf and fruit abscission (drop) • auxins can also be used to promote flowering • auxins are also a key ingredient of **rooting powder**, which the ends of cuttings from plants can be dipped in to encourage root growth when replanted • treating unpollinated flowers with auxins can help to promote seedless fruit growth
Cytokinins	• can be used to prevent the yellowing of lettuce leaves, as cytokinins prevent senescence in fruits and leaves (the removal of nutrients) • used in **tissue culture** to help with mass production of plants • help to promote bud and shoot growth when cuttings are treated with cytokinins, producing a short plant with lots of side branches which can be separated and grown individually
Ethene	• ethene is a gas and so cannot be sprayed directly, but a **liquid spray** has been developed which encourages ethene production inside targeted plants, speeding up the ripening of fruits • promoting abscission in cotton, cherry and walnut plants, as enhanced ethene production stimulates the production of cellulase enzymes which digest the petioles • promoting lateral growth in some plants, so compact plants can be generated for sale
Gibberellins	• involved in fruit production, where they can help to delay senescence, extending the amount of time fruits can be left unpicked or left in the shops • also, acting with cytokinins, gibberellins can help to promote elongation in apples, improving their shape • adding gibberellins to the process of produce **malt** speeds up the brewing process

Plant hormones are used in commercial contexts to improve their qualities, either by enhancing features of them, or encouraging the growth process or increasing the quantity yielded. This allows them to generate more profit