Bio Factsheet

Number 95

Asexual Reproduction

After reading this Factsheet you will be able to describe:

- **asexual reproduction methods in each of the five kingdoms;**
- **the advantages and disadvantages of asexual reproduction;**
- **how knowledge of growth and development has been used commercially to develop methods of artificial propagation;**
- **cloning of plants from tissue culture, including its advantages and disadvantages.**

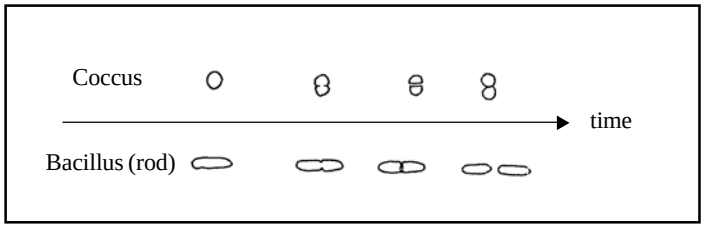
Asexual reproduction methods in the five kingdoms

Asexual reproduction means reproduction not involving sex. Unlike the offspring of sexual reproduction, which are genetically variable due to meiosis, offspring resulting from asexual reproduction are genetically identical and hence make up a population called a **clone**.

1. Prokaryotae (bacteria)

These can only reproduce asexually because different sexes do not occur in this kingdom. They reproduce by the method of **binary fission**. In this process the DNA replicates and the two resulting nuclear areas become constricted and stick to the cell membrane in different places. A cross wall then starts to grow inwards from the outer walls, between the two nuclear areas, eventually dividing the protoplast into two, each with their separate DNA. Due to the DNA replication, the offspring will have the same genotype as the parent, unless mutation has occurred. Division may take from 20 minutes to several hours depending on the species. Binary fission is illustrated in Fig 1.

Fig 1. Binary fission in bacteria



Remember: *– Binary fission is not the same as mitosis . A common exam error made by candidates is to describe mitosis in bacteria.*

2. Protoctista

The *Amoeba* is a single-celled aquatic organism which undergoes binary fission when there is plenty of food, oxygen, a suitable temperature and the *Amoeba* has grown to a certain size (Fig 2).

3. Fungi

In the pin or bread mould, *Mucor mucedo*, asexual reproduction occurs using spores. The body of the fungus (mycelium) consists of many thread-like hyphae situated on the substrate surface (often bread) from which they gain nutrients by saprobiontic nutrition. Growth of the hyphae involves mitotic division and the hyphae are multinucleate with no or few cross walls.

When nutrients are plentiful, some hyphae start to grow erect and a flow of cytoplasm, nuclei and nutrients passes up the erect hyphae causing the end to swell. An erect hypha is called a **sporangiophore** (sporangium-bearer) and the swelling at the top is a **sporangium** (spore-container). The swollen end of the sporangiophore becomes separated by a cross wall which bulges into the sporangium. This bulge is called the **columella**.

The dense contents of the sporangium then separate into spores. These each contain a nucleus (some species have spores with several nuclei) and their cytoplasm secretes a thick wall to surround the spore. The remaining cytoplasm in the sporangium forms mucilage. At the same time, the sporangial wall becomes thick and brittle and is covered with a black layer of calcium oxalate crystals.

When the sporangium is mature, it absorbs water from the sporangiophore through the columella. This causes the mucilage to swell building up a pressure which eventually bursts the sporangial wall. Initially the spores remain embedded in the mucilage, but as it dries out they can be dispersed by wind currents. The thick walls can withstand adverse conditions when no food or water is available or when temperatures are cold. If they land on a suitable substrate, with water present and a suitable temperature, then they germinate and grow (involving mitosis) into new hyphae and mycelium. Very large numbers of spores are produced to allow for the massive wastage that must occur during dispersal.

Fig 2. Binary fission in *Amoeba*.

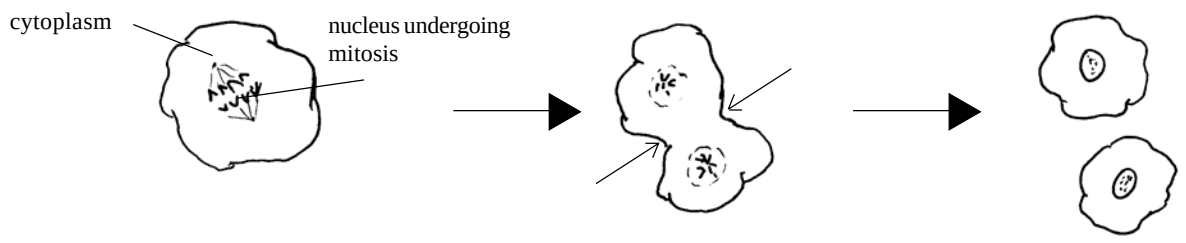
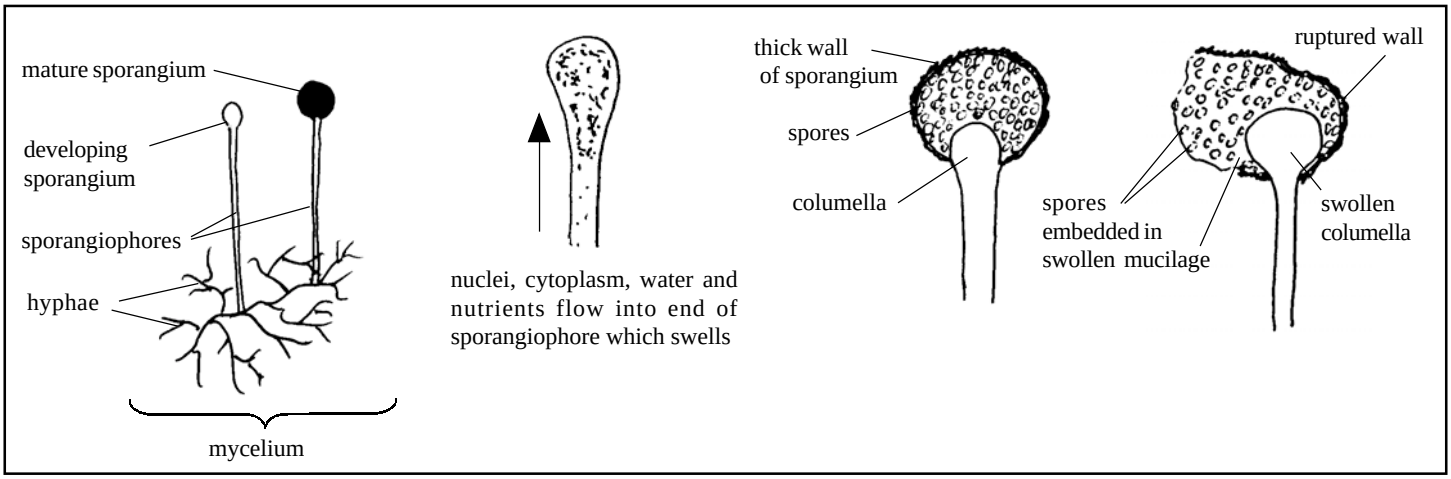


Fig 3. Asexual reproduction in Mucor

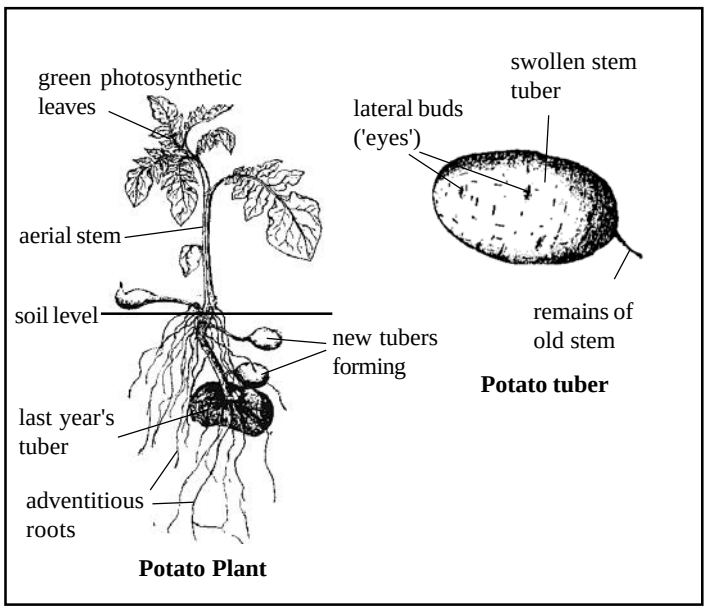


4. Plants

Asexual reproduction involving spores is used by mosses, liverworts and ferns. In flowering plants asexual reproduction (known as vegetative propagation) involves food storage so that the asexual structure can overwinter and withstand adverse conditions. This is called **perennation**.

A potato plant (*Solanum tuberosum*) reproduces from stem tubers. These are the ends of stems which grow under the soil surface and swell as they become full of starch food reserves from photosynthesis. After the aerial parts of the plant die back at the end of the growing season, the potato tubers remain dormant under the soil until the next growing season. These tubers then produce new potato plants by growth (mitosis) from the buds situated on the tuber using the food reserves within as an energy source. Since one parent potato plant can produce several potatoes and also because each potato has several buds, each of which could develop a new plant, then several new potato plants can be produced from the one parent (Fig 4).

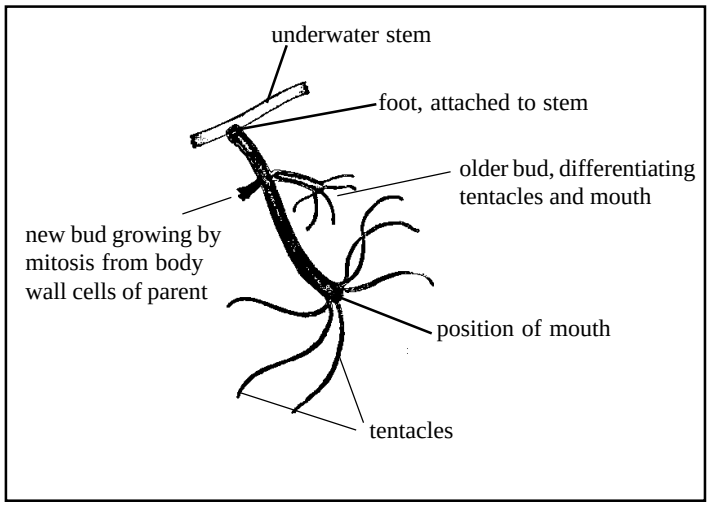
Fig 4. Vegetative propagation in the potato



5. Animalia

Asexual reproduction occurs only in some of the lower phyla of the kingdom, for example in the phylum Cnidaria (hydras, sea anemones and jellyfish) and in the phylum Turbellaria (for example, tapeworms which bud off new segments, called proglottids). Fig 5 illustrates asexual reproduction in the freshwater cnidarian, *Hydra vulgaris. This* occurs by a process of 'budding off' new hydras, by mitosis, from the body wall of the parent. Mature buds become pinched of at the base from the parent and become independent hydras.

Fig 5. *Hydra vulgaris* showing the growth of asexual buds (budding)



General advantages of asexual reproduction

- Because sex is not involved only one organism is needed as parent; there is no need for courtship rituals, meiosis, gamete formation, mating, fertilisation and so on.
- When conditions are suitable, large numbers of offspring can be produced quickly (more quickly than by seeds). In the case of spore production, the offspring can be widely dispersed.
- The offspring form a clone. This means they are all identical genetically. Providing the original parent was genetically well adapted to its environment, the offspring will be similarly well adapted to that environment.
- Individuals that have been produced by sexual reproduction may be then able to reproduce asexually, thus greatly increasing the reproductive capacity of the organism.
- Asexual reproduction enables organisms to survive harsh conditions, either by means of dormant resistant spores or by dormant vegetative structures, for example bulbs, which store food.

General disadvantages of asexual reproduction

- Because the offspring from asexual reproduction show no genetic variation (unless it has arisen by mutation), if their environment changes and becomes inhospitable then they have little chance of producing favourable genetic variations which would enable them to survive the new environment. They might then be selected out and become extinct. For instance, this might be caused by the development of a new strain of plant disease-causing virus to which the plants were not resistant. There would be no chance of genetic variation producing resistant plants. Organisms which reproduce solely by asexual reproduction can be considered to be in an 'evolutionary cul-de-sac'.

- Asexual reproduction might result in overcrowding and increased competition for food, light and space. This occurs due to the binary fission of bacteria in a limited nutrient supply or in flowering plants where vegetative propagation, by means of runners or rhizomes for example, occurs without wide dispersal. For example, couch grass reproduces asexually by vigorous underground rhizomes and can quickly choke a garden.

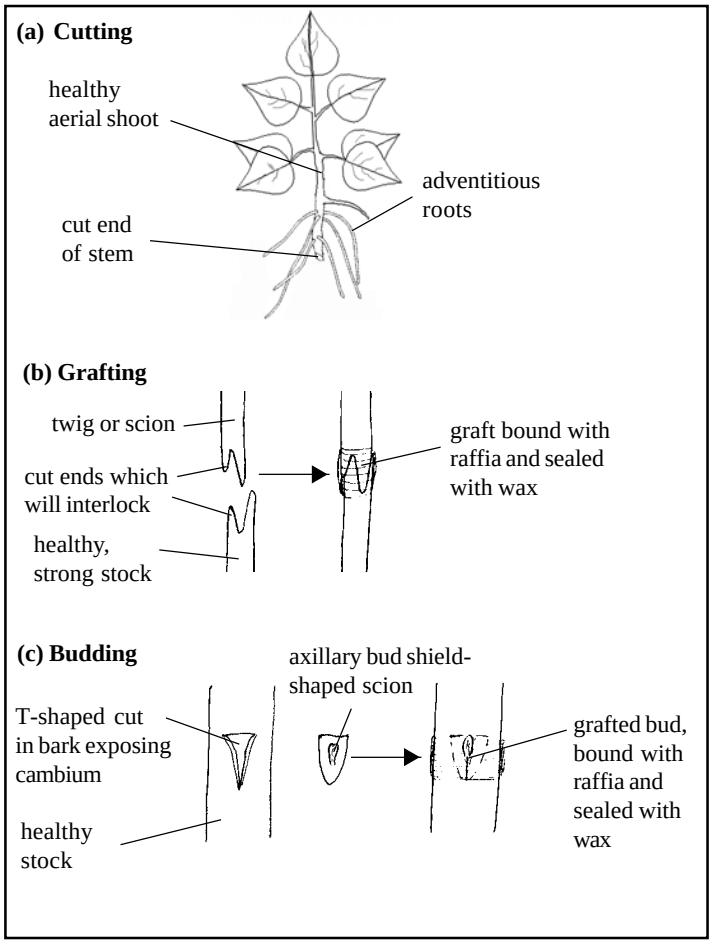
Artificial propagation

Horticulturists and agriculturists exploit vegetative reproduction commercially to produce fresh stocks of plants. This can be done naturally by;

- planting bulbs (daffodils, tulips, gladioli), corms (crocuses), potatoes,
- dividing up rootstocks (dahlia root tubers)
- pegging down runners (strawberries) at their nodes to induce rooting.

There are also methods which do not occur naturally in the plant's life cycle. These include taking cuttings, budding, grafting and plant tissue culture. Fig 6 illustrates some methods of artificial propagation.

Fig 6. Some methods of artificial propagation



It is possible to produce new individuals from certain plants, for example, geraniums, carnations, chrysanthemums and busy lizzies, by putting the cut end of a shoot into water or moist soil. Roots will grow from near the base of the cut stem into the soil while the shoot continues to grow and produce leaves. The process of rooting can be enhanced by dipping the cut end of the stem into rooting hormone powder (auxin). The cuttings should be covered with polythene or a glass jar to prevent dehydration. A cutting is shown in Fig 6(a)

Grafting is used to rapidly propagate varieties of fruit trees and flowering shrubs. It is used because plants derived from cuttings often develop weak root systems and take a long time to reach the stage of flowering and fruiting. Propagation from seeds is unsatisfactory because germination and seedling growth is slow and genetic variation means the plants obtained are often 'not true to type'. The shoots of the variety that it is desired to propagate are grafted onto a strong healthy root of a related wild species or a common variety. Thus shoots of a choice variety of apple can be grafted onto crab apple root systems.

The shoot is called the **scion** and the rooted plant is the **stock**. The top of the stock is cut off and the cut end of the scion is placed closely in contact with the cut stock surface so that as much as possible of their cambial tissues is in contact. In tongue grafting the stock and scion are both cut obliquely, a tongue is cut on the end of the scion and a groove on the end of the stock. The two surfaces are dovetailed together, bound with raffia or tape and covered with grafting wax. This reduces evaporation and prevents the entry of disease-causing organisms. This is illustrated in Fig 6(b)

In budding, a single bud from the desired variety (for example, roses, peaches, plums) is grafted onto the root stock. A suitable root stock for rose buds is that of a dog rose. A T-shaped cut is made in the bark of the stock and the bark is folded back to expose the cambium. The scion consists of a bud, cut off from the desired rose, attached to a shield-shaped piece of bark, which also contains the cambium. This scion is fitted under the bark of the stock, so that the two layers of cambium are in contact, then bound with raffia or tape and sealed with grafting wax. Once the bud has commenced growing the remaining aerial parts of the dog rose are cut off (including all dog rose buds). Budding is illustrated in Fig 6(c)

Plant tissue culture (cloning)

Using this technique, huge numbers of plants can be produced from small pieces of plant tissue. The plants are free from fungal and bacterial infections, and almost certainly free from viral infections. The plants formed in this way form clones since they all produced from one parent plant. Thus the good qualities of the parent plant are perpetuated.

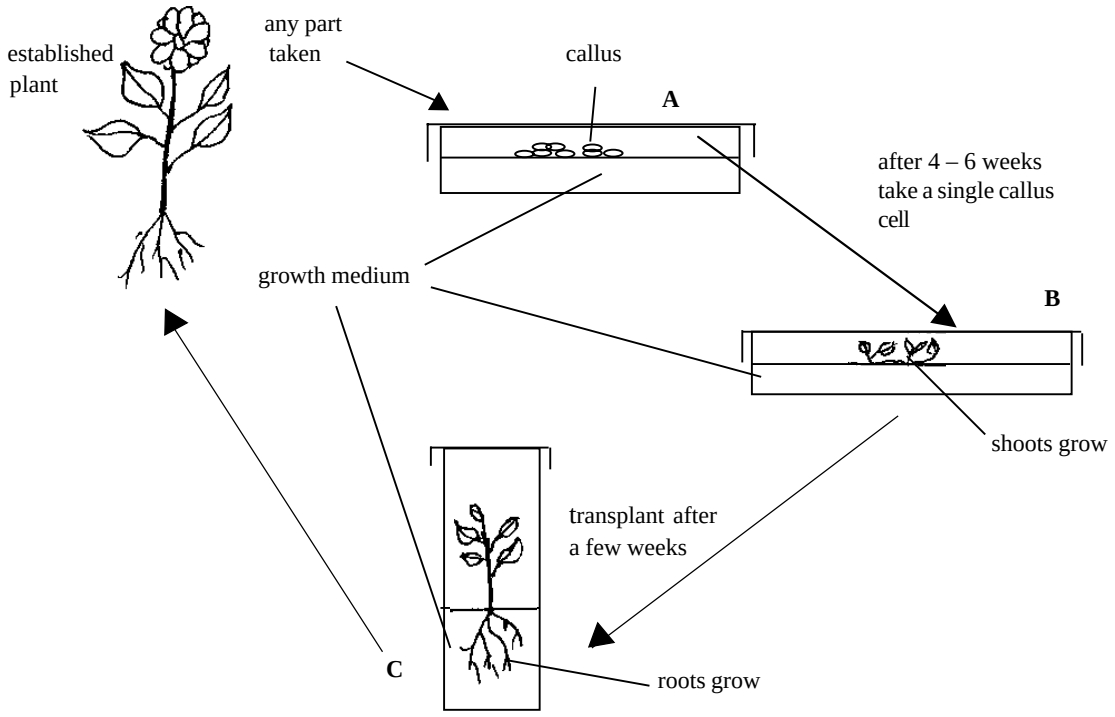
Once a cell has differentiated to form part of a tissue it usually loses the ability to divide. However, the nucleus of any cell in a plant holds all the genes for making a complete plant. In certain circumstances they can be reactivated.

Single plant cells can be induced to divide by mitosis and grow and differentiate into complete plants. One technique is to treat a small piece of plant tissue (called an **explant**) from a root or stem with enzymes to separate it into individual cells. The cells are then exposed to specific plant growth substances at specific concentrations. This induces mitosis and the differentiation of roots, stems and leaves.

Another techniques is to start with a small explant and place it on a nutrient agar jelly. Cells in the tissue start to divide and produce many cells which form a shapeless undifferentiated mass called a **callus.** When the callus is treated with the appropriate growth hormones at the appropriate concentrations, it develops into a complete plant. The technique of plant tissue culture is illustrated in Fig 7 overleaf.

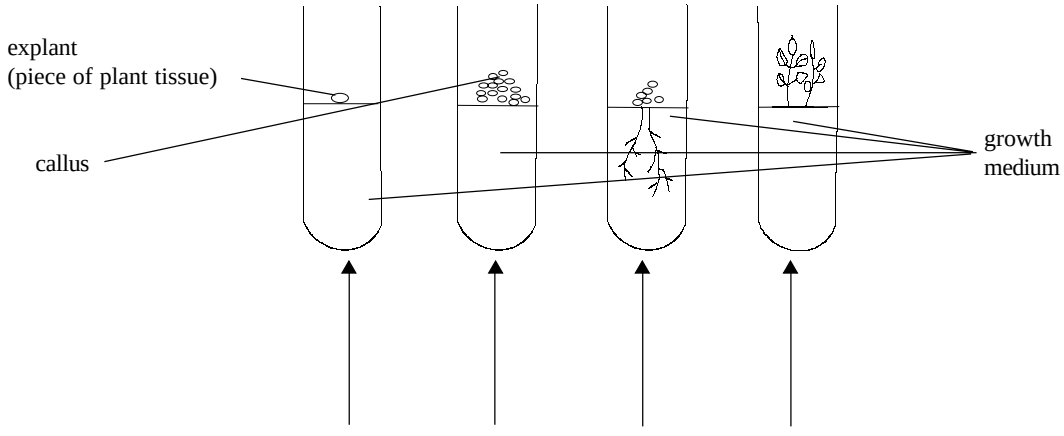
Fig 7 below shows a technique of plant tissue culture.

Fig 7. Plant tissue culture



The hormone treatment is given at stage B of the sequence shown above.

Callus are induced to develop into shoots and roots by varying the auxin and kinin concentrations.



Auxin/mg dm^{-3}	0	3	3	0.03
Kinin/mg dm^{-3}	0.2	0.2	0.02	1

Once whole plants are obtained they can be grown and reproduced in bulk.

Practice Questions

The table below refers to various features of asexual and sexual reproduction. If a feature is correct place a tick (✓) in the appropriate box and if it is incorrect place a cross (✗) in the appropriate box.

Feature of reproduction	Asexual	Sexual
Involves mitosis		
Involves meiosis		
Occurs in flowering plants and mammals		
Occurs in bacteria		
Occurs in fungi		
Genetic variation is introduced by random assortment		
Genetic variation may be introduced by mutation		
Produces a cloned population		
Always involves two individuals		

9

2. For each of the following statements say whether it is true or false. In each case explain your answer

   (a) Asexual reproduction always produces genetically identical offsprings. 2

   (b) In plant tissue cloning a high concentration of kinin (cytokinin) and a low concentration of auxin is required to stimulate root development. 2

   (c) An advantage of asexual spores over seeds is that the spores can remain dormant during unfavourable conditions. 2

   (d) Organisms which rely solely on asexual reproduction are incapable of further evolution. 2

3. Explain why,
   (a) If a rose plant is not pruned regularly or correctly it may revert to a dog rose. 2

   (b) Fruit trees with good characteristics are propagated by budding or grafting. 3

   (c) The pin mould, *Mucor mucedo*, will grow readily on bread but will not grow as well on jam. 3

Answers

1.

Feature of reproduction	Asexual	Sexual
Involves mitosis	✓	✓ ;
Involves meiosis	✗	✓ ;
Occurs in flowering plants and mammals	✗	✓ ;
Occurs in bacteria	✓	✗ ;
Occurs in fungi	✓	✓ ;
Genetic variation is introduced by random assortment	✗	✓ ;
Genetic variation may be introduced by mutation	✓	✓ ;
Produces a cloned population	✓	✗ ;
Always involves two individuals	✗	✗* ;

9

* sexual reproduction usually involves two individuals except in the case of self-pollinated plants.

2. (a) false; genetic variation can be introduced by mutation; 2

   (b) false; need a high concentration of auxin is needed and a low concentration of kinin; 2

   (c) false; both seeds and many spores can remain dormant over harsh conditions. 2

   (d) false; if genetic variation occurs through mutation then further evolution is possible (although unlikely); 2

3. (a) the rose was budded/grafted onto a dog rose stock; dog rose buds must not be allowed to form or develop and would be removed during pruning; 2

   (b) this ensures the fruit trees have a robust healthy root system; it ensures that good traits (such as high fruit quality) are perpetuated/ not lost; it is faster than growing from seed; 3

   (c) the spores of *Mucor* will not germinate on jam; because the high sugar content of jam causes them to dehydrate; by causing osmotic loss of water; bread does not cause this problem; max 3

Acknowledgements:
This Factsheet was researched and written by Martin Griffin
Curriculum Press, Unit 305B, The Big Peg, 120 Vyse Street, Birmingham. B18 6NF

ISSN 1351-5136