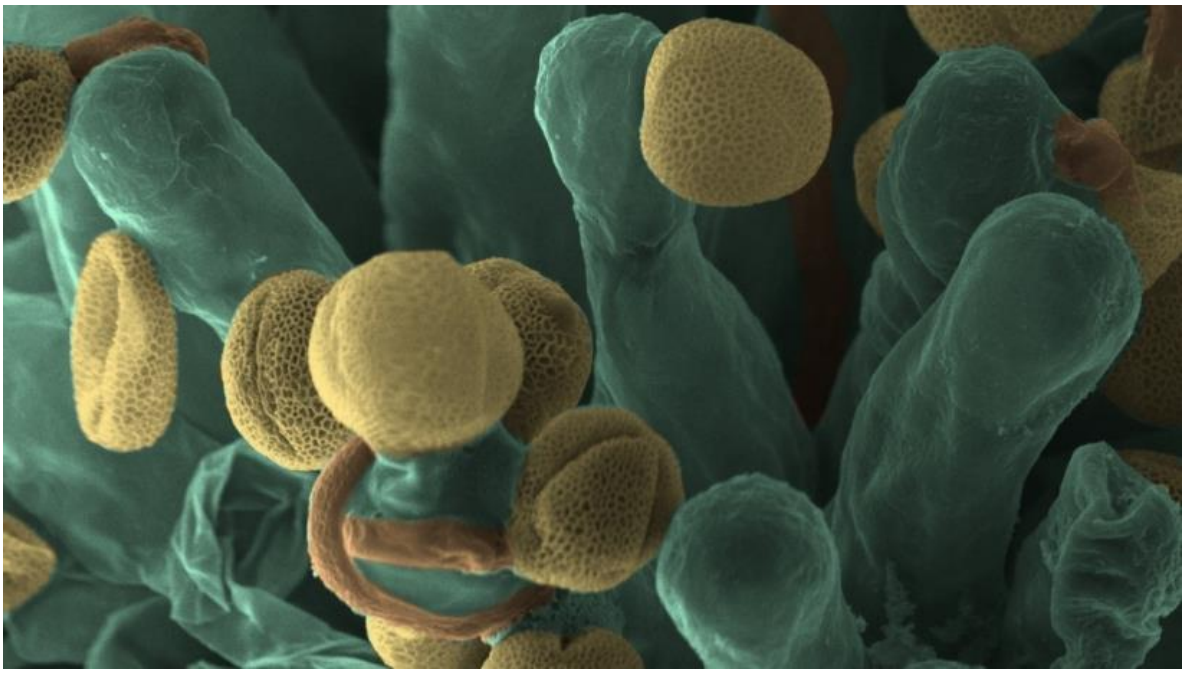
FOURTH FORM BIOLOGY



Arabidopsis thaliana stigma with germinating pollen grains

SUMMER TERM

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Reproduction

Basic Genetics

The largest organelle in Eukaryotic cells is the nucleus. Nearly all cells of plants, animals and fungi contain a nucleus. The few exceptions are cells such as xylem vessels, which are dead, or those which are very short-lived, such as red blood cells.

The nucleus contains the genetic material of a cell in the form of DNA. Each nucleus contains several very long DNA molecules (46 molecules in the case of a human cell). The DNA is packaged into **chromosomes**. In human cells there are 46 chromosomes, but different species have different numbers of chromosomes. Chromosomes are only visible with a light microscope when a cell is dividing.

The genetic information in a cell takes the form of **genes**. A gene is a specific instruction that the cell can use to manufacture a particular protein. A human cell contains between 20 000 and 22 000 genes. The genes are arranged along the chromosomes. The number of different genes along any one chromosome varies depending on how long the chromosome is.

The 46 chromosomes that are found in a human cell can be arranged into two sets, each set containing 23 chromosomes. Thus, there are two copies of each chromosome in the nucleus. A cell that contains two sets of chromosomes is referred to as **diploid**.

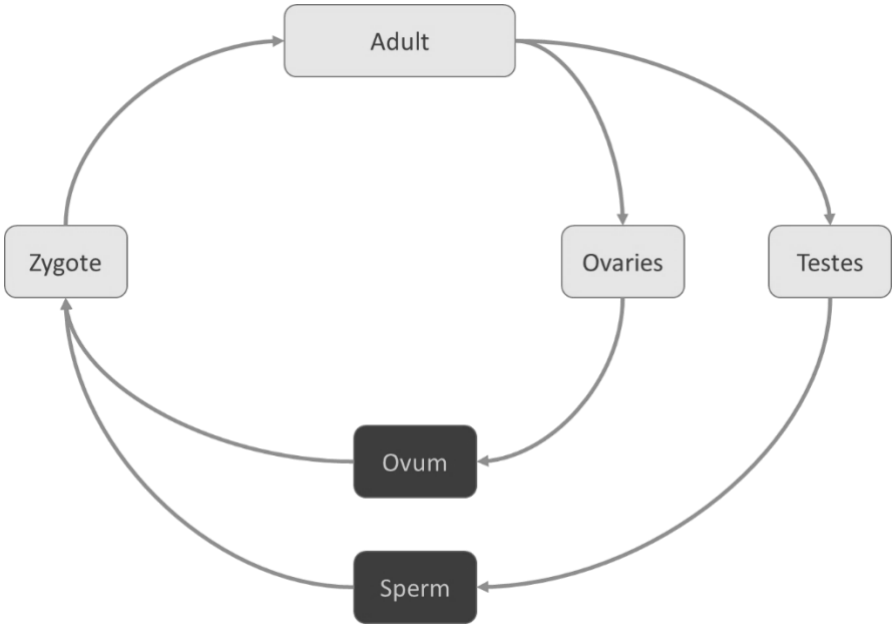
When a cell divides into two daughter cells, all of the chromosomes in the nucleus are first duplicated to make an identical copy of each chromosome. These are divided between the two new daughter cells when it divides, so that they each receive the same number and type of chromosomes as in the original cell.

However, when sex cells (**gametes**) are produced, each cell produced only contains half the number of chromosomes as in the original cell. Gametes, therefore, only contain one set of chromosomes. They are termed **haploid** cells. When two gametes fuse as part of sexual reproduction, the zygote that is formed receives two sets of chromosomes – one set from the male gamete (e.g. a sperm cell) and one set from the female gamete (the egg cell). Thus, a diploid cell is formed.

The diagram below shows the generalised life cycle of an animal. The gametes (eggs and sperm) are formed in the ovaries and testes respectively; they are haploid cells. When they fuse at fertilisation, they produce a diploid zygote which will divide and develop into the embryo.

Sexual reproduction – the production of gametes followed by fertilisation – is important since it generates offspring that are genetically variable since they inherit genes from two different parents. This

is in contrast to **asexual reproduction**, in which all of the offspring are genetically identical to each other and to the parent.



A generalised life cycle of animals, showing the production of haploid gametes and their fusion to produce a diploid zygote. The zygote (a fertilised egg) develops into the embryo and then the adult organism.

Plant Reproduction

Introduction

The flowering plants are the most diverse of all of the groups of plants on land. They produce haploid gametes in their flowers. The male gametes are contained in **pollen grains** and the female gametes are the **egg cells** or **ova**, contained in the ovule. Just as in animals, the male gamete must be transferred to the female gamete. This is **pollination** and can be carried out either by wind or insects.

Following pollination, **fertilisation** takes place where the two gametes fuse and a **zygote** formed. The zygote develops into an embryo which is enclosed within a **seed**, which in turn is enclosed in a **fruit**.

Flower Structure

Despite the great diversity in size, colour, scent and form of flowers, they all have the same basic organisation: concentric rings or whorls of floral organs. The outermost whorl are the **sepals**, followed by a whorl of **petals**. Next are the pollen-producing **stamens,** and in the centre the ovule-producing **carpels**.

Sepals are typically green and leaf-like and envelop the flower while it is in bud, protecting it. When the flower bud opens, the sepals sometimes fold back.

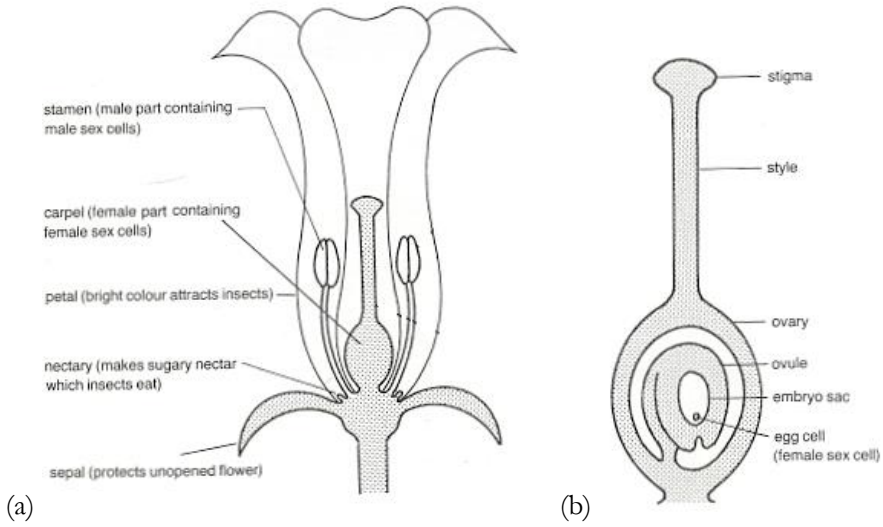
The petals are also leaf-like in many species, but can be modified into a wide variety of forms in different species. In insect-pollinated flowers the petals are integral to the attraction of the pollinator. In wind-pollinated flowers, such as grasses, the petals are often highly reduced in size and not colourful. Petals may be fused to form a tube-like structure into which a pollinating insect may have to crawl. In some insect-pollinated flowers there are **nectaries** at the base of the flower which produce a sugary-solution (**nectar**) as a reward to visiting insects.

The stamens are the male reproductive parts and consist of a stalk-like **filament**, at the end of which are the **anthers**. It is within the anthers that pollen grains are formed and develop. There are usually four chambers within the anther where pollen forms, and when the pollen is ready to be released the anthers usually split length-ways, releasing the pollen grains.

In the centre of each flower are the carpels – the female part of the flower. A carpel consists of a flask-like **ovary** in which the **ovules** are produced, a stalk-like **style**, and at the top of the style, the **stigma**. Often several carpels are fused together to form just a single structure, sharing one style and stigma. If you cut open a tomato fruit, for example, you will see how there are five chambers in the fruit where the seeds are found.

Within each ovary are one or more ovules, which when fertilised will become the seeds. Some species produce just a single (usually large) seed in an ovary, others (such as tomato) produce many ovules. The ovule is attached to the wall of the ovary by a **placenta** by a very short stalk.

The female gamete is formed within the ovule. It is a single cell, the egg cell, which will fuse with a nucleus from the pollen grain. Surrounding the egg cell is tissue that will develop into a food store for the seed (the **endosperm**) and the seed coat (the **testa**).



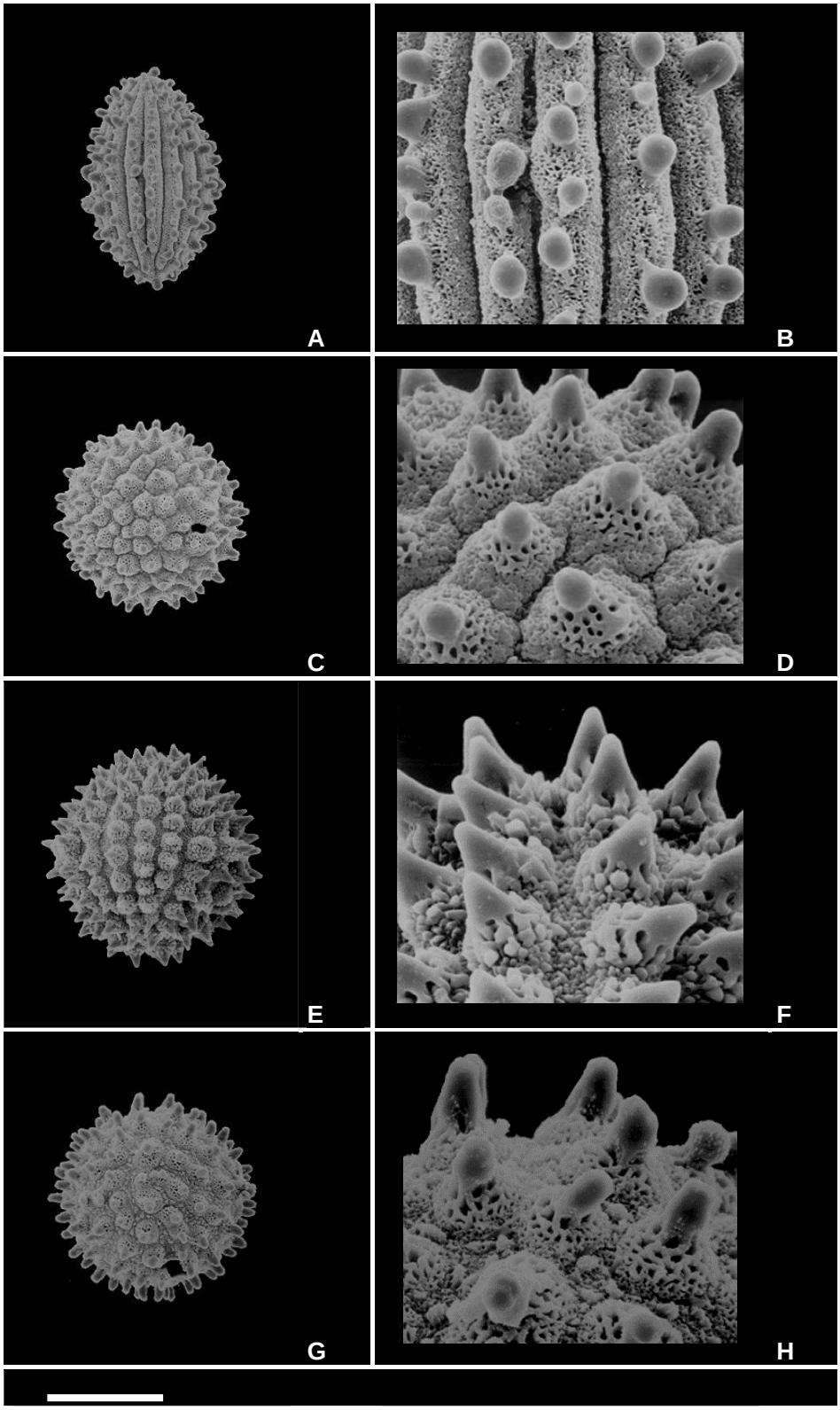
The reproductive parts of a flower. (a)The main reproductive parts showing the four whorls of sepals, petals, stamens and carpel. (b) Details of the structure of a carpel, showing the stigma, style and ovary containing the ovule. Inside the ovule is the egg cell – the female gamete.

Pollination Biology

Pollination is the transfer of a pollen grain from the anther to the stigma. This may sometimes happen within the same flower, between flowers on the same plant, or between flowers on different plants. If this occurs within the same flower it is called **self-pollination**. If the pollen grains are transferred to a different plant, it is called **cross-pollination**. Cross-pollination is beneficial to plants because it results in greater genetic variation amongst the offspring. Self-pollination can lead to a reduction in the genetic diversity of the offspring – it is a very extreme form of inbreeding. Some plants may resort to self-pollination if no pollen has landed on the stigma from a different plant. Note that self-pollination is not the same as cloning or asexual reproduction – the seeds produced by self-pollination are <u>not</u> *genetically identical* to the parent plant.

Pollination can occur by wind or by animals, commonly insects. The outer coat of the pollen grain is made of a tough, resistant material which enables pollen grains to survive long periods of time. The

outer surface is frequently sculptured into ridges and spines in insect pollinated species so they stick to the insect's body. Wind pollinated plants usually produce smaller, smooth pollen grains.



A selection of pollen grains from four different species of Strobilanthes. *Scale bar for A, C, E & G = 25 μm, for B, D, F & H = 5 μm. Note the sculptured outer surface and the holes in the outer coat through which the pollen tube will emerge when it germinates.*

The table below summarises the differences between insect-pollinated flowers and wind-pollinated flowers.

Feature of flower	**Type of flower**	
	Insect-pollinated	**Wind-pollinated**
Position of stamens	Enclosed within flower so that insect must make contact	Exposed so that wind can easily blow pollen away
Position of stigma	Enclosed within flower so that insect must make contact	Exposed to catch pollen blowing in the wind
Type of stigma	Sticky so that pollen grains attach from insects	Feathery, to catch pollen grains blowing in the wind
Size of petals	Large to attract insects	Small
Colour of petals	Brightly coloured to attract insects	Not brightly coloured, usually green
Nectaries	Present – nectar is a 'reward' for insects	Absent
Pollen grains	Larger, sticky to stick to insects' bodies	Smaller, smooth inflated grains to carry in the wind

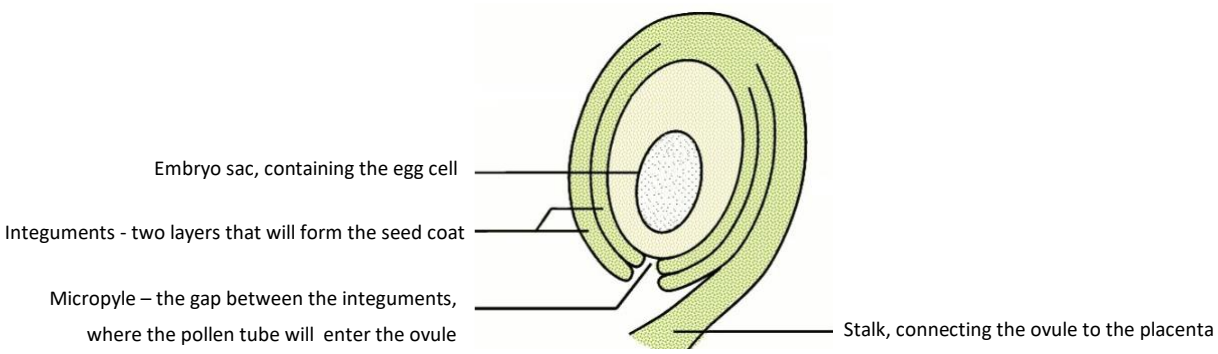
Fertilisation

Pollination only transfers the pollen grain to the stigma. However, for fertilisation to take place, the nucleus of the pollen grain must fuse with the nucleus of the egg cell, which is inside the ovule in the ovary.

To get the male nucleus in the pollen grain to the egg cell, the pollen grain **germinates** and produces an elongated tube-like structure called a **pollen tube**. This grows down the style towards the ovary, guided by chemical signals in the style. There may be many pollen tubes growing at once down a style because many pollen grains may have been deposited on the stigma at the same time. The pollen tube secretes enzymes which digest the tissue of the style so that it can reach the ovary where the ovules are located.

The pollen tube grows towards the ovules in the ovary and enters the ovule via an opening at the tip of the ovule called the **micropyle**. The tip of the tube dissolves and allows the pollen grain nucleus to

move out of the tube and into the ovule. Here it fuses with the egg cell nucleus (**fertilisation**) and the diploid zygote is formed.



The structure of an ovule

In most flowering plants, a second nucleus from the pollen tube fuses with *two* other nuclei that are found in the ovule. This process is known as **double fertilisation**. The cell that forms divides to produce tissue called **endosperm**. This is an energy store for the seed and will be used when the seed germinates. The endosperm of some grasses is particularly rich in starch and forms the basis of cereal crops – wheat, maize, rice, for example. It is the starchy endosperm in these seeds that provides a major source of carbohydrates in human diets. In some other plants, notably peas and beans, the embryo itself is the energy store in the form of proteins, which is why beans are a rich source of protein in the diet.

Seeds and Fruits

Once fertilisation has occurred, a number of changes take place:

1. The zygote develops into the embryonic plant with a small root (**radicle**) and shoot (**plumule**).

2. One or two very simple leaves called **cotyledons** form. In some species these can also act as a food reserve which the seedling will use before emerges above ground and is able to photosynthesise. The seeds of plants such as peas or beans have two cotyledons. They are called **dicotyledonous** plants or **dicots**. Seeds of grasses and other narrow-leaved plants such as irises and orchids have only one cotyledon. They are **monocotyledonous** or **monocots.**

3. The outer tissue layers of the ovule harden and become the seed coat or **testa**.

4. The ovary wall becomes the fruit coat; this can take many forms depending on the type of fruit. Some ovaries become fleshy, such as the tomato or the pepper; in others the wall becomes woody and hard, developing into a nut which will split open to release the seeds.

If all the seeds produced by a plant began to germinate in the same place, there would be competition between them for resources such as water, mineral ions and oxygen. To avoid this, plants disperse their seeds far from the parent plant. Some are dispersed still inside the fruits (usually fleshy fruits); others are dispersed as individual seeds. Seeds may be dispersed by a variety of methods such as wind, water and animals.

Germination

A seed contains a plant embryo and a food store, both enclosed in a tough seed coat. When seeds are dispersed from the parent plant they are usually very dry, containing only about 5 – 15% water, compared with 80 – 95% in most plant tissue. This low water content reduces a seed's metabolism, so that it can remain alive but **dormant** for a long time, sometimes for many years.

When conditions are suitable, the seed absorbs water. The contents of the seed have a very low water potential and so water readily moves into the cells of the seed, as long as the tough outer seed coat is made permeable to water. Initially the seed is usually below ground and so cannot photosynthesise. The nutrient source for growth of the seedling comes from the seed's reserves in the endosperm or the cotyledons. The seed's food store is broken down by enzymes and respired aerobically. The radicle grows down into the soil, where it will absorb further water and mineral ions. The plumule grows upwards towards the light, where it can start the process of photosynthesis. For germination to occur, the following conditions need to be present:

- Warm temperatures, so that enzymes can work effectively
- Water, for chemical reactions to take place in solution
- Oxygen, for respiration.

Key Terms and Definitions

Anther: Part of the stamen where pollen grains are produced.

Cotyledons: Seed leaves. May act as food store in the seed.

Cross-pollination: Transfer of pollen from an anther of one plant to a stigma of a different plant of the same species.

Dicot (dicotyledonous plant): Plant with two seed leaves.

Diploid: A cell or organism containing two sets of chromosomes.

Filament: the stalk part of a stamen.

Fruit: Structure containing a seed or several seeds. Formed from the ovary following fertilisation.

Gamete: A sex cell, e.g. a sperm or egg cell.

Germination: Sequence of events taking place when the embryo in a seed begins to develop into a young plant.

Haploid: A cell or organism containing only one set of chromosomes.

Monocot (monocotyledonous plant): Plant with one seed leaf.

Nectaries: organs found in the base of a flower in some plant species that produce a sugary solution as a reward for pollinating insects.

Ovule: Structure within the ovary in plants. Cells in the ovules divide by meiosis to produce ova.

Plumule: Embryonic shoot of a plant.

Pollen grain: Structure in plants that contains the male gamete.

Pollen tube: Tube that grows from a pollen grain and down through the style to allow the transfer of the male gamete to the ovule for fertilisation.

Pollination. Transfer of pollen from anther to stigma.

Radicle: Embryonic root of a plant.

Seed: Structure that forms from the ovule following fertilisation. Contains the embryo plant and its food store.

Self-pollination. Transfer of pollen from an anther to a stigma of the same flower or to another flower of the same plant.

Stamen: Male reproductive organ in plants, consisting of the anther and a stalk called the filament.

Stigma: Part of the carpel of a flower which receives the pollen during pollination.

Style: Part of the carpel of a flower. Stalk connecting the stigma to the ovary, through which the pollen tube grows.

Testa: Seed coat.