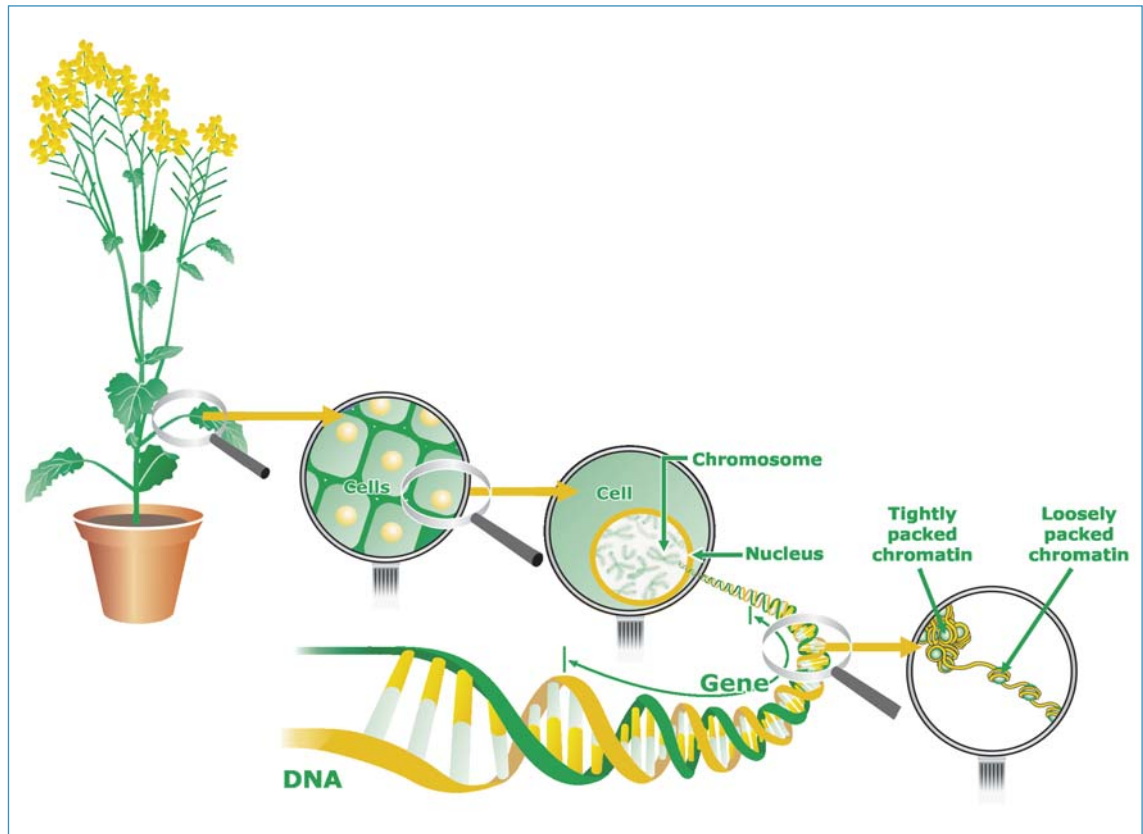


# Inheritance... more than just genes

A new wave of research is unravelling the secrets beyond genes to identify what other biological 'information' parents pass to their offspring, and cells pass on to each when they divide. It seems that it is not just genes that are inherited from one generation to the next but other factors that particularly affect development and disease.

## Genetics – the basics



Every plant and animal is made up of billions of tiny cells. These cells are constantly dividing and multiplying to replace dead or damaged cells.

Within each cell is a complete set of all the genes that make up the coded instructions for the whole organism. Parents pass on their genetic information and associated traits to their offspring, and cells pass it on as they divide.

Because of their role in determining the functions and traits of a living organism scientists are researching genes in plants and animals to try and find out what they do. This has led to important discoveries including genes involved in flowering in plants and genes linked to breast cancer in humans.

Genes are sections of DNA. DNA looks a bit like a twisted ladder and is commonly called a double helix. This double helix DNA is packed into a structure called chromatin which forms chromosomes.

## Epigenetics

Research into what happens in cells has shown something remarkable – it is not just the genes that influence the traits and functions of an organism but also ‘epigenetic’ or non-gene factors.

These epigenetic factors are features within the cell that can be inherited when cells divide but they don’t change the genes themselves.

Epigenetic factors can however modify the behaviour of genes. Epigenetic factors have important roles in regulating human disease and development in both plants and animals.

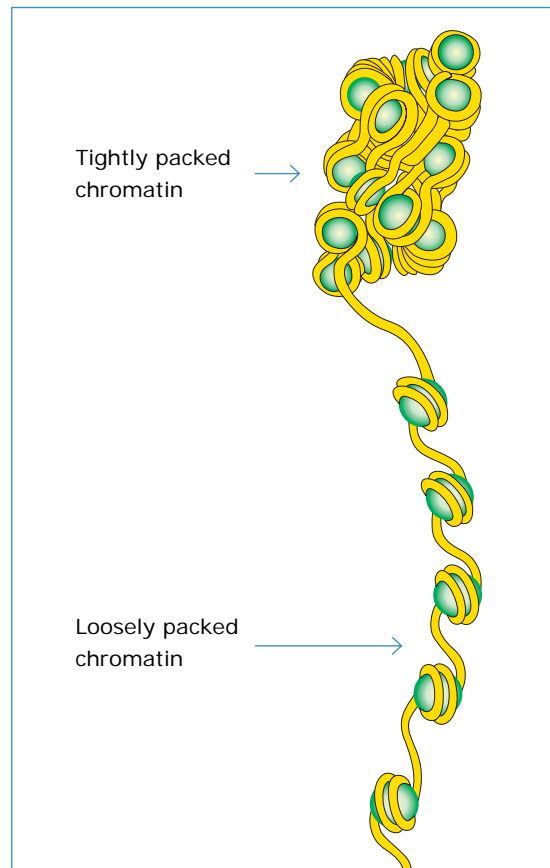
Understanding epigenetics is fundamental to unravelling the intricacies of how genes and organisms work. Because of its fundamental nature epigenetics has broad potential implications across all the biological sciences from plant crops to animal production to human health.

## Epigenetic factors

Epigenetic factors that can influence the behaviour of genes include:

1. Chromatin structure – how DNA is packed
2. DNA methylation – turning genes off
3. Small RNAs – made from DNA and can influence gene behaviour in many ways

## 1. Chromatin structure – how DNA is packed



Chromatin structure

In a similar way a piece of paper with writing on it can be folded to form different origami shapes – DNA can be packed together differently into ‘chromatin’ resulting in chromatin with different structures.

It doesn’t matter how you fold the paper, the information written on it remains the same – just like when DNA is packed together into different chromatin structures the genes remain the same.

The resulting structure of the chromatin, however, can influence how the genes behave.

For example, how crop plants respond to long periods of cold depends on chromatin structure. A crop’s response to cold often determines when it will flower and therefore how much it will yield.

In plants chromatin structure can be flexible, changing over the plant's life.

In animals chromatin structure can manage the expression of genes on the X chromosome. In female humans one X chromosome is mostly turned off because the chromatin structure is very tightly packed. The expression of the second X chromosome in females is equivalent to the expression of the single X chromosome in human males.

Chromatin structure can be influenced by:

- *the outside environment*, for example temperature or number of daylight hours;
- *the developmental stage of the organism*, for example if the plant is just a seedling or if it is starting to flower; and
- *small RNAs*.

The structure of chromatin, can be passed from one cell to the next during normal cell division, but is often reset in the offspring of the organism.

## 2. DNA methylation – when and how much genes turn off

DNA methylation is a normal chemical process that modifies DNA after it replicates. DNA replicates when cells divide.

Although every cell in an organism has all the genes for the entire operation of the organism only certain genes are active in certain cells. For example genes responsible for flower colour aren't active in the cells of the plant's roots.

DNA methylation is one of the processes that can permanently turn off genes for the life of the organism.

In plants, flowering occurs early when there are low levels of DNA methylation and scientists are now searching to identify the role DNA methylation may play in this process.

In animals, one of the mechanisms that turns off cancer suppressing genes is DNA methylation. Scientists are now



Researching how DNA methylation affects flowering will improve our understanding of this process and may eventually lead to discoveries that could improve crop health and productivity.

looking at using this understanding of DNA methylation to develop a test for prostate cancer.

Researching basic biological processes like flowering and all the factors that are involved, including DNA methylation, will improve our understanding of these processes and may eventually lead to discoveries that could improve crop health and productivity.

The causes of DNA methylation are not well known yet but it seems to be directed from within the DNA itself.

When DNA methylation does not operate normally, alterations in gene behaviour may occur and in turn can cause disease or developmental disorders. For example plants with abnormally low levels of DNA methylation experience abnormal changes to their seed size and fertility. A better understanding of how DNA methylation works may provide insights into addressing different diseases and developmental disorders in both plants and animals.

## 3. Small RNAs

RNA is made from DNA and has several different forms and functions.

Primarily RNA is involved in making protein, the building blocks of life. But small RNAs do not help make protein

Instead small RNAs are involved in:

- Changing chromatin structure
- Blocking the ability of other RNA to make protein – thereby turning off or ‘silencing’ genes
- Directing DNA methylation
- Directing different developmental stages
- Providing virus protection

‘Hairpin RNAi’ gene silencing technology triggers the production of certain small RNAs that can ‘turn off’ genes. Hairpin RNAi gene silencing has broad application in plants to discover genes, turn off unwanted genes and to provide plants with protection against viruses. It has already been used to make healthier oils in oilseed plants and to help develop a blue rose.

HairpinRNAi can also be used to identify useful genes in animals and target virus and parasite genes in for the development of precise therapeutics for animal diseases.



Using hairpin RNAi CSIRO developed a virus resistant barley (left) which performs better than a conventional plant (right) when exposed to the virus.

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