Making Molecules

Learning Objectives:

- To understand that x-rays can be used to image molecules;
- To understand that molecules are made of atoms;
- To build on the idea that we see things when light travels from an object, or reflects off it, into our eyes.

Science Skills:

- Make detailed observations and comparisons, taking note of patterns;
- Work together in a team, planning ahead, using equipment and following practical instructions with accuracy and precision;
- Using the method of trial and error;
- Explore and talk about ideas;
- Encounter more abstract scientific ideas and begin to recognise how these ideas help to understand and predict how the world operates;
- Recognise how scientists learn and make small steps towards new scientific ideas over time;
- Gain new scientific vocabulary.

Resources:

- Dorothy Hodgkin Making Molecules PowerPoint
- Pens and paper
- Ruler
- Corrugated cardboard
- Protractors
- Pencils
- Scissors

What you should know before you start - *See Slide 1 of Dorothy Hodgkin: Making Molecules PowerPoint*

Molecules

We see things when light travels from an object, or reflects off it, into our eyes. **Molecules** are made up of lots of atoms bonded together. **Molecules** that are found naturally in the body or in plants are called **biomolecules**.

Penicillin is an antibiotic made by moulds. It is used as a medicine to kill of harmful bacteria.

Insulin is a hormone in the body which regulates the amount of sugar in our blood. People with diabetes don't make enough.

Vitamin B12 is essential for building blood cells and bone. We have to get it in our diet, and can't make it in our bodies. Going without can make you ill.

X-rays

Molecules are too small to see with our eyes, or even a microscope. But we can see them with **x-rays** so long as the molecules are set into a hard crystal. **Biomolecules** are notoriously difficult to make into crystals.

QUICKSTARTER – X-ray imaging

Ask:

- What do you know about x-rays?
- Which of these are x-ray pictures?

Introduce children to the three pictures on *Slide 2*. All of these are x-ray images, but one is a medical picture of bones, and the others are scatter patterns from molecules. The first image is Photo 51, Rosalind Franklin's photograph of DNA. Scientists use a bit of maths and a bit of guesswork to turn scatter patterns into pictures of molecules. Can you see the patterns?

Photo 51: https://en.wikipedia.org/wiki/File:Photo_51_x-ray_diffraction_image.jpg
First medical x-ray: https://commons.wikimedia.org/wiki/File:First_medical_X-ray_by_Wilhelm_R%C3%B6ntgen_of_his_wife_Anna_Bertha_Ludwig%27s_hand_-_18951222.jpg
Protein scattering pattern: https://en.wikipedia.org/wiki/X-ray_scattering_techniques#/media/File:X-ray_diffraction_pattern_3clpro.jpg

Ask:

- Why might it be important for scientists to find out the structures of molecules like penicillin, insulin, and vitamin B12?

Dorothy Hodgkin's story *[See Photos on Slide 3]*
Listen to the story about Dorothy Hodgkin, make a timeline of her life, draw her in her laboratory, create a costume, or build a piece of her equipment.

Dorothy's story began in Egypt in May 1910, where her father was working for the Ministry of Education and her mother was a midwife campaigning for better medicine for local women. Dorothy admired her mother, both as a scientist and as a warrior for equality. But Dorothy did not live this exotic life with her parents for long: aged four, she and her sisters were brought up by their grandparents, their parents visiting in the summer.

Just one of two girls "allowed" to study chemistry at Sir John Leman Grammar state school, Dorothy was determined to apply to Oxford University. But to go, she had to pass a test including Latin… and Dorothy knew no Latin whatsoever! Undaunted, she took up Latin in her spare time with the help of her headmaster and, in an exhausting feat, mastered it for the test a few months later!

That summer, Dorothy took a much needed break, and visited her parents at an archaeological site abroad, where she sketched the mosaics from 5th century Byzantine churches. This was her first introduction to the beauty and maths of patterns that would be so important for the rest of her life.

After becoming the third woman ever to obtain a First from Oxford, Dorothy went to Cambridge to study for a doctorate (PhD). Her supervisor, John Desmond Bernal, nicknamed "Sage", introduced her to how atoms in crystals scatter x-rays, and she began drawing molecules from x-ray patterns. Perhaps because of her mother, it was **biomolecules** that excited Dorothy most. These were very hard to make intro crystals and involved moving tiny crystals with tweezers under a microscope – tough and detailed work! Dorothy found this delicate work particularly challenging because she was getting pain in her hands. After a visit to her doctor, she found that, aged 24, she had crippling rheumatoid arthritis, which was only going to get worse!

After marrying and returning to Oxford, Dorothy worked with a biochemist, Barbara Low, to solve the structure of penicillin, refuting scientific opinion. To show everyone the true structure, Dorothy built her most famous piece of art: a 3D model made using layers of Perspex. At the same time, she had 3 children, and became the first woman to draw maternity pay from Oxford University!

She then tried to solve the structure of insulin, but x-rays couldn't picture enough detail, so she solved vitamin B12 instead, an achievement described as "breaking the sound barrier" in chemistry!

In 1964, she was awarded the Nobel Prize in Chemistry, the only British woman to ever win one in science! It wasn't her only prize: she also won a Lenin Peace Prize. Like her mother, Dorothy cared about social justice, and protested against nuclear weapons.

However, for Dorothy, the greatest achievement came five years later, when better x-ray and computing techniques allowed her to photograph insulin: now severely crippled with arthritis, Dorothy solved the structure 35 years later.

In 1994, she died of a stroke.

MAIN TASK – Make a cardboard ball (or half ball)

Ask:

- What is a sphere? What is a spheroid?
- How can we build a ball from layers of cardboard?

Teachers with limited time or resources may wish to have their class or groups within the class make only a half sphere/spheroid.

Method

You are going to build a sphere out of pieces of corrugated cardboard, by gluing them on top of each other. This task involves working together **as a group** and making sure everybody has a job to do. It is your mission to assign jobs so everybody is equally valuable. For example, one person might do the calculations, one might draw the circles, and a different person might cut out each circle and glue it to the tower.

See Slide 4

1. To begin, read through all the instructions. Make a plan showing everybody's role, and draw a picture of the planned product.

2. Using your protractor, ruler and pencil, draw a circle that is 10 cm in diameter on the cardboard. Carefully cut it out. This is your middle circle. You will need to make two of every other circle, gluing one above and one below your middle circle, like building a sandwich outwards from the filling.

3. First, you will need to make some decisions:

- How many circles will you make?

*If you make too many or too few circles, you might end up with a **spheroid** overall, not a **sphere**. Scientists call the number of circles used **resolution**. You might have to use **trial and error** to get your **resolution** right.*

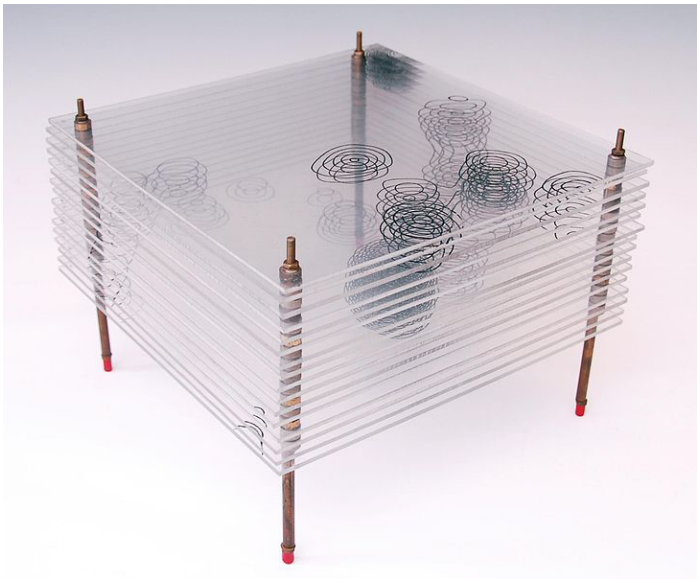
- How big will your smallest circle be?

You could keep going infinitely, but this lesson is finite, so you will have to compromise. ~1 cm in diameter is a good small circle size.

Wrap up

Ask:

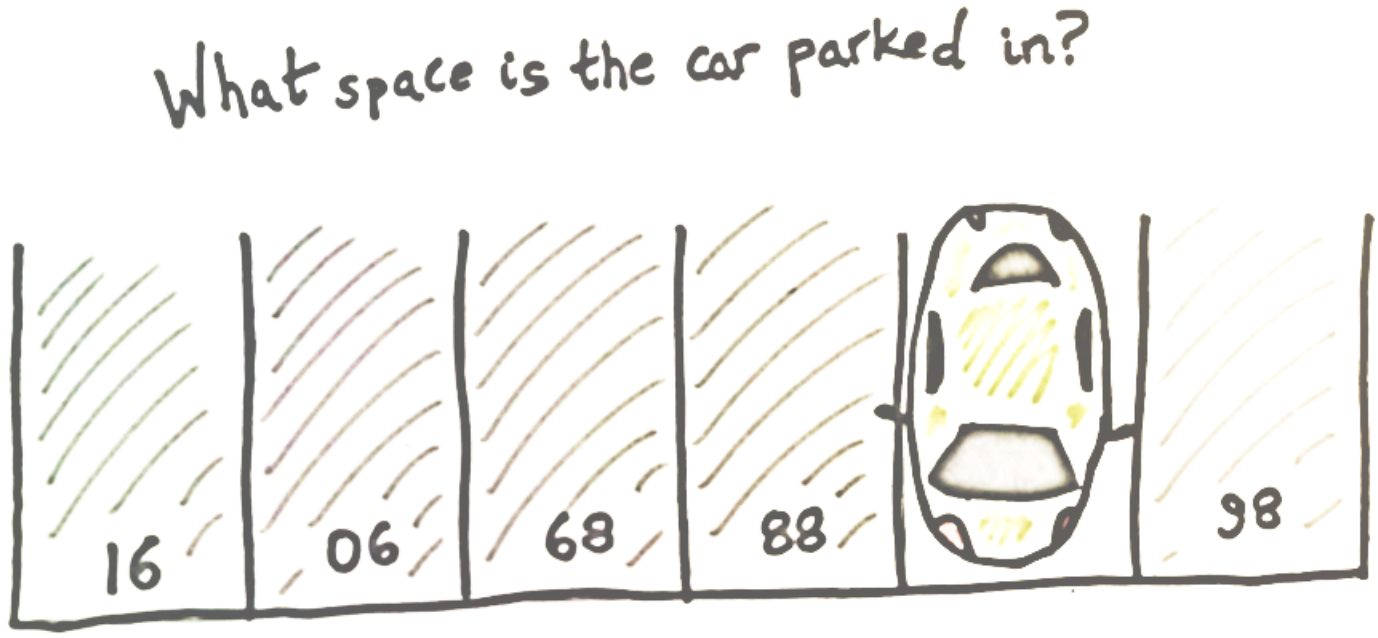
- When you have completed your whole or half sphere/spheroid, compare it to Dorothy Hodgkin's penicillin model. *See Slide 5*. Do you have a map? You can also compare it to the contour lines on a map. What similarities and differences do you notice?



Dorothy Hodgkin's penicillin model:
https://en.wikipedia.org/wiki/File:Model_of_the_Structure_of_Penicillin,_by_Dorothy_Hodgkin,_Oxford,_c.1945.jpeg

EXTENSION ACTIVITY – puzzle solving

Crystallographers work out atomic positions using a bit of a maths and a bit of guesswork to transform their x-ray map into a 3D picture of the atoms. Visual puzzles are often very different from other kinds of puzzles. Like this one, for instance on *Slide 6*. Can you solve it?



Answer – 87 (the picture is upside down)

REVIEW

ALL: Can recall that x-rays are used to picture things too small to see with light and that biomolecules are important for human health. Can tell part of Dorothy Hodgkin's story of discovery.
MOST: Can identify that knowing the structures of biomolecules helps us identify them or make them. Can identify that x-ray images need decoding.
SOME: Can link the pattern produced by x-ray imaging to a visual code.