Lesson Plan 3: Vaccine Development Pipeline

AQA Links:

4.3.1.7 Vaccination

4.3.1.9 Discovery and development of drugs

Learning Outcomes:

1) Understand the key steps involved in developing a vaccine.

2) Identify different careers associated with the development pipeline.

3) Explain how scientific research helps solve real-world problems and improve public health.

Materials Needed:

- Whiteboards and pens
- Printer
- Powerpoint presentation and screen
- Notepad and pens

Introduction:

Starter Discussion: Recap of what was learnt in previous lessons

- What is immune memory? *Immune memory is when your body remembers a germ it has fought before so it can respond faster next time.*
- How does your body 'remember' a germ it has seen before? *Your body keeps special memory cells that recognise the germ if it comes back.*
- Why is immune memory useful? *It helps protect you from getting the same illness again by fighting it off more quickly.*

Introduce natural vs artificial immunity:

Natural immunity – happens when your body fights off an infection on its own. **Artificial immunity**: Happens when your immune system is trained using a vaccine.

Optional short activity:

List several scenarios on the board and get students to write on whiteboards whether these are examples of natural or artificial immunity.

Example scenarios:

- You catch chickenpox from a friend and don't get it again *(Natural)*
- You get the HPV vaccine at school *(Artificial)*
- Your body fights off a cold without any medicine *(Natural)*
- You had COVID-19 once and now you have some protection *(Natural)*
- You receive a travel vaccine before going abroad *(Artificial)*

Bridge to lesson theme: how scientists and healthcare workers create vaccines that help the body build artificial immunity. The lesson will trace with students how a vaccine is made, from the lab to the real world, highlighting the people and processes that make it possible. Optional: Show British Society for Immunology video: https://www.youtube.com/watch?v=hjTQN2b-fuo

Activity 1: Vaccine Pipeline (LO1)

Objective: Students will understand the steps of vaccine development by exploring each stage of the vaccine pipeline.

Instructions: Randomly place the vaccine pipeline posters (included in this pack) around the room, and ask students to walk around and take notes from each poster on their worksheets. Or, print out enough posters so that each table can be given them all in an envelope.

Then, give each table the shuffled pipeline cards and ask them to individually or in groups arrange the stages of the pipeline in the correct sequence. After putting the cards in the correct sequence, ask students to make a flowchart with 2 bullet points for each step. They should then check their flowcharts with their peers and add any additional bullet points that they had not originally included.

Materials Needed: Please refer to the Vaccine Pipeline posters and cards within the pack.

Answer: Discovery > Pre-clinical tests > Clinical Trials > Regulatory Approval > Production and Distribution > Quality Control

Activity 2: Career spotlight (LO2 + LO3)

Objective: Explore the diversity of careers in science and healthcare

Materials Needed: Please refer to the Career Spotlight cards within the pack.

Instructions: Print out the career cards representing a different job involved in the vaccine pipeline. Each student receives one of these career identities and a bingo sheet.

Instructions for students:

1) Keep your career identity secret.

2) Walk around the room and ask classmates questions to figure out what they do.

3) Try to match their career to a clue on your Bingo sheet (e.g. “Do you write safety reports?” or “Do you test vaccines in the lab?”).

4) When you find someone who fits a clue, write their name and job in that box. Some jobs may have multiple bingo box options, but only add one box per person. You can play it so that the fastest student wins, and then keep playing until every student has filled out their bingo card.

Reflection Task:

Ask students to write down on their worksheet another example of a disease, beyond covid, where science research helped human health. Ask students to highlight what they found most interesting about this example.

Some examples to share:

- Penicillin (Bacterial Infections). How research helped: Alexander Fleming’s discovery of penicillin led to antibiotics, saving countless lives from infections that were once deadly. What might interest students: That it was discovered by accident from a mould — showing how mistakes can lead to breakthroughs.

- Smallpox. How research helped: The world’s first vaccine (developed by Edward Jenner) led to smallpox being completely wiped out. What might interest students: That this is the only human disease ever fully eradicated — thanks to science!

Plenary: Quick Quiz

Quiz questions (on whiteboards):

- Is a vaccine natural or artificial immunity? *A vaccine gives **artificial** immunity because it is made and given to you on purpose to protect against disease.*
- What is the main goal of a vaccine? *The main goal of a vaccine is to train your immune system to recognise and fight a specific disease without making you seriously ill.*
- Who decides whether a vaccine is safe enough to be used in the public? *Government health agencies like the MHRA (in the UK) or FDA (in the US) decide if a vaccine is safe and effective for public use.*
- Why might vaccines need a booster shot? *Booster shots are needed when immunity weakens over time or to improve protection against new versions of a virus.*

Summary

Students write a sentence about what job they might like and why, based on today's lesson.

Lesson 3, Activity 2 resource—Career Spotlight Bingo Card

Someone who works in a lab	Someone who works with patients	Someone who checks medicine quality
Someone who needs a university degree		Someone who writes safety reports
Someone who teaches the public	Someone who works in a factory	Someone who explains science to others

Thanks for the Memories

DISCOVERY

Scientists need to understand the disease:

- What type of disease is it?
- Who does this disease affect?
- What are the symptoms of this disease?

Scientists need to find what type of pathogen might be causing the disease and find a target for the vaccine

- Is it a viral disease?
- Is it a bacterial disease?
- Is it a parasitic disease?

Scientists do experiments and collect data to identify vaccine targets, then show they can lead to an effective vaccine . They use techniques like:

- Microscopy
- Tissue culture
- Cell culture

Thanks for the Memories

PRE-CLINICAL TESTS

In vitro testing:

The vaccine is tested on lab-grown cells

In vivo testing:

The vaccines is tested on animals

Important to know:

- The UK is using a '3 R's' approach to animal use - Reduce, Refine, Replace
- This means scientists are currently moving to more *In silico* testing - the use of machine-learning to model how a drug will work

Researchers are checking:

- **Vaccine safety**: what possible side effects does the vaccine produce?
- **Effectiveness**: how effective is the vaccine at creating an immune response?
- **Dosage**: what is the safe amount to test on people?

Thanks for the Memories

CLINICAL TRIALS

Clinical trials test the vaccine on people in three phases:

Phase 1:

Participants: A small group of healthy volunteers.
Aim: To test vaccine safety.
Type of trial: Open trial. One group are given the real vaccine and the other group are given a placebo - a 'dummy' treatment with no medical or therapeutic value. An open trail means that everyone knows who gets the vaccine and who get a placebo.

Researchers are checking vaccine safety

Phase 2:

Participants: A larger group of volunteers, including the target group.
Aims: To check for side effects and immune response.
Type of trial: Randomised and controlled trial. Like in Phase 1, one group are given the real vaccine and the other group are given a placebo. These participants are split into these groups entirely at random, in order to reduce bias.

Researchers are checking vaccine safety, effectiveness, dosage and the best ways to administer the vaccine

Phase 3:

Participants: Thousands of people.
Aim: To test if the vaccine really prevents disease.
Type of trial: Randomised and double-blind trail. Like in Phase 2, participants are given the vaccine or placebo at random. Here, neither participants nor researchers know who gets the real vaccine or placebo - this makes the trial double-blind.

Researchers are checking vaccine safety

Thanks for the Memories

REGULATORY APPROVAL

Government agencies, like the MHRA in the UK or the FDA in the USA, review the data from the clinical trials and decide if the vaccines can be used.

If approved, the vaccine can be made available to the public.

What questions do government agencies ask?

- Is the vaccine better than other vaccines that are currently on the market?
- What are the side effects of the vaccine?
- What age group is the vaccine for?

Thanks for the Memories

PRODUCTION AND DISTRIBUTION

2+ YEARS

The vaccine is made in large quantities, requiring the cooperation of different sites and manufacturers across the world. For example, this is how a Pfizer–BioNTech COVID-19 vaccine - that you or your family member may have received during the pandemic - is produced and distributed:

1 Missouri, USA. Scientists make DNA instructions for the spike protein inside bacteria, then purify and freeze the DNA ready for transporation.

2 BioNTech plants, Germany. The DNA is used as a template to make mRNA strands, which are then cleaned, frozen in large bags holding millions of doses, and sent out by truck.

3 Belgium. Here, mRNA is mixed with fats to protect it, put into vials, boxed, frozen, and then kept in deep storage for weeks while passing strict quality checks.

4 The vaccine is delivered across the UK - to GP surgeries, community centres, and schools.

Thanks for the Memories

QUALITY CONTROL

Every batch of vaccines are tested for quality. Scientists make sure vaccines are

- safe
- effective and
- uncontaminated

before they are sent out for use.

Quality Control Scientists are checking:

- Does the vaccine produce any rare side effects?
  - **Action:** Possible symptoms will be added to the vaccine side effects warnings
- Is every vaccine produced to the same levels of safety and effectiveness?
  - **Action:** Scientists test each batch from the manufacturing site
- Are the people administering the vaccines qualified?
  - **Action:** Nurses and practitioners are fully trained for vaccinating. During the covid-19 pandemic, members of the public could even be trained as volunteer vaccinators to help speed up the rollout of the COVID-19 vaccine

Lesson 3, Activity 1 - Vaccine pipeline cards

CLINICAL TRIALS

PRODUCTION AND DISTRIBUTION

PRE-CLINICAL TESTS

DISCOVERY

QUALITY CONTROL

REGULATORY APPROVAL

IMMUNOLOGIST

What do they do?

Study how the immune system protects the body from illness, how vaccines work, and find new ways to prevent or treat diseases

Where do they work?

- Universities
- Hospitals
- Government labs
- Pharmaceutical companies

Key skills

- Biology
- Problem-solving
- Research skills

Vaccine pipeline stage

Discovery and Pre-Clinical Testing

Pathway

A Levels:
Biology and at least one other Science or Maths

↓

Undergraduate degree:
Biology or Biomedical Sciences

↓

PhD/Masters

↓

Research jobs

Scan the QR code for more info on this pathway!

Thanks for the Memories

PHARMACOLOGIST

What do they do?

Investigate how medicines affect the body and help to design new drugs

Josh

Where do they work?

- Pharmaceutical and biotech companies
- Universities

Key skills

- Chemistry
- Attention to detail
- Teamwork

Vaccine pipeline stage

Discovery and Pre-Clinical Testing

Pathway

A Levels:
Two Science subjects or one Science and Maths

↓

Undergraduate degree:
Pharmacology
or a Pharmacology postgraduate degree after studying a related subject like Physiology/Biomedical Sciences/Biochemistry

↓

Scan the QR code for more info on this pathway!

Lab jobs

NURSE

What do they do?

Provide care for patients and administer vaccinations

Tom

Where do they work?

- Hospitals
- Clinics
- Community Centres

Key skills

- Compassion
- Clear communication
- Organisation

Vaccine pipeline stage

Clinical trials

Pathway

A Levels:
At least one Science or Science related subject (such as Sociology, Psychology, or Health and Social Care). Some Universities will also accept BTEC diplomas in a Science or Science related subject or an Access to HE Nursing course

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Undergraduate degree: Nursing, or a Nursing apprenticeship

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Nursing job in NHS or private sector

Scan the QR code for more info on this pathway!

REGULATORY AFFAIRS SPECIALIST

What do they do?

Make sure vaccines and medicines meet all safety laws before being made available for public use

Chloe

Where do they work?

- Government bodies
- Pharmaceutical companies

Key skills

- Understanding guidelines
- Attention to detail
- Written communication

Vaccine pipeline stage

Regulatory approval

Pathway

A Levels:
Two Science A Levels or one science and Maths

↓

Undergraduate degree:
Biology, Chemistry, related subjects like Biochemistry, Biomedical Science, or Pharmacology, applied subjects such as Engineering, or Medicine

↓

On-the-job training, or a Masters degree or Regulatory Affairs apprenticeship

Scan the QR code for more info on this pathway!

MANUFACTURING TECHNICIAN

What do they do?

Help produce vaccines in clean and controlled settings

Elena

Where do they work?

- Pharmaceutical factories
- Production labs

Key skills

- Technical knowledge
- Accuracy
- Reliability

Vaccine pipeline stage

Production

Pathway

No A Levels required - 3 GCSEs required above a 4 including English, Maths and a Science

Science Manufacturing Technician Apprenticeship, which might include opportunity to study for additional Diplomas, or on-the-job training in manufacturing/biotech

Scan the QR code for more info on this pathway!

PUBLIC HEALTH EDUCATOR

What do they do?

Teach the public about vaccines and how to stay healthy

Carlos

Where do they work?

- NHS
- Charities
- Councils
- Schools

Key skills

- Communication
- Creativity
- Confidence

Vaccine pipeline stage

Regulatory, Production, Quality Control

Pathway

A Levels:
At least one Science or Maths

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Undergraduate degree: Public Health/Health Science, Public Health Practitioner Apprenticeship, or on-the-job training

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On-the-job training or Masters degree in Public Health

Scan the QR code for more info on this pathway!

CLINICAL RESEARCH ASSOCIATE

What do they do?

Organise and monitor vaccine trials, making sure that they run correctly

Amina

Where do they work?

- Research companies
- NHS trial units

Key skills

- Organisation
- Understanding guidelines
- Time management

Vaccine pipeline stage

Clinical trials

Pathway

A Levels:
Two Science subjects or one Science and Maths

↓

Undergraduate degree:
Any STEM subject

↓

Clinical research training and on-the-job training

Scan the QR code for more info on this pathway!

QUALITY CONTROL SCIENTIST

What do they do?

Test vaccines during and after production to ensure safety and quality

Liam

Where do they work?

- Pharmaceutical labs
- Vaccine production centres
- NHS

Key skills

- Organisation
- Attention to detail
- Communication

Vaccine pipeline stage

Quality Control

Pathway

A Levels:
Two Science subjects or one Science and Maths

↓

Undergraduate degree:
Science subject like Chemistry or Pharmacy

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On-the-job training or Masters degree in Pharmacy Technology and Quality Assurance

Scan the QR code for more info on this pathway!

Vaccine Development Pipeline

Learning Outcomes:

1. Understand the key steps involved in developing a vaccine
2. Identify different careers associated with the development pipeline
3. Explain how scientific research helps solve real-world problems and improve public health

Lesson Key Words:

Immune System - the body's defence against entry of any foreign body, including pathogens. Its role is to prevent disease

Memory Cell - a lymphocyte (B-cell or T-cell) that remains in the bloodstream after an infection, allowing the immune system to respond faster and more effectively if the same pathogen invades again

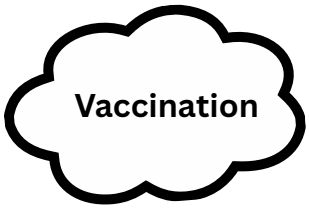
Natural Immunity - when the body is activated and produces the antibodies needed to fight an infection

Artificial Immunity - when ready-made antibodies, from another source, are introduced to the body

Vaccine - substances containing dead or altered form of the disease-causing pathogen antigens, to stimulate the body to produce antibodies to provide immunity against that disease

Video

While watching the video, mind-map 3 key points about vaccination:

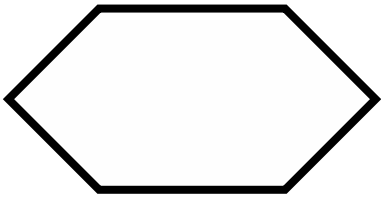


Lesson created by Holly Sedgwick, University of Manchester, Olivia Shorthouse, University of Manchester and Rachel Hindmarsh, University of Oxford
as part of the *Thanks for the Memories* Public Engagement Project

Vaccine Development Pipeline

Activity 1

What is the correct sequence of the vaccine pipeline? Fill in this flow chart with 2 bullet points describing each step.



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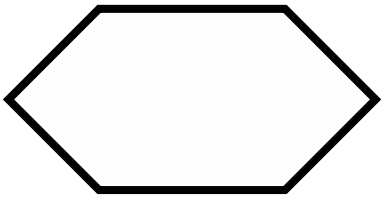

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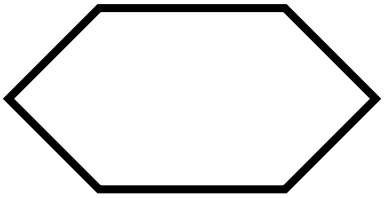

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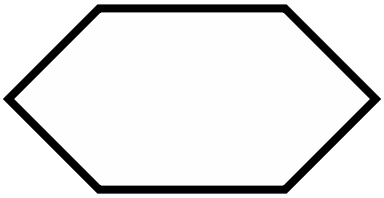

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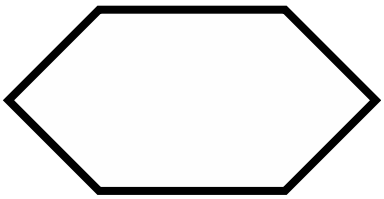

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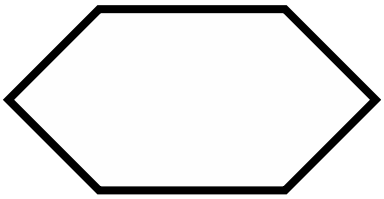

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Vaccine Development Pipeline

Activity 2

Write down another example of a disease where scientific research helped human health. Explain what you find most interesting about this example.

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Reflection

1. Write down which job explored in today's lesson you might like, and why.

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2. And one question you still have!

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