Uses of monoclonal antibodies

4.3.2.2 · Infection and response · revision notes

How the specificity of monoclonal antibodies is used in pregnancy tests, laboratory tests, research and cancer treatment, and their advantages and disadvantages. GCSE Biology only and Higher tier only; the pregnancy test and cancer treatment are the favourite contexts, including 6-mark 'evaluate' questions.

Key facts

- Uses: diagnosis (pregnancy tests), measuring hormones and chemicals in blood, detecting pathogens, locating molecules in research, treating cancer
- Test line: fixed antibodies bind hCG. Control line: fixed antibodies bind the mobile antibodies
- Cancer: antibody + radioactive substance, toxic drug or chemical that stops cell division
- Drawback: more side effects than expected; not yet as widely used as hoped
- Pregnancy tests detect the hormone hCG in urine
- Research: antibody + fluorescent dye shows where a specific molecule is
- Delivers the substance to cancer cells without harming other cells

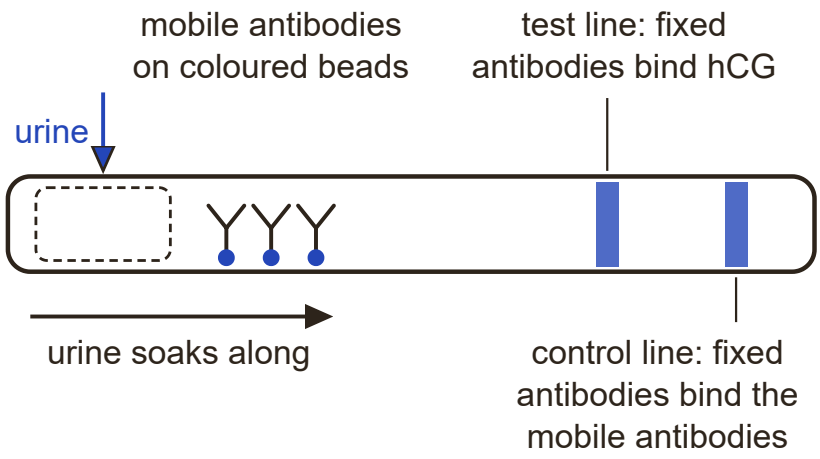
Notes

Why they are useful

- Each monoclonal antibody binds to only one specific antigen, so it can find one particular chemical, pathogen or type of cell among many others. Its binding site is complementary in shape to that antigen.

Diagnosis: pregnancy tests

- The urine of a pregnant woman contains the hormone **hCG**.
- Urine is added to one end of the test stick and moves along it. It picks up **mobile** monoclonal antibodies attached to coloured beads, which bind to any hCG.
- At the **test line**, antibodies fixed to the stick bind to hCG. If hCG is present, the hCG with its bead-carrying antibodies is held there and a coloured line appears: the woman is pregnant.
- At the **control line**, fixed antibodies bind to the mobile antibodies themselves, so a line appears whenever the test is working.



Two lines: pregnant (hCG present).
Control line only: not pregnant.

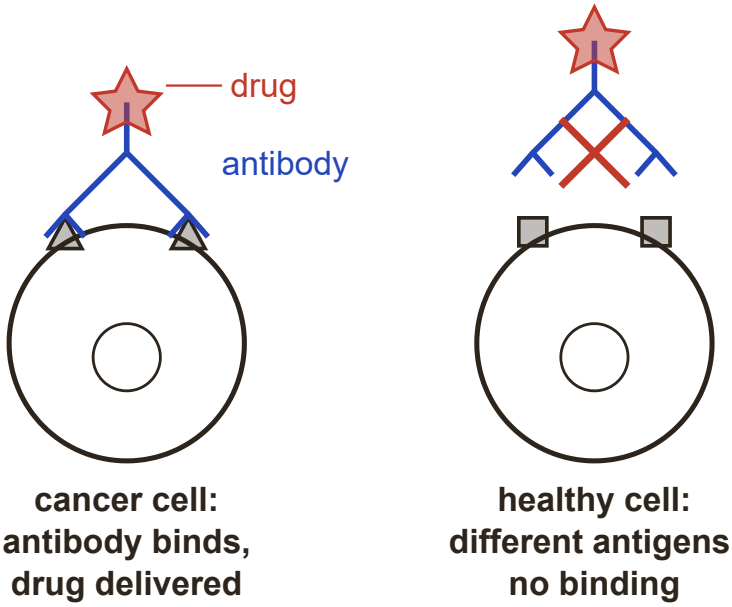
A positive test: coloured lines at both the test line and the control line.

Laboratories and research

- Measuring the levels of **hormones** and other chemicals in **blood**.
- Detecting **pathogens**, e.g. in blood samples or in diseased plants.
- Locating or identifying **specific molecules** in a cell or tissue: the antibodies are attached to a **fluorescent dye**, so the place where they bind can be seen.

Treating cancer

- A monoclonal antibody that binds to an antigen on cancer cells is attached to a **radioactive substance**, a **toxic drug** or a **chemical that stops cells growing and dividing**.
- It delivers the substance to the **cancer cells** without harming other cells in the body.



The antibody carries the drug only to cells with the matching antigen.

- Standard chemotherapy drugs, by contrast, reach and harm healthy cells as well.

Advantages and disadvantages

- Advantages: they are very specific, so they bind only to their target; in cancer treatment fewer healthy cells are harmed.
- Disadvantages: they cause **more side effects than expected**, so they are not yet as widely used as everybody hoped when they were first developed. They are also expensive to develop, and mice are used to produce them.

How to answer each type of question

Explain how a pregnancy test works

3 to 4 marks | **Grade 6**

1. Say that hCG in the urine binds to the mobile antibodies (with coloured beads).
2. Say that the fixed antibodies at the test line bind to hCG, so the beads collect and form a line.
3. Say that the fixed antibodies at the control line bind to the mobile antibodies, showing the test has worked.

Example. Explain why a coloured line appears at the test line of a pregnancy test when a woman is pregnant, and why a line appears at the control line whether or not she is pregnant.

Model answer. hCG in the urine binds to the mobile antibodies, which are attached to coloured beads (1). The urine carries them along to the test line, where fixed antibodies bind to the hCG (1), so the beads are held there and a coloured line forms (1). At the control line, fixed antibodies bind to the mobile antibodies themselves, so a line forms whenever the test is working (1).

Explain how monoclonal antibodies are used to treat cancer

3 marks | **Grade 7**

1. Say that the antibody is specific to an antigen on the cancer cells.
2. Say what it carries: a radioactive substance, toxic drug or chemical that stops cell division.
3. Say why healthy cells are not harmed: they do not have the antigen.

Example. Explain how a monoclonal antibody attached to a toxic drug can kill cancer cells while causing less harm to healthy cells than standard chemotherapy.

Model answer. The monoclonal antibody binds only to a specific antigen on the cancer cells (1). So the toxic drug is carried to the cancer cells (1). Healthy cells do not have this antigen, so the antibody does not bind to them and they are not harmed, whereas standard chemotherapy drugs reach all cells (1).

Suggest how to locate a molecule in research

2 marks | **Grade 7**

1. Attach a fluorescent dye to a monoclonal antibody specific to the molecule.
2. The antibody binds only to that molecule, so the dye shows where it is.

Example. Scientists want to find out where a particular protein is found in a sample of plant tissue. Suggest how they could use monoclonal antibodies to do this.

Model answer. Attach a fluorescent dye to monoclonal antibodies that bind only to that protein (1). Add them to the tissue: the antibodies bind to the protein, so the dye shows where the protein is when the tissue is viewed with a microscope (1).

6-mark: evaluate the use of monoclonal antibodies

6 marks | Grade 8

1. Give advantages, linked to specificity.
2. Give disadvantages: more side effects than expected, cost, use of mice, a specific antibody needed for each target.
3. Finish with a judgement that follows from the points you have made.

Example. Evaluate the use of monoclonal antibodies to treat cancer. (6 marks)

Model answer.

For: the antibody binds only to an antigen on the cancer cells, so the radioactive substance, toxic drug or chemical is delivered to them. Fewer healthy cells are harmed than with standard chemotherapy, so some side effects may be reduced. Against: monoclonal antibodies have caused more side effects than expected. A specific antibody has to be made for each antigen, they are expensive to produce, and mice are used to make them. Conclusion: they are a useful, targeted treatment for some cancers, but they are not yet as widely used as was hoped.
Level 3 (5 to 6 marks) needs advantages AND disadvantages and a justified conclusion.
Advantages only would be Level 1 or 2.

Don't lose marks

- Forgetting to say what the antibody carries in cancer treatment: a radioactive substance, a toxic drug or a chemical that stops cells growing and dividing.
- Saying the control line shows that the woman is not pregnant. It only shows that the test has worked.
- Saying the pregnancy test detects the baby, or a hormone in blood. It detects hCG in urine.
- Giving only advantages in an 'evaluate' question. You need both sides and a conclusion.
- Saying monoclonal antibodies have no side effects. They have caused more side effects than expected.
- Saying the antibody is the 'same shape' as the antigen. It is complementary in shape to the antigen.

More tips

Memory tricks

- Four uses: diagnose (pregnancy tests), measure and detect (labs), locate (research), treat (cancer).
- Pregnancy test: the test line asks 'is hCG here?'; the control line asks 'did the test work?'.
- Cancer treatment: the antibody is the guided missile; the radioactive substance, drug or chemical is the payload.

Exam technique

- For every use, link back to specificity: the antibody binds only to one antigen.
- In pregnancy test questions, say where each antibody is (mobile or fixed) and what it binds to.
- In 6-mark 'evaluate' answers, give advantages and disadvantages, then a judgement that follows from them.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 5

List four uses of monoclonal antibodies

Diagnosis (e.g. pregnancy tests), laboratory tests on blood, locating molecules in research, and treating diseases such as cancer.

Grade 6

Explain how a pregnancy test works

Antibodies bind to the hormone hCG in urine, so coloured beads collect at the test line only if hCG is present.

Grade 6

Explain the control line in a pregnancy test

Fixed antibodies there bind to the mobile antibodies, so a line shows that the test has worked.

Grade 7

Explain how they are used to treat cancer

The antibody binds only to cancer cells, delivering a radioactive substance, toxic drug or chemical that stops cell division.

Grade 7

Explain their use in research with dyes

An antibody attached to a fluorescent dye binds to a specific molecule, showing where it is in a cell or tissue.

Grade 8

Evaluate the use of monoclonal antibodies

Weigh their specificity and reduced harm to healthy cells against unexpected side effects, cost and the use of mice.

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