17.4.1 Pedigrees, test crosses, blood groups and sex linkage

Name: _____ Class: _____ Date: _____ **Total: 37 marks**

KEY WORDS genotype 基因型 • dominant 显性 • pedigree diagram 系谱图 • inheritance 遗传 • recessive 隐性

Objective

Sheet 17.4 gave you the words and one cross. This sheet is the rest of 17.4, and it is the part the exam spends most of its marks on: reading a **pedigree diagram** 系谱图, using a **test cross** 测交, **codominance** 共显性 and the ABO **blood groups** 血型, and **sex linkage** 伴性遗传. Every one of these is answered by writing out a genetic diagram in full, so this sheet trains the layout as well as the biology. This sheet covers syllabus 17.4.

You must be able to:

- describe **inheritance** 遗传 as the passing of genetic information from generation to generation
- use **genotype** 基因型, **phenotype** 表现型, **homozygous** 纯合子, **heterozygous** 杂合子, **dominant** 显性 and **recessive** 隐性 correctly, and state which of them breeds true
- interpret pedigree diagrams for the inheritance of a given characteristic
- use genetic diagrams and **Punnett squares** 庞纳特方格 to predict the results of monohybrid crosses, and calculate 1:1 and 3:1 **ratios** 比例
- explain how to use a test cross to identify an unknown genotype
- describe codominance, and explain the inheritance of the ABO blood groups with the alleles I^A, I^B and I^o
- describe a sex-linked characteristic, and red-green **colour blindness** 色盲 as the example
- use genetic diagrams for crosses involving codominance or sex linkage

1 Worked examples

Study these first. Each one shows a **method** that a question later on this sheet needs.

The six words, and the two that decide everything

word	what it means	how it is written
genotype	the **alleles** 等位基因 an organism has	BB, Bb or bb
phenotype	the feature you can **see**	black fur, blue eyes
homozygous	two **identical** alleles; this organism is **pure-breeding** 纯种	BB or bb
heterozygous	two **different** alleles; **not** pure-breeding	Bb
dominant	shows even with **one** copy	capital letter, B
recessive	shows only with **two** copies	small letter, b

- A **recessive phenotype pins the genotype exactly**: a white rabbit can only be bb. Always start a question from the recessive individual and work outwards. This one habit answers most of the marks on this subtopic.
- Choose one letter for the gene and say what it stands for before you use it: *"B = black fur, b = white fur"*. An answer using two different letters for the same gene loses the diagram mark.

The layout a genetic diagram must have

parents: Bb × bb

gametes: B or b and b or b

1 parent genotypes
2 gametes, one allele each
3 fill the grid
4 read the genotypes
5 give the ratio

	B	b
b	Bb	bb
b	Bb	bb

2 Bb and 2 bb, so **1 black : 1 white**, a **1:1** ratio

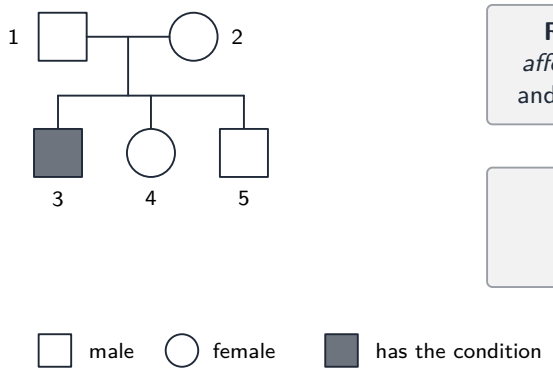
Bb × Bb gives **3:1**. Bb × bb gives **1:1**. Those are the only two ratios this syllabus asks for, so if you get a third one, check the gametes.

Five steps, and every one of them is a marking point:

1. write both **parent genotypes**;
2. write the **gametes** 配子 – each gamete carries **one** allele of the gene;
3. fill the **grid**;
4. read off the offspring **genotypes**;
5. turn them into a **phenotype ratio**.

- Only two ratios are examined: Bb × Bb gives **3:1**, and Bb × bb gives **1:1**.
- A ratio is a prediction about *large numbers*. The **probability** 概率 for one individual offspring is the same every time, so three black rabbits in a row do not make the fourth one white.

Reading a pedigree



Rule 1 Two *unaffected* parents with an *affected* child means the allele is **recessive**, and both parents are **heterozygous** carriers.

Rule 2 If every affected person is *male*, suspect **sex linkage**: the gene is on the X chromosome.

Squares are males, circles are females, and a shaded symbol means the person has the condition.

Worked example. Use the diagram above to show that the allele is recessive, and give the genotypes of individuals 1 and 2.

1. Find a **person who has the condition but whose parents do not**. Here that is individual 3.
2. If the allele were dominant, one parent would have to show it – neither does. So the allele is **recessive**, and it was carried, hidden, by both parents.
3. Individual 3 shows the recessive feature, so the genotype is **aa**, with one a from each parent.
4. Both parents show the normal feature, so each also carries an A. Individuals 1 and 2 are both **Aa**.

- Then the probability follows: Aa × Aa gives a $\frac{1}{4}$ chance for each later child.

A test cross finds a hidden heterozygote

An organism showing the **dominant** feature may be BB or Bb, and you cannot tell by looking. Cross it with a **homozygous recessive** (bb) and read the offspring:

what the offspring show	what the unknown parent was
any offspring with the recessive feature	**heterozygous**, Bb – because that offspring needed a b from each parent
all offspring show the dominant feature	very probably **homozygous**, BB

- The recessive parent is chosen because it can only give a b, so every offspring reveals what the other parent gave.

■ Codominance: the ABO blood groups

genotype	blood group
$I^A I^A$ or $I^A I^o$	**A**
$I^B I^B$ or $I^B I^o$	**B**
$I^A I^B$	**AB**
$I^o I^o$	**O**

← **codominance**: both alleles show, so the phenotype is AB and not A or B

I^A and I^B are **codominant** with each other; I^o is **recessive** to both. Those two sentences generate every row above.

In **codominance**, **both** alleles of a heterozygote show in the phenotype – neither one masks the other.

- I^A and I^B are **codominant with each other**; I^o is **recessive** to both.
- So $I^A I^B$ gives group **AB**, in which both features appear. That is the only place codominance is visible.
- Write blood-group alleles with the superscript every time. A bare "A" or "B" is not a genotype.

■ Sex linkage

mother $X^B X^b$ (a carrier) × father $X^B Y$

	X^B	X^b
X^B	$X^B X^B$ girl, normal	$X^B X^b$ girl, carrier
Y	$X^B Y$ boy, normal	$X^b Y$ **boy, colour-blind**

A boy has **one** X, so a single recessive allele on it always shows. A girl needs **two**, which is far rarer – hence "more common in one sex".

Here half the sons are colour-blind and none of the daughters are, although half the daughters are carriers. Always write the chromosomes, never bare letters.

A **sex-linked** characteristic is controlled by a gene on a **sex chromosome** 性染色体, in practice always the X.

- Write the chromosome with the allele on it: X^B, X^b, and a plain Y, which carries no allele of this gene.

- A male is $X^?Y$. He has only **one** X, so a single recessive allele on it **always shows**.
- A female is $X^?X^?$. She needs **two** copies to show the feature, and with only one she is a **carrier** 携带者 with normal vision.
- That is the whole reason red-green colour blindness is far more common in males.

2 Practice

Now use the methods above.

2.1 A pea plant is homozygous for tall stems (T). State its genotype, and explain why it is pure-breeding. [2]

2.2 In cats, short hair (S) is dominant to long hair (s). A heterozygous short-haired cat is crossed with a long-haired cat. Draw a genetic diagram for this cross and give the ratio of the offspring phenotypes. [4]

2.3 A short-haired cat may be SS or Ss. Describe a test cross that would show which it is, and state how you would read the result. [3]

2.4 A man has blood group AB. State his genotype, and explain what codominance means in this case. [3]

2.5 State the genotype of a person with blood group O, and the two possible genotypes of a person with blood group A. [2]

2.6 Explain why red-green colour blindness is more common in boys than in girls. [3]

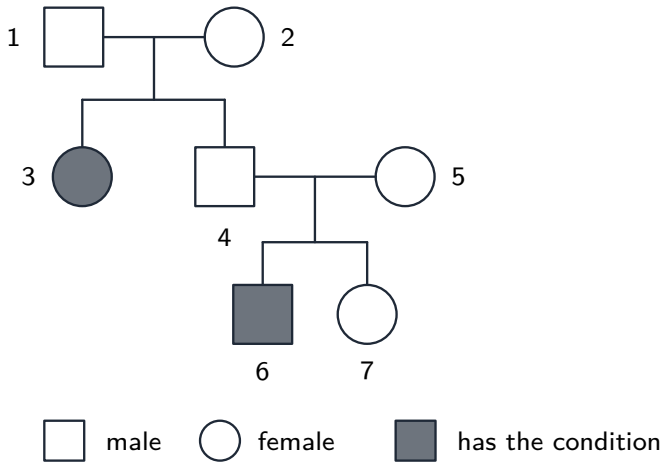
3 Exam-style questions

3.1 A woman of blood group A and a man of blood group B have a child of blood group O. Which row gives the genotypes of the parents? [1]

A	B
C	D

A I^AI^A and I^BI^B
B I^AI^o and I^BI^o
C I^AI^B and I^oI^o
D I^AI^o and I^BI^B

3.2 The pedigree diagram shows how an inherited condition passes through one family.



(a) State whether the allele for the condition is dominant or recessive, and give the evidence from the diagram. [2]

(b) Explain how the diagram shows that the gene is **not** on the X chromosome. [2]

(c) Using the symbols A and a, give the genotypes of individuals 4 and 5, and explain how you worked them out. [2]

(d) Calculate the probability that the next child of individuals 4 and 5 has the condition. [1]

3.3 A woman with normal colour vision has a father who is red-green colour-blind. She marries a man who is red-green colour-blind.

(a) Explain why the woman must be a carrier of the colour-blindness allele. [2]

(b) Draw a genetic diagram for this couple. Show the parents' genotypes, their gametes, and all the possible children with their phenotypes. [4]

(c) State the probability that a daughter of this couple is colour-blind, and the probability that a son is colour-blind. [2]

(d) The couple have three children, none of them colour-blind. State the probability that a fourth child is colour-blind, and explain your answer. [2]

(e) The couple have a daughter with normal colour vision. State her genotype and explain how you know it exactly. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- genotype **TT**
- both alleles are the same, so every gamete carries T and all the offspring of a cross with another TT plant are TT – the feature never changes between generations

2.2

- state the parents: heterozygous short-haired is **Ss**, long-haired is **ss**
- gametes: S or s from the first parent, s or s from the second
- the grid gives **Ss, ss, Ss, ss**
- so **1 short-haired : 1 long-haired**, a **1:1** ratio

2.3

- cross the unknown cat with a **long-haired (ss)** cat
- if **any** kitten has long hair, that kitten is ss, so it received an s from the unknown parent, which must therefore be **Ss**
- if every kitten has short hair, the unknown parent is very probably **SS**

2.4

- genotype $\mathbf{I^AI^B}$
- codominance means **both** alleles are expressed in the phenotype
- neither allele masks the other, so this man's blood has **both** the A and the B features, rather than only one of them

2.5

- group O: $\mathbf{I^oI^o}$
- group A: $\mathbf{I^AI^A}$ or $\mathbf{I^AI^o}$

2.6

- the gene is on the **X chromosome**, and the allele for colour blindness is **recessive**
- a boy is $X^?Y$, with only **one** X, so a single copy of the recessive allele always shows
- a girl is $X^?X^?$ and needs **two** copies; with one copy she is a carrier with normal vision, and two copies are far less likely

3.1 B

- the child is group O, so its genotype is I^oI^o and it received an I^o from **each** parent
- so each parent carries an I^o as well as the allele for their own group: I^AI^o and I^BI^o
- **A** and **D** give no I^o to pass on; **C** gives the wrong blood groups for the parents themselves

3.2

(a)

- the allele is **recessive**
- individuals 1 and 2 do not have the condition, but their daughter 3 does, so the allele must have been carried without showing

(b)

- individual 3 is an **affected female**, so she has the recessive allele on **both** of her X chromosomes, one of them from her father, individual 1
- individual 1 has only one X, so he would then have the condition himself – and he does not, so the gene cannot be on the X chromosome

(c)

- individual 6 has the condition, so he is **aa**, with one a from each parent
- individuals 4 and 5 do not have the condition, so each also carries an A: both are **Aa**

(d)

- Aa × Aa gives AA, Aa, Aa, aa, so the probability is $\frac{1}{4}$, or **25%**

3.3

(a)

- her father is colour-blind, so his genotype is X^bY, and his only X carries X^b
- every daughter receives that X, so she has X^b; she has normal vision, so her other X must carry X^B, making her X^BX^b – a carrier

(b)

- parents: mother X^BX^b, father X^bY
- gametes: X^B or X^b from the mother, X^b or Y from the father
- the grid gives X^BX^b, X^bX^b, X^BY and X^bY
- phenotypes: a **carrier daughter** with normal vision, a **colour-blind daughter**, a **son with normal vision** and a **colour-blind son**

(c)

- a daughter: $\frac{1}{2}$, or **50%**
- a son: $\frac{1}{2}$, or **50%**

(d)

- **50%**, the same as for every other child
- each fertilisation is independent of the ones before it, so the three earlier children do not change the chance

(e)

- $\mathbf{X^BX^b}$, a carrier
- her father is X^bY, so his only X gave her X^b; she has normal vision, so her mother's X must have carried X^B – no other genotype is possible