Genetics Problems

For each of the problems, show the cross involved using the standard problem-solving format. Read each problem carefully, be certain of the information you are given before you start.

Monohybrid Crosses

1. In the pea plant, yellow seed is dominant to green seed. Illustrate the cross between a pure yellow and a pure green plant, through to the F_2 generation.
2. In tomatoes, red fruit colour is dominant over yellow. Pollen from a heterozygous red-fruited plant is placed on the pistil of a yellow-fruited plant. Show the phenotypes and genotypes and the ratios of each fruit colour that might be expected from the seeds produced in the cross. If 100 seeds are produced, how many should be of each type?
3. In human, blue eyes are recessive to brown eyes. If two brown-eyed parents have a blue-eyed child, what are the genotypes of the parents?
4. A blue-eyed man, whose parents were both brown-eyed, married a brown-eyed woman whose mother was blue-eyed. The couple have a blue-eyed son and a brown-eyed daughter. Indicate the genotypes of the grandparents, parents and children. For whom is there uncertainty?
5. The polled (hornless) trait in cattle is dominant; the horned trait is recessive. A certain polled bull is mated to three cows. Cow A, which is horned, gives birth to a polled calf. Cow B, also horned, produces a horned calf. Cow C, which is polled, produces a horned calf. What are the genotypes of the four parents?

Monohybrid Crosses with Incomplete Dominance/Codominance

6. In shorthorn cattle, when a red bull is crossed with a white cow, the offspring are roan (intermingled red and white hairs).
   a) Illustrate this cross and explain what is happening.
   b) Illustrate the following crosses: red x roan, white x roan, roan x roan
7. When two plants with orange flowers were crossed and the resulting seeds were planted they produced 38 orange-flowered, 24 yellow-flowered, and 18 red-flowered plants. Explain and illustrate the cross. What is the expected ratio of offspring?

Dihybrid Crosses

8. In the tomato plant, green stem is recessive to purple stem, and tall plants are dominant over dwarf. If a purple-stemmed dwarf plant is crossed with a green-stemmed tall plant (both parents pure-breeding), what offspring would be expected in the F_1 and F_2 generations?
9. What offspring would you expect if an F_1 plant from the above cross had been bred with a green-stemmed dwarf plant?

10. In pleas, a gene for tall plants is dominant over its allele for short plants. The gene for wrinkled peas is recessive to its allele for smooth peas. Calculate the phenotypic ratio for the following crosses;
    a) Both plants heterozygous for both characteristics
    b) One plant heterozygous for height, homozygous recessive for pea type, and the other plant homozygous recessive for both characteristics.
11. In Four O'clock plants, tall plants are dominant over dwarf, while red and white flower colour show incomplete dominance. Illustrate a cross between a pure-breeding tall red plant, and a dwarf white plant through to the F_2 generation.
12. In the fowl, genotype rrpp gives single com, R_P_ walnut comb, rrP_pea comb, and R_pp rose comb. What comb types will appear in the F_1 and F_2 generation if single-combed birds are crossed with true-breeding walnut-combed birds?

<u>Sex-linked Crosses</u>

13. Colour-blindness is a sex-linked trait in humans. A normal woman, whose father was colour-blind, marries a normal man. What will be the proportion of colour-blind sons and colour-blind daughters? Is it possible for a normal male to be carrying the colour-blind gene? Explain.
14. In humans, hemophilia is a condition in which the blood does not clot normally. It is caused by a sex-linked recessive gene, but occurs only in males because females who are homozygous for the gene die before birth (during the early stages of pregnancy).

If a woman whose father was a hemophiliac marries a hemophiliac man, what ratio of children would the woman be expected to give birth to?

15. The black and yellow pigments on the coats of cats seem to be controlled by a sex-linked pair of genes in such way that the heterozygote is the familiar tortoise-shell or calico. A calico cat has a litter of eight kittens: two yellow males, two black males, two yellow females and two calico females. What is the probable colour of the male mate?

How would you explain the presence of a calico tomcat (male cat)?

<u>Combination Problems</u>

16. In humans, white forelock (a tuft of white hair at the front of the head) is caused by a sex-linked recessive gene. The ability to taste the chemical PTC is caused by a autosomal recessive gene. Illustrate the cross of a non-taster man with normal hair (whose mother was a taster and a carrier of white forelock), and a normal-haired taster woman (whose father had white forelock). Show only the F_1 offspring.
17. A-B-O blood types in humans are caused by 3 alleles of a gene that can occupy one locus (point) on a pair of chromosome. Hemophilia is caused by a sex-linked recessive gene. Illustrate the cross between a hemophiliac Type A man (whose mother had Type O blood), and a carrier woman with Type AB blood. Show only the F_1 offspring.

Monohybrid Crosses

① S → yellow seed
s → green seed

F_1	S	S
s	Ss	Ss
s	Ss	Ss

→ 100 % yellow

F_2	S	s
S	SS	Ss
s	Ss	ss

→ 75 % yellow
25% green

② R → red fruit
r → yellow fruit

F_1	R	r
r	Rr	rr
r	Rr	rr

Genotypes: 50% heterozygous
50% homozygous recessive

Phenotypes: 50% red
50% yellow

0 RR : 2Rr : 2rr

~~0 [illegible]~~2

∴ If 100 seeds were produced, I would expect 50 red fruits and 50 yellow fruits

③ B → brown
b → blue

Bb x Bb

F_1	B	b
B	BB	Bb
b	Bb	bb

→ only blue-eyed possibility from 2 parents with brown eyes ∴ parents must both be heterozygous

brown eyed possibilities: BB, Bb
→ possible crosses:
BB x BB
BB x Bb
Bb x Bb

(4)

Male: Brown x Brown → Blue bb

Female: ? x Blue bb → Brown Bb

couple: Blue bb x Brown Bb → Blue, Brown (bb, Bb)

Parents must both be Bb

→ father must be brown eyed Bb or BB

	B	B
b	Bb	Bb
b	Bb	Bb

or

	B	b
b	Bb	bb
b	Bb	bb

* uncertainty for woman's father as he can be homozygous dominant or heterozygous

(5) H → hornless (polled)

h → horned

1) hh cow A x 2) HH or Hh polled bull → 3) Hh polled calf

4) hh cow B x 6) Hh (must be Hh) polled bull → 5) hh horned calf

9) Hh cow C x 7) Hh polled bull → 8) hh horned calf

∴ cow A is hh, cow B is hh, cow C is Hh, and the polled bull is Hh

Dihybrid Crosses

Pp / PP - purple stem
pp - green stem
Tt / TT - tall
tt - dwarf

8. genotypes PPtt x ppTT

gametes Pt, Pt   pT, pT

	Pt	Pt
pT	PpTt	PpTt
pT	PpTt	PpTt

F_1

Genotype PpTt x PpTt

Gametes PT, Pt, pT, pt
x
PT, Pt, pT, pt

F_2

	PT	Pt	pT	pt
PT	PPTT	PPTt	PpTT	PpTt
Pt	PPTt	PPtt	PpTt	Pptt
pT	PpTT	PpTt	ppTT	ppTt
pt	PpTt	Pptt	ppTt	pptt

9 Purple Tall :
3 Purple dwarf :
3 green tall :
1 green dwarf

9. Genotype - PpTt x pptt

Gametes PT, Pt, pT, pt
x
pt, pt, pt, pt

	PT	Pt	pT	pt
pt	PpTt	Pptt	ppTt	pptt
pt	PpTt	Pptt	ppTt	pptt

phenotype: 2 purple tall, 2 purple dwarf, 2 green tall, 2 green dwarf

T - tall
t - dwarf
R - smooth
r - wrinkled

10. a) Genotype RrTt x RrTt
gametes RT, Rt, rT, rt
x
RT, Rt, rT, rt

- same as #8. F_2

b) Genotype rrTt x rrtt
rT, rt, rT, rt
x
rt, rt, rt, rt

	rT	rt
rt	rrTt	rrtt
rt	rrTt	rrtt

1 tall wrinkled : 1 dwarf wrinkled.

Genotype

11. TTRR x ttrr

Gametes TR, TR x tr, tr

T - tall
t - dwarf
R - red } incomp. domin
r - white

F₁

	TR	TR
tr	TtRr	TtRr
tr	TtRr	TtRr

phenotype - all tall pink

Genotype TtRr x TtRr

Gametes
TR, Tr, tR, tr x TR, Tr, tR, tr

	TR	Tr	tR	tr
TR	TTRR	TTRr	TtRR	TtRr
Tr	TTRr	TTrr	TtRr	Ttrr
tR	TtRR	TtRr	ttRR	ttRr
tr	TtRr	Ttrr	ttRr	ttrr

phenotype 3 tall red : 6 tall pink : 3 tall white : 1 dwarf red : 2 dwarf pink : 1 dwarf white.

12 Genotype rrpp x RRPP

gametes rp, rp
RP, RP

rrpp = single comb
RRPp / RRPP / RrPp / RrPP R-P- = walnut comb
rrPP / rrPp rrP- = pea comb
Rrpp / RRpp R-pp = rose comb.

	rp	rp
RP	RrPp	RrPp
RP	RrPp	RrPp

all walnut comb

Genotypes RrPp x RrPp
Gametes RP, Rp, rP, rp x RP, Rp, rP, rp

	RP	Rp	rP	rp
RP	RRPP	RRPp	RrPP	RrPp
Rp	RRPp	RRpp	RRPp	Rrpp
rP	RrPP	RrPp	rrPP	rrPp
rp	RrPp	Rrpp	rrPp	rrpp

phenotype : 9 walnut comb : 3 pea comb : 3 rose comb : 1 single comb.

sheet #6,7

OR use #1

hybrid Crosses w Incomplete Dominance

RR x rr

↓

	R	R
r	Rr	Rr
r	Rr	Rr

- all roan.

RR - red

rr - white

Rr - roan

- Codominance both alleles expressed at the same time.

RR x Rr

↓

	R	R
R	RR	RR
r	Rr	Rr

1 red : 1 roan.

rr x Rr

↓

	r	r
R	Rr	Rr
r	rr	rr

1 roan : 1 white

Rr x Rr

↓

	R	r
R	RR	Rr
r	Rr	rr

1 red : 2 roan : 1 white

Red - Dominant

Yellow - Ressessive.

Orange = Incomplet Dominance.

7 Rr x Rr

↓

	R	r
R	RR	Rr
r	Rr	rr

RR - red

rr - yellow

Rr - orange.

1 red : 2 orange : 1 yellow.

22% : 48% : 30%

↑ ↑ ↑

$\frac{18 \text{ red}}{80}$: $\frac{38 \text{ orange}}{80}$: $\frac{24 \text{ yellow}}{80}$

Combination Problems (# 16-17)

* dihybrid, sex-linked & autosomal

(16) F → normal hair
f → forelock

T → normal taste
t → PTC

* doesn't matter order of alleles, as long as right pairs are together

mother [tt $X^F X^f$] — father [__ $X^f Y$]

man [Tt $X^F y$] —— woman [tt $X^F X^f$]

Tt $X^F y$ · tt $X^F X^f$

one way: Tt x tt → gametes → T, t x t, t

F_1	T	t
t	Tt	tt
t	Tt	tt

$\frac{2}{4}$ non-taster (heterozygous)
$\frac{2}{4}$ taster

$X^F y$ x $X^F X^f$ → gametes → X^F, y x X^F, X^f

F_1	X^F	y
X^F	$X^F X^F$	$X^F y$
X^f	$X^F X^f$	$X^f y$

Females: $\frac{2}{2}$ normal hair

Males: $\frac{1}{2}$ normal hair, $\frac{1}{2}$ forelock

* look at females & males separately

normal hair, non-taster female: $\frac{2}{2} \cdot \frac{2}{4} = \frac{4}{8} = \frac{1}{2}$ (50%)
normal hair, taster female: $\frac{2}{2} \cdot \frac{2}{4} = \frac{1}{2}$ (50%)

Males
normal hair, non-taster: $\frac{1}{2} \cdot \frac{2}{4} = \frac{2}{8} = \frac{1}{4}$ (25%)
normal hair, taster: $\frac{1}{2} \cdot \frac{2}{4} = \frac{1}{4}$ (25%)
forelock, non-taster: $\frac{1}{2} \cdot \frac{2}{4} = \frac{1}{4}$ (25%)
forelock, taster: $\frac{1}{2} \cdot \frac{2}{4} = \frac{1}{4}$ (25%)

another way:

$Tt X^F Y \cdot tt X^F X^f$

gametes: TX^F, TY, tX^F, tY $\cdot$ tX^F, tX^f, ~~tX^F, tX^f~~

already have 2 of the same, don't need to include all

F_1	TX^F	TY	tX^f	tY
tX^F	TtX^FX^F	TtX^FY	ttX^FX^F	ttX^FY
tX^f	TtX^FX^f	TtX^fY	ttX^FX^f	ttX^fY

females → 4 possibilities → $\frac{2}{4}$ normal hair, non-taster
→ $\frac{2}{4}$ normal hair, taster

males → 4 possibilities → $\frac{1}{4}$ normal hair, non-taster
$\frac{1}{4}$ normal hair, taster
$\frac{1}{4}$ forelock, non-taster
$\frac{1}{4}$ forelock, taster

17 Blood Types: $\left.\begin{matrix} I^A I^A \\ I^A I^O \end{matrix}\right\}$ Type A $\quad I^A I^B \}$ Type AB

$I^O I^O \}$ Type O

$\left.\begin{matrix} I^B I^B \\ I^B I^O \end{matrix}\right\}$ Type B

* dihybrid, multiple alleles & sex-linked

Hemophilia: H → normal h → hemophilia

mother [$I^O I^O$ _]

man [$I^A I^O X^h Y$] —— woman [$I^A I^B X^H X^h$]

$I^A I^O X^h Y \cdot I^A I^B X^H X^h$

gametes: $I^A X^h$, $I^A Y$, $I^O X^h$, $I^O Y$ • $I^A X^H$, $I^A X^h$, $I^B X^H$, $I^B X^h$

F_1	$I^A X^h$	$I^A Y$	$I^O X^h$	$I^O Y$
$I^A X^H$	$I^A I^A X^H X^h$	$I^A I^A X^H Y$	$I^A I^O X^H X^h$	$I^A I^O X^H Y$
$I^A X^h$	$I^A I^A X^h X^h$	$I^A I^A X^h Y$	$I^A I^O X^h X^h$	$I^A I^O X^h Y$
$I^B X^H$	$I^A I^B X^H X^h$	$I^A I^B X^H Y$	$I^B I^O X^H X^h$	$I^B I^O X^H Y$
$I^B X^h$	$I^A I^B X^h X^h$	$I^A I^B X^h Y$	$I^B I^O X^h X^h$	$I^B I^O X^h Y$

Phenotypes

females → 8 possibilities → Type A, no hemophilia → $\frac{2}{8}$

Type B, no hemophilia → $\frac{1}{8}$

Type AB, no hemophilia → $\frac{1}{8}$

Type A, hemophilia → $\frac{2}{8}$

Type B, hemophilia → $\frac{1}{8}$

Type AB, hemophilia → $\frac{1}{8}$

males → 8 possibilities → Type A, no hemophilia → $\frac{2}{8}$

Type B, no hemophilia → $\frac{1}{8}$

Type AB, no hemophilia → $\frac{1}{8}$

Type A, hemophilia → $\frac{2}{8}$

Type B, hemophilia → $\frac{1}{8}$

Type AB, hemophilia → $\frac{1}{8}$

Sex-Linked Crosses (# 13–15)

13 $B \rightarrow$ normal vision

$b \rightarrow$ colourblindness

woman: father $\rightarrow X^bY$, so she must be X^BX^b

man: X^BY

F_1	X^B	X^b
X^B	X^BX^B	X^BX^b
Y	X^BY	X^bY

colourblind sons: $\frac{1}{2}$ chance

colourblind daughters: $\frac{0}{2}$ chance

A normal male cannot carry the colourblind gene as they only have one X-chromosome. Since the gene is X-linked, they either carry the gene & have the disease, or don't carry it & don't have the disease.

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14 $H \rightarrow$ normal $h \rightarrow$ hemophilia

woman: X^HX^h man: X^hY

F_1	X^H	X^h
X^h	X^HX^h	X^hX^h
Y	X^HY	X^hY

$\rightarrow \frac{3}{4}$, or 75% of children will be born

$\rightarrow \frac{1}{4}$ chance of X^hX^h (female hemophilic, will die before birth)

15* codominance / sex-linked

B → black

b → yellow

Bb → calico / tortoise-shell

calico cat → X^BX^b

X^bY, X^bY yellow M

X^BY, X^BY black M

X^bX^b, X^bX^b yellowF

X^BX^b, X^BX^b calico F

$X^BX^b \cdot X^{?}Y$ → either X^BY or X^bY

①

F_1	X^B	X^b
X^B	X^BX^B	X^BX^b
Y	X^BY	X^bY

1 black F, 1 black M, 1 calico F, 1 yellow M

* no yellow F_1 so not possible *

+ black F when there wasn't any

②

F_1	X^B	X^b
X^b	X^BX^b	X^bX^b
Y	X^BY	X^bY

1 calico F, 1 yellow F, 1 black M, 1 yellow M

1:1:1:1 ratio, or 2:2:2:2

$\boxed{\therefore \text{ 1 calico F, 1 yellow M}}$

③ only possibility of male tomcat: X^BX^bY

↳ meiosis non-disjunction can give male cats an extra X chromosome, so one must carry the B allele & the other a b allele