Cross 1

Parents
(P_0)

X

Grey fish
Glo^-/Glo^-; Glo^-/Glo^-

Purple fish
Glo^{RFP}/Glo^-; Glo^{BFP}/Glo^-

Progeny
(F_1)

Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 2

Parents
(P₀)

Red fish
Glo^{RFP}/Glo^-

X

Red fish
Glo^{RFP}/Glo^-

Progeny
(F₁)

Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

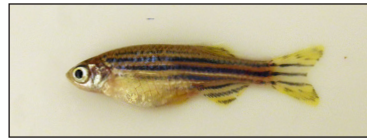# Cross 3

Parents
(P₀)

Grey fish
Glo⁻/Glo⁻; Glo⁻/Glo⁻

X

Red fish
Glo^RFP/Glo⁻
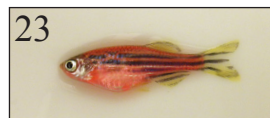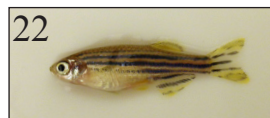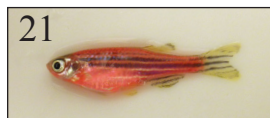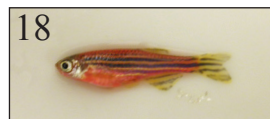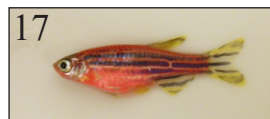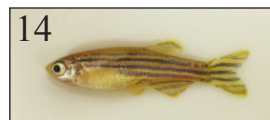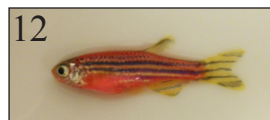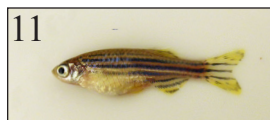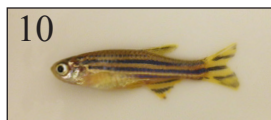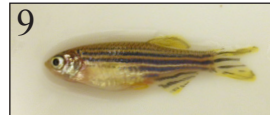
Progeny
(F₁)

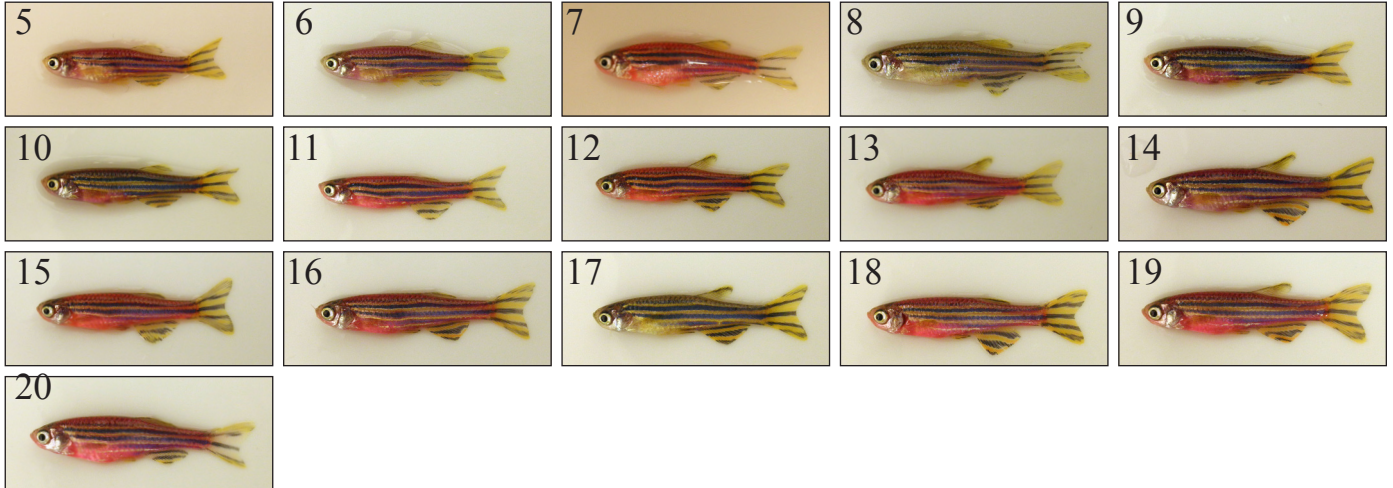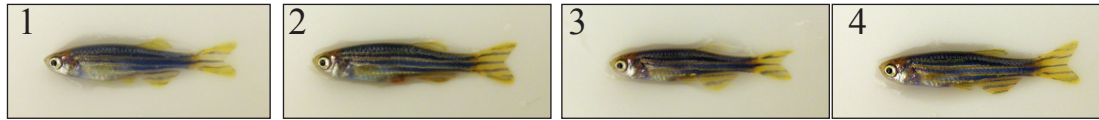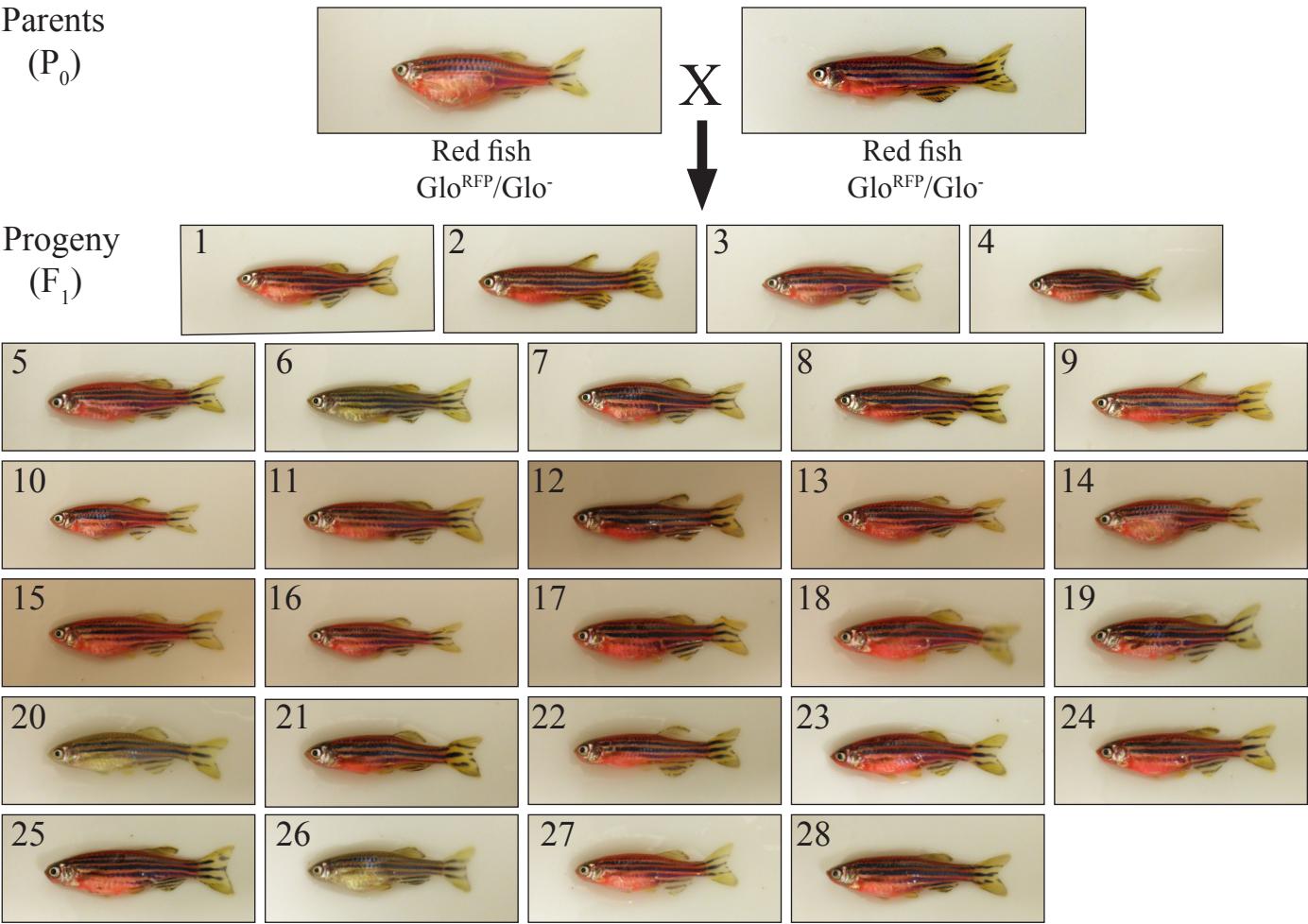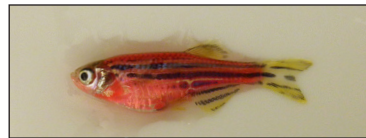Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 4

Parents
(P$_0$)

Red Spotted fish
Glo^{RFP}/Glo^{RFP}; Spot /Spot

X
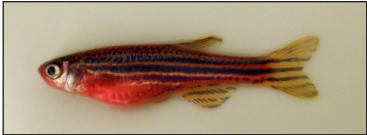
Red Striped fish
Glo^{RFP}/Glo^{RFP}; Stripe /Stripe

Progeny
(F$_1$)
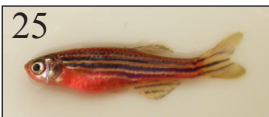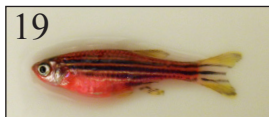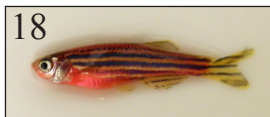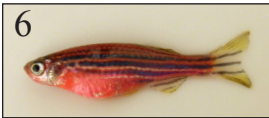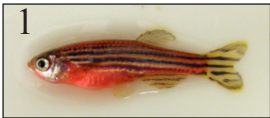
Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 5

Parents
(P$_0$)

Red fish
Glo^{RFP}/Glo$^-$; Glo$^-$/Glo$^-$

X

Yellow fish
Glo$^-$/Glo$^-$; Glo^{YFP}/Glo^{YFP}

Progeny
(F$_1$)

Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 6

Parents
(P$_0$)

Red fish
Glo^{RFP}/Glo^{RFP}; Glo$^-$/Glo$^-$

X
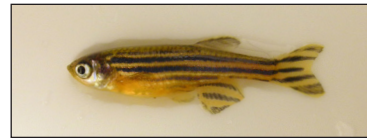
Yellow fish
Glo$^-$/Glo$^-$; Glo^{YFP}/Glo$^-$

Progeny
(F$_1$)
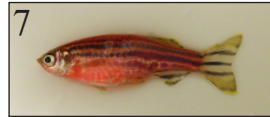
Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 7

Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Parents (P$_0$): Purple fish Glo^{PFP}/Glo$^-$; *gol*/+ X Purple fish Glo^{PFP}/Glo$^-$; *gol*/+

Progeny (F$_1$): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
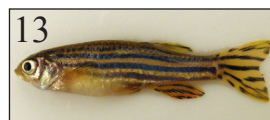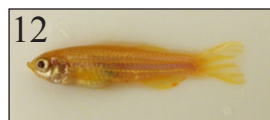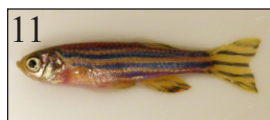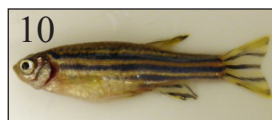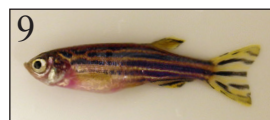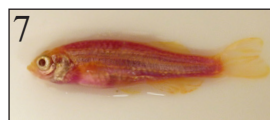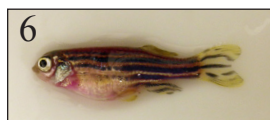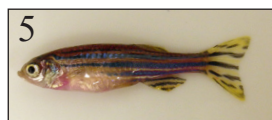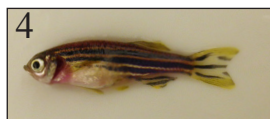
Cross 8

Parents
(P$_0$)

Red fish
Glo^{RFP}/Glo$^-$; Glo$^-$/Glo$^-$; *gol*/+

X

Purple fish
Glo$^-$/Glo$^-$; Glo^{PFP}/Glo$^-$; *gol*/+

Progeny
(F$_1$)
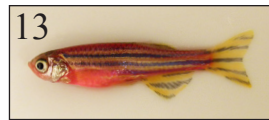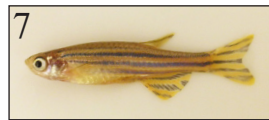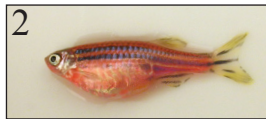
Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 9

Parents
(P$_0$)

Grey fish
Glo$^-$/Glo$^-$; Glo$^-$/Glo$^-$

X

Orange fish
Glo^{RFP}/Glo$^-$; Glo^{YFP}/Glo$^-$
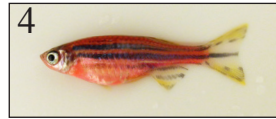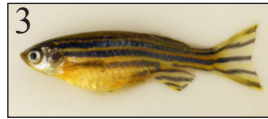
Progeny
(F$_1$)

Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 10

Parents
(P$_0$)
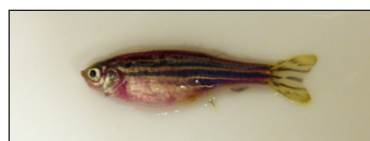
Purple fish
Glo^{PFP}/Glo$^-$; Glo$^-$/Glo$^-$;
stripe/stripe; short/short

X
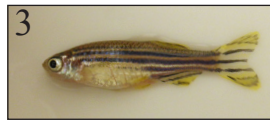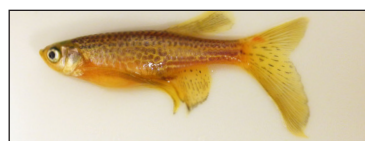
Yellow fish
Glo$^-$/Glo$^-$; Glo^{YFP}/Glo^{YFP};
spot/spot; long/short

Progeny
(F$_1$)
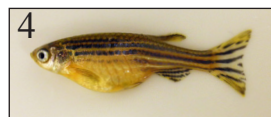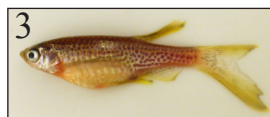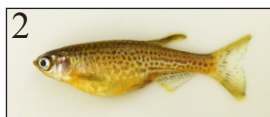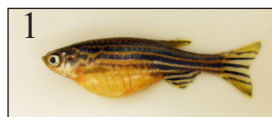
Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 11

Parents
(P$_0$)

Orange fish
Glo^{RFP}/Glo$^-$; Glo^{YFP}/Glo$^-$

X

Orange fish
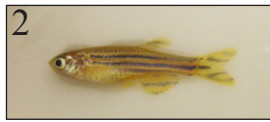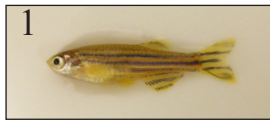Glo^{RFP}/Glo$^-$; Glo^{YFP}/Glo$^-$
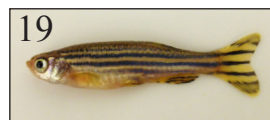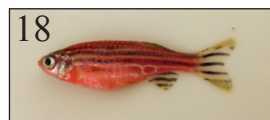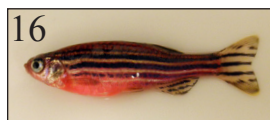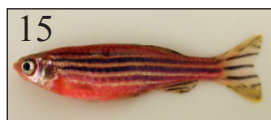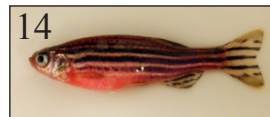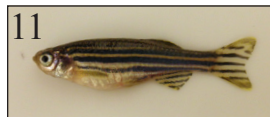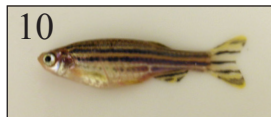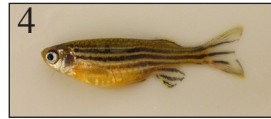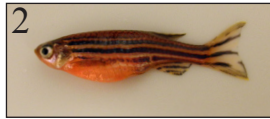
Progeny
(F$_1$)

Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 12

Parents
(P$_0$)

X

Purple fish
Glo^{RFP}/Glo$^-$; Glo^{BFP}/Glo$^-$

Purple fish
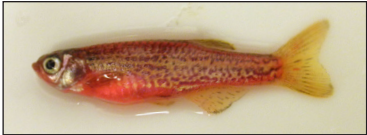Glo^{RFP}/Glo$^-$; Glo^{BFP}/Glo$^-$
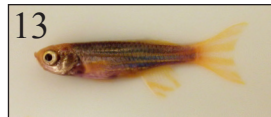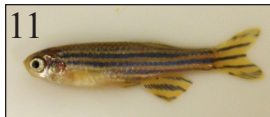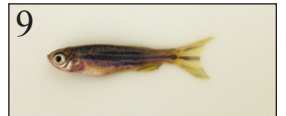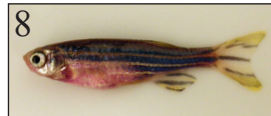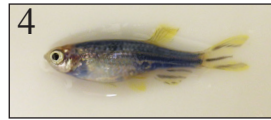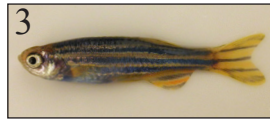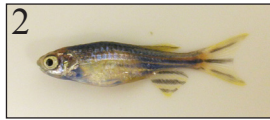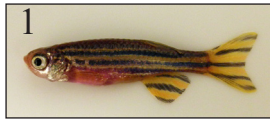
Progeny
(F$_1$)

Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 13

Parents
(P$_0$)

Red fish
Glo^{RFP}/Glo^{RFP}; Glo$^-$/Glo$^-$; +/+

X

Yellow fish
Glo$^-$/Glo$^-$; Glo^{YFP}/Glo^{YFP}; *gol*/*gol*

Progeny
(F$_1$)
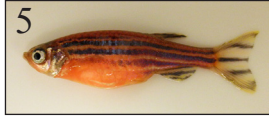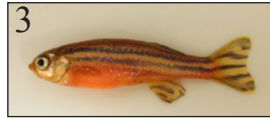
Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 14

Parents
(P$_0$)
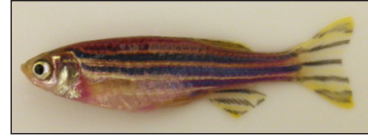
Green fish
Glo^{GFP}/Glo$^-$; Glo$^-$/Glo$^-$; *gol/gol*

X

Purple fish
Glo$^-$/Glo$^-$; Glo^{PFP}/Glo$^-$; +/+

Progeny
(F$_1$)

1

2

3

4

5

6

7

8

9

10

11

12
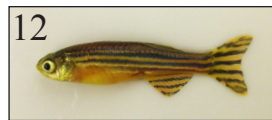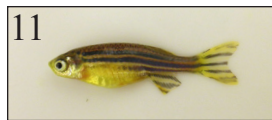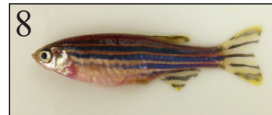
Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Cross 15

Parents
(P$_0$)

Grey fish
Glo$^-$/Glo$^-$

X

Red fish
Glo^{RFP}/Glo$^-$

Progeny
(F$_1$)

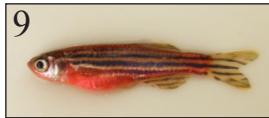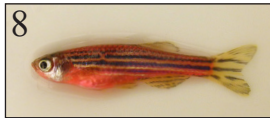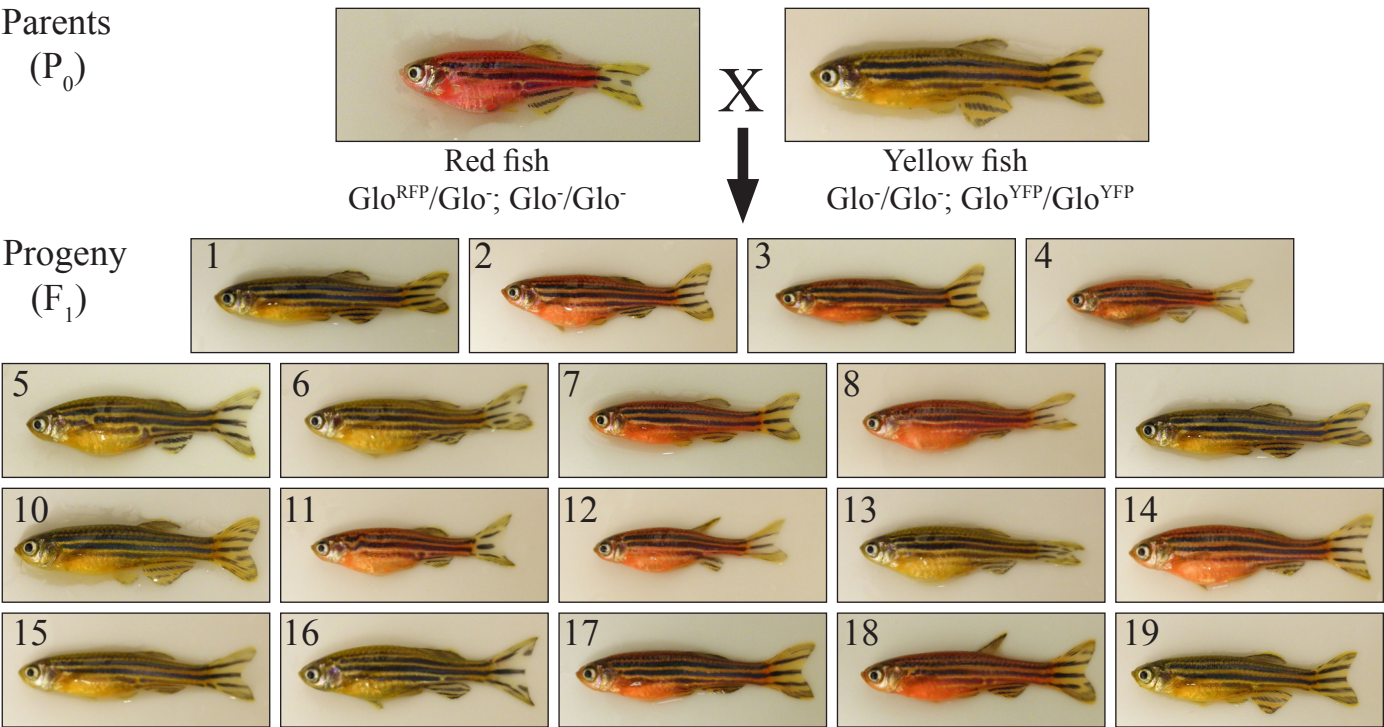Figure by Sooji (Katie) Jo
Pictures by Sooji (Katie) Jo, Bethanie Borg, and Suzzy Arika

Figure Legends and Key
Zebrafish Pedigree Data
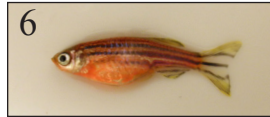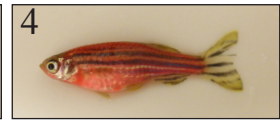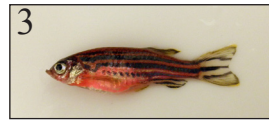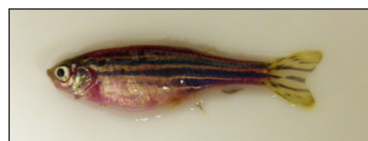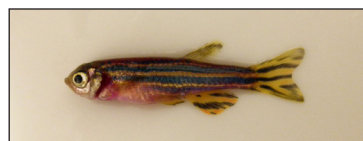# By Sooji (Katie) Jo

Cross 1: Progeny of a dihybrid cross between a purple male and WT female zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 1. Key: Grey 8, 17; Purple 5, 6, 9, 10, 14; Blue 1, 2, 3, 4; Red 7, 11, 12, 13, 15, 16, 18, 19, 20; Male 1, 2, 3, 4, 5, 6, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18 , 19, 20; Female 7, 10.

Cross 2: Progeny of a monohybrid cross between red male and female zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 2. Key: Red 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25, 27, 28; Grey 20, 26; Male 5, 8, 9, 11, 12, 21, 22, 25; Female 1, 2, 3, 4, 6, 7, 10, 13, 14, 15, 16, 17, 18, 19, 20, 23, 24, 26, 27, 28.

Cross 3: Progeny of a monohybrid cross between a red female and WT male zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 3. Key: Red 4, 5, 6, 7, 12, 13, 15, 16, 17, 18, 19, 20, 21, 23; Grey 1, 2, 3, 8, 9,10, 11, 14, 22, 24.

Cross 4: Progeny of a dihybrid cross between a non-striped, red female and striped, red male zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 4. Key: Red and striped 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25; Male 1, 4, 5, 7, 10, 13, 14, 15, 16, 24; Female 2, 3, 6, 8, 9, 11, 12, 17, 18, 19, 20, 21, 22, 23.

Cross 5: Progeny of dihybrid cross between a red female and yellow male zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 5. Key: Yellow 1, 5, 6, 10, 13, 15, 16, 19, 20; Orange 2, 3, 4, 7, 8, 11, 12, 14, 17, 18; Male 1, 7, 10, 15, 16, 17, 18, 19, 20; Female 2, 3, 4, 5, 6, 8,11, 12, 13, 14.

Cross 6: Progeny of a monohybrid cross between a homozygous red female and yellow male zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 6. Key: Red 3, 4, 5, 7, 8; Orange 1,2, 6, 9; Male 1, 5, 8; Female 2, 3, 4, 6, 7, 9.

Cross 7: Progeny of dihybrid cross between a purple female and purple male zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 7. Key: Purple 1, 2, 3, 4, 5, 6, 8, 9, 11; Grey 10, 13; Purple; no pigment 7; Grey; no pigment 12; Male 2, 3, 4, 5, 7, 8, 11; Female 1, 6, 9, 10, 12, 13.

Cross 8: Progeny of trihybrid cross between a red male and a purple female zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 8. Key: Grey, striped 7; Purple, striped 4, 8; Red, striped 1, 2, 6, 9, 16; Red-purple, striped 13, 15, 17; Grey; no pigment 3, 5; Red; no pigment 10, 11; Red-purple; no pigment 12, 14; Male 1, 3, 4, 5, 6, 7, 8, 9, 10, 11 12, 14, 15, 16, 17; Female 2, 13.

Cross 9: Progeny of dihybrid cross between a WT female and orange male zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 9. Key: Grey 2; Yellow 1, 3, 6, 7, 8; Red 4, 5, 9, 10, 12; Orange 11, 13, 14; Male 7; Female 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14.

Cross 10: Progeny of tetrahybrid cross between a short finned, striped, purple male and long finned, spotted, yellow female zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 10. Key: Yellow 1, 2, 4; Yellow-purple 3; Short finned 1, 2, 4; Long finned 3; Striped 1, 4; Spotted 2, 3; Female 1, 2, 3, 4.

Cross 11: Progeny of a dihybrid cross between an orange male and orange female zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 11. Key: Orange 1, 2, 3, 7, 12, 17; Yellow 4, 5, 8, 9, 13; Grey 6, 10, 11, 19; Red 14, 15, 16, 18; Female 2, 4, 6, 8, 10, 11, 12, 14, 15, 16, 17, 18; Male 1, 3, 5, 7, 9, 13, 19.

Cross 12: Progeny of trihybrid cross between a purple male and purple female zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 12. Key: Grey, striped 16; Blue, striped 2, 3, 4; Red, striped 5, 6, 7, 10, 12, 14; Purple, striped 1, 8, 9, 15; Grey, striped 11; Purple, no pigment 13; Female 2, 4, 8, 9,10,13; Male 1, 5, 6, 7,11,12,14,15,16.

Cross 13: Progeny of dihybrid cross between a homozygous red male and homozygous yellow female zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 13. Key: Orange 1, 2, 3, 4, 5, 6; Female 2, 5; Male 1, 3, 4, 6.

Cross 14: Progeny of a dihybrid cross between a green, no pigment male and purple, striped female zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 14. Key: Grey 1, 3, 10; Green 2, 4, 9, 11, 12; Purple 5, 8; Green-purple 6, 7; Female 1, 3, 5, 11; Male 2, 4, 6, 7, 8, 9, 10, 12.

Cross 15 (20): Progeny of a monohybrid cross between a grey female and red male zebrafish. Images of the parents and all of the progeny were auto-toned using Photoshop. Data and chi-square analysis for this cross are found in Table 15. Key: Grey 1, 2, 3, 4, 6, 7, 8, 9; Red 5, 10, 11, 12; Female 2, 3, 4, 5, 7, 10; Male 1, 6, 8, 9, 11, 12.

Chi Square Answer sheet for Crosses 1-15
By Sooji (Katie) Jo and Jennifer Liang

Table 1: Cross 1: Dihybrid between purple (bluered) male and WT female

Step 3 Analysis

RFP	-	-	Red 1/2
	RFP/-	RFP/-	Non red 1/2
-	-/-	-/-	

BFP	-	-	Blue 1/2
	BFP/-	BFP/-	Non blue 1/2
-	-/-	-/-	

Grey 1/2 *1/2* 20 = 5
Purple 1/2 *1/2* 20 =5
Blue 1/2 *1/2 *20 =5
Red 1/2 *1/2* 20 =5

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) $d = (o - e)$	(5) d^2	(6) d^2/e
Grey	2	5	-3	9	1.8
Purple	5	5	0	0	0
Blue	4	5	-1	1	0.2
Red	9	5	4	16	3.2
Total	20	20			3.2

(7) X^2 = the sum of all of the numbers in column 6 = 3.2
(8) Degrees of freedom (df) = n-1 = 3

Conclusion:
(9) P-value and conclusion about your hypothesis: $0.1 < p < 0.5$

Table 2: Cross 2: Monohybrid between red female and red male

	Red	-
Red	R/R	R/-
-	R/-	-/-

Red 3/4 *27 (Total observed number) = 20.25 = 20
Not red 1/4 * 27 = 6.75 = 7

Chi Square Table for this clutch:

(1)	(2)	(3)	(4)	(5)	(6)
Phenotype	Observed Number, o	Expected Number, e	$d = (o - e)$	d^2	d^2/e
Red	25	20	5	25	1.25
Grey	2	7	-5	25	3.57
Total	27	27			4.82

(7) X^2 = the sum of all of the numbers in column 6 = 4.82
(8) Degrees of freedom (df) = n-1 =1

Conclusion:
(9) P-value and conclusion about your hypothesis:
$$0.03 < P < 0.02$$

Table 3: Cross 3: Monohybrid between red female and WT male

Step 3 analysis

	-	-
Red	R/-	-/-
-	R/-	-/-

Red: 1/2 *24 = 12
Not red: 1/2*24 = 12

Chi Square Table for this clutch:

(1)	(2)	(3)	(4)	(5)	(6)
Phenotype	Observed Number, o	Expected Number, e	$d = (o - e)$	d^2	d^2/e
Red	14	12	2	4	0.33
Grey	10	12	-2	4	0.33
Total	24	24	0		0.66

(7) X^2 = the sum of all of the numbers in column 6 = 0.66
(8) Degrees of freedom (df) = n-1 = 1

Conclusion:
(9) P-value and conclusion about your hypothesis: $0.4 < P < 0.5$

Table 4: Cross 4: Dihybrid between nonstriped, red female and striped, red male

Step 3 analysis

	RFP	RFP
RFP	R/R	R/R
RFP	R/R	R/R

Red: 1

	Stripe	Stripe
Spot	Sp/St	Sp/St
Spot	Sp/St	Sp/St

Stripe: 1

Red/striped 1*1*25 =25

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) d = (o − e)	(5) d^2	(6) d^2/e
Red/Striped	25	25	0	0	0
Total	25	25		0	0

(7) X^2 = the sum of all of the numbers in column 6 = 0

(8) Degrees of freedom (df) = n-1 = 0

Conclusion:

(9) P-value and conclusion about your hypothesis: Cannot do Chi-square analysis when df=0

Table 5: Cross 5: Dihybrid between red female and yellow male

Step 3 Analysis

	-	-
RFP	R/-	R/-
-	-/-	-/-

Red : 1/2
Not Red : 1/2

	-	-
YFP	Y/-	Y/-
YFP	Y/-	Y/-

Yellow 1

Orange: 1/2*1 *19 = 9.5
Yellow 1/2 * 1 *19=9.5

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) $d = (o - e)$	(5) d^2	(6) d^2/e
Yellow	9	10	1	1	0.1
Orange	10	10	0	0	0
Total	19	19			0.1

(7) X^2 = the sum of all of the numbers in column 6 = 0.1
(8) Degrees of freedom (df) = n-1 = 1

Conclusion:
(9) P-value and conclusion about your hypothesis:
$$0.7 < P < 0.8$$

Table 6: Cross 6: Dihybrid between red female and yellow male

Step 3 Analysis

	-	-
RFP	R/-	R/-
RFP	R/-	R/-

Red : 1

	-	-
YFP	Y/-	Y/-
-	-/-	-/-

Yellow 1/2
Grey 1/2

Orange 1 *1/2* 9 = 4.5
Red   1*1/2*9=4.5

Chi Square Table for this clutch:

(1)	(2)	(3)	(4)	(5)	(6)
Phenotype	Observed Number, o	Expected Number, e	$d = (o - e)$	d^2	d^2/e
Red	5	5	0	0	0
Orange	4	5	1	0.20	0.04
Total	9	10			0.04

(7) X^2 = the sum of all of the numbers in column 6 = 0.04
(8) Degrees of freedom (df) = n-1 = 1

Conclusion:
(9) P-value and conclusion about your hypothesis: 0.8 < P < 0.9

Table 7: Cross 7: Dihybrid between a purple female and purple male

Step 3 analysis

	PFP	-
PFP	P/P	P/-
-	P/-	-/-

Purple: 3/4
Grey: 1/4

	gol	+
gol	*gol/gol*	*gol*/+
+	*gol*/+	+/+

No pigment: 3/4
Pigment: 1/4

Purple, pigment   3/4* 3/4 * 13 = 7.3125
Purple, no pigment   3/4*1/4 *13 = 2.4375
Grey, pigment   1/4* 3/4 *13 = 2.4375
Grey, no pigment   1/4*1/4 *13 = 0.8125

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) $d = (o - e)$	(5) d^2	(6) d^2/e
Purple, pigment	9	7	2	4	0.57
Grey, pigment	2	1	1	1	1.00
Purple, no pigment	1	2	-1	1	0.50
Grey, no pigment	1	2	-1	1	0.50
Total	13	12			2.57

(7) X^2 = the sum of all of the numbers in column 6 = 2.57
(8) Degrees of freedom (df) = n-1 = 3

Conclusion:
(9) P-value and conclusion about your hypothesis: $0.4 < P < 0.5$

Table 8: Cross 8: Trihybrid between red male and purple male

	Red	-
Red	R/R	R/-
-	R/-	-/-

Red: 3/4
Not red: 1/4

	-	-
PFP	P/-	P/-
-	-/-	-/-

Purple: 2/4
Not purple: 2/4

	gol	+
gol	*gol/gol*	*gol/+*
+	*gol/+*	+/+

Pigment: 3/4
No pigment: 1/4

Red purple, pigment	3/4 * 2/4 * 3/4 *17 = 4.78
Red purple, no pigment	3/4 * 2/4 * 1/4 *17 = 1.59
Red not purple, pigment	3/4 * 2/4 * 3/4 *17 = 4.78
Red not purple, no pigment	3/4 * 2/4 * 1/4 *17 = 1.59
Not red, purple, pigment	1/4 * 2/4 * 3/4 *17 = 1.59
Not red, purple, no pigment	1/4 * 2/4 * 1/4 *17 = 0.53
Not red, not purple, pigment	1/4 * 2/4 * 3/4 *17 = 1.59
Not red, not purple, no pigment	1/4 * 2/4 * 1/4 *17 = 0.53

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) $d = (o - e)$	(5) d^2	(6) d^2/e
Purple, pigment	2	2	0	0	0
Grey, pigment	1	2	-1	1	0.50
Red, pigment	5	5	0	0	0
Red purple, pigment	3	5	2	4	0.80
Grey, no pigment	2	1	1	1	1.00
Red, no pigment	2	2	0	0	0
Red purple, no pigment	2	2	0	0	0
Purple, no pigment	0	1	-1	1	1.00
Total	17				3.30

(7) X^2 = the sum of all of the numbers in column 6 = 3.30

(8) Degrees of freedom (df) = n-1 = 7
(9) P-value and conclusion about your hypothesis: 0.8 < P < 0.9

Table 9: Cross 9: Dihybrid between WT female and orange male

Step 3 Analysis

	-	-
RFP	R/-	R/-
-	-/-	-/-

Red : 1/2
Not Red : 1/2

	-	-
YFP	Y/-	Y/-
-	-/-	-/-

Yellow 1/2
Not yellow 1/2

Red: 1/2*1/2 = 1/4   *14 =3.5
Orange : 1/2*1/2 = 1/4   *14 =3.5
Yellow 1/2 * 1/2 = 1/4   *14 =3.5
Grey: 1/2*1/2 =1/4   *14 =3.5

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) d = (o – e)	(5) d^2	(6) d^2/e
Grey	1	4	-3	9	2.25
Yellow	5	4	1	1	0.25
Red	5	4	1	1	0.25
Orange	3	4	-1	1	0.25
Total	14	14			3.00

(7) X^2 = the sum of all of the numbers in column 6 = 3.00
(8) Degrees of freedom (df) = n-1 = 3

Conclusion:
(9) P-value and conclusion about your hypothesis: 0.3 < P < 0.4

Table 10: Cross 10: Tetrahybrid between short finned, purple male and long finned, yellow female

PFP	-	-	Purple: 1/2
	P/-	P/-	Not purple: 1/2
-	-/-	-/-	

YFP	-	-	Yellow 1
YFP	YFP/-	YFP/-	
YFP	YFP/-	YFP/-	

	Long	Short	Long 1/2
Short	S/L	S/S	Short 1/2
Short	S/L	S/S	

	Stripe	Spot	Stripe 1/2
Spot	Sp/St	Sp/Sp	Spot 1/2
Spot	Sp/St	Sp/Sp	

Purple yellow, long fin, stripe   1/2 * 1 * 1/2 *1/2* 4 = 0.5
Purple yellow, long fin, spot   1/2 * 1 * 1/2 *1/2* 4 = 0.5
Purple yellow, short fin, stripe   1/2 * 1 * 1/2 *1/2* 4 = 0.5
Purple yellow, short fin, spot   1/2 * 1 * 1/2 *1/2* 4 = 0.5
Yellow, long fin, stripe   1/2 * 1 * 1/2 *1/2* 4 = 0.5
Yellow, long fin, spot   1/2 * 1 * 1/2 *1/2* 4 = 0.5
Yellow, short fin, stripe   1/2 * 1 * 1/2 *1/2* 4 = 0.5
Yellow, short fin, spot   1/2 * 1 * 1/2 *1/2* 4 = 0.5

(1)	(2)	(3)	(4)	(5)	(6)
Phenotype	Observed Number, o	Expected Number, e	$d = (o - e)$	d^2	d^2/e
Purple yellow, long fin, stripe	0	1	1	1	1
Purple yellow, long fin, spot	1	1	0	0	0
Purple yellow, short fin, stripe	0	1	-1	1	1
Purple yellow, short fin, spot	0	1	-1	1	1
Yellow, long fin, stripe	0	1	-1	1	1
Yellow, long fin, spot	0	1	-1	1	1
Yellow, short fin, stripe	2	1	1	1	1
Yellow, short fin, spot	1	1	0	0	0
Total	4				6

(7) X^2 = the sum of all of the numbers in column 6 = 6
(8) Degrees of freedom (df) = n-1 = 7
(9) P-value and conclusion about your hypothesis: $0.5 < P < 0.6$

Table 11: Cross 11: Dihybrid between orange male and orange female

	RFP	-
RFP	R/R	R/-
-	R/-	-/-

Red : 3/4
Not red : 1/4

	YFP	-
YFP	Y/Y	Y/-
-	Y/-	-/-

Yellow 3/4
Not yellow 1/4

Red/ Yellow : 3/4 * 3/4 *19 = 10.688
Red/ not yellow : 3/4 * 1/4 *19 = 3.5625
Not red/ yellow : 1/4 *3/4 *19 = 3.5625
Not red/ not yellow : 1/4 * 1/4 *19 =1.1875

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) d = (o − e)	(5) d^2	(6) d^2/e
Orange	6	11	-5	25	2.27
Yellow	5	4	1	1	0.25
Grey	4	1	3	9	9.00
Red	4	4	0	0	0
Total	19				11.52

(7) X^2 = the sum of all of the numbers in column 6 = 11.52
(8) Degrees of freedom (df) = n-1 = 3

Conclusion:
(9) P-value and conclusion about your hypothesis: P < 0.01

Table 12: Cross 12: Trihybrid between purple male and purple female

	RFP	-
RFP	RFP/RFP	RFP/-
-	RFP/-	-/-

Red: 3/4
Not Red: 1/4

	BFP	-
BFP	BFP/BFP	BFP/-
-	BFP/-	-/-

Blue: 3/4
Not blue: 1/4

	gol	+
gol	*gol/gol*	*gol/+*
+	*gol/+*	*gol/+*

Pigment: 3/4
No pigment: 1/4

Red blue, no pigment	3/4*3/4*1/4 *15 = 2.109
Red blue, pigment	3/4*3/4*3/4*15 = 6.328
Red not blue, no pigment	3/4*1/4*1/4*15= 0.703
Red not blue, pigment	3/4*1/4*3/4*15= 2.109
Not red blue, no pigment	1/4*3/4*1/4*15= 0.703
Not red blue, pigment	1/4*3/4*3/4*15= 2.109
Not red not blue, no pigment	1/4*1/4*1/4*15= 0.0156
Not red not blue, pigment	1/4*1/4*3/4*15= 0.703

Chi Square Table for this clutch:

(1)	(2)	(3)	(4)	(5)	(6)
Phenotype	Observed Number, o	Expected Number, e	$d = (o - e)$	d^2	d^2/e
Purple, pigment	4	6	-2	4	0.66
Grey, pigment	1	1	0	0	0
Blue, pigment	3	2	1	1	0.50
Red, pigment	6	2	4	16	8
Purple, no pigment	1	2	-1	1	0.50
Grey, no pigment	0	0	0	0	0
Blue, no pigment	0	1	-1	1	1
Red, no pigment	0	1	-1	1	1
Total	15				11.66

(7) X^2 = the sum of all of the numbers in column 6 = 11.66
(8) Degrees of freedom (df) = n-1 =7
(9) P-value and conclusion about your hypothesis: 0.1 < P < 0.15

Table 13: Cross 13: Trihybrid between red male and yellow female

	-	-	
RFP	RFP/-	RFP/-	Red : 1
RFP	RFP/-	RFP/-	

	-	-	
YFP	YFP/-	YFP/-	Yellow: 1
YFP	YFP/-	YFP/-	

	gol	*gol*	
+	*gol*/+	*gol*/+	Pigment: 1
+	*gol*/+	*gol*/+	

Orange, pigment 1* 1* 1* 6 = 6

Chi Square Table for this clutch:

(1)	(2)	(3)	(4)	(5)	(6)
Phenotype	Observed Number, o	Expected Number, e	d = (o – e)	d^2	d^2/e
Orange, striped	6	6			
Total	6	6			

(7) X^2 = the sum of all of the numbers in column 6 =
(8) Degrees of freedom (df) = n-1 = 0

Conclusion:
(9) P-value and conclusion about your hypothesis:
Cannot carry out Chi square analysis with 0 degrees of freedom

Table 14: Cross 14: Trihybrid between Green, no pigment male and purple, striped male

	-	-
GFP	GFP/-	GFP/-
-	-/-	-/-

Green : 1/2
Not green: 1/2

	PFP	-
-	PFP/-	-/-
-	PFP/-	-/-

Purple: 1/2
Not purple: 1/2

	gol	*gol*
+	*gol*/+	*gol*/+
+	*gol*/+	*gol*/+

Pigment: 1

Green-purple	½ * ½ * 1 * 12 = 3
Green, not purple	½ * ½ * 1 * 12 = 3
Purple, not green	½ * ½ * 1 * 12 = 3
Note green, not purple	½ * ½ * 1 * 12 = 3

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) $d = (o - e)$	(5) d^2	(6) d^2/e
Green-purple	5	3	2	4	1.33
Green	4	3	1	1	0.33
Purple	2	3	-1	1	0.33
Grey	1	3	-2	4	1.33
Total					3.32

(7) X^2 = the sum of all of the numbers in column 6 = 3.32
(8) Degrees of freedom (df) = n-1 = 3

Conclusion:
(9) P-value and conclusion about your hypothesis: $0.3 < P < 0.4$

Table 15: Cross 15: Monohybrid between WT female and red male

	-	-
RFP	R/-	R/-
-	-/-	-/-

Red: 1/2 *12 = 6
Not Red: 1/2 *12 = 6

Chi Square Table for this clutch:

(1) Phenotype	(2) Observed Number, o	(3) Expected Number, e	(4) d = (o – e)	(5) d^2	(6) d^2/e
Red	4	6	-2	4	0.66
Grey	8	6	2	4	0.66
Total	12	12			1.32

(7) X^2 = the sum of all of the numbers in column 6 = 1.32
(8) Degrees of freedom (df) = n-1 = 1

Conclusion:
(9) P-value and conclusion about your hypothesis: 0.2 < P < 0.3

											Chi squared														
											Degrees of freedom (df)														
25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	p value
11.52	10.86	10.20	9.54	8.90	8.26	7.63	7.01	6.41	5.81	5.23	4.66	4.11	3.57	3.05	2.56	2.09	1.65	1.24	0.87	0.55	0.30	0.11	0.02	0.00	.99
16.47	15.66	14.85	14.04	13.24	12.44	11.65	10.86	10.09	9.31	8.55	7.79	7.04	6.30	5.58	4.87	4.17	3.49	2.83	2.20	1.61	1.06	0.58	0.21	0.02	.90
18.94	18.06	17.19	16.31	15.44	14.58	13.72	12.86	12.00	11.15	10.31	9.47	8.63	7.81	6.99	6.18	5.38	4.59	3.82	3.07	2.34	1.65	1.01	0.45	0.06	.80
20.87	19.94	19.02	18.10	17.18	16.27	15.35	14.44	13.53	12.62	11.72	10.82	9.93	9.03	8.15	7.27	6.39	5.53	4.67	3.83	3.00	2.19	1.42	0.71	0.15	.70
22.62	21.65	20.69	19.73	18.77	17.81	16.85	15.89	14.94	13.98	13.03	12.08	11.13	10.18	9.24	8.30	7.36	6.42	5.49	4.57	3.66	2.75	1.87	1.02	0.27	.60
24.34	23.34	22.34	21.34	20.34	19.34	18.34	17.34	16.34	15.34	14.34	13.34	12.34	11.34	10.34	9.34	8.34	7.34	6.35	5.35	4.35	3.36	2.37	1.39	0.45	.50
26.14	25.11	24.07	23.03	21.99	20.95	19.91	18.87	17.82	16.78	15.73	14.69	13.64	12.58	11.53	10.47	9.41	8.35	7.28	6.21	5.13	4.04	2.95	1.83	0.71	.40
28.17	27.10	26.02	24.94	23.86	22.77	21.69	20.60	19.51	18.42	17.32	16.22	15.12	14.01	12.90	11.78	10.66	9.52	8.38	7.23	6.06	4.88	3.66	2.41	1.07	.30
30.68	29.55	28.43	27.30	26.17	25.04	23.90	22.76	21.61	20.47	19.31	18.15	16.98	15.81	14.63	13.44	12.24	11.03	9.80	8.56	7.29	5.99	4.64	3.22	1.64	.20
32.28	31.13	29.98	28.82	27.66	26.50	25.33	24.16	22.98	21.79	20.60	19.41	18.20	16.99	15.77	14.53	13.29	12.03	10.75	9.45	8.12	6.74	5.32	3.79	2.07	.15
34.38	33.20	32.01	30.81	29.62	28.41	27.20	25.99	24.77	23.54	22.31	21.06	19.81	18.55	17.28	15.99	14.68	13.36	12.02	10.64	9.24	7.78	6.25	4.61	2.71	.10
34.90	33.71	32.51	31.31	30.10	28.89	27.67	26.45	25.21	23.98	22.73	21.48	20.21	18.94	17.65	16.35	15.03	13.70	12.34	10.95	9.52	8.04	6.49	4.82	2.87	.09
35.47	34.27	33.06	31.85	30.63	29.41	28.18	26.95	25.71	24.46	23.20	21.93	20.66	19.37	18.07	16.75	15.42	14.07	12.69	11.28	9.84	8.34	6.76	5.05	3.06	.08
36.11	34.89	33.68	32.45	31.22	29.99	28.75	27.50	26.25	24.99	23.72	22.44	21.15	19.85	18.53	17.20	15.85	14.48	13.09	11.66	10.19	8.67	7.06	5.32	3.28	.07
36.82	35.60	34.37	33.13	31.89	30.65	29.40	28.14	26.87	25.59	24.31	23.02	21.71	20.39	19.06	17.71	16.35	14.96	13.54	12.09	10.60	9.04	7.41	5.63	3.54	.06
37.65	36.42	35.17	33.92	32.67	31.41	30.14	28.87	27.59	26.30	25.00	23.68	22.36	21.03	19.68	18.31	16.92	15.51	14.07	12.59	11.07	9.49	7.81	5.99	3.84	.05
38.64	37.39	36.13	34.87	33.60	32.32	31.04	29.75	28.44	27.14	25.82	24.49	23.14	21.79	20.41	19.02	17.61	16.17	14.70	13.20	11.64	10.03	8.31	6.44	4.22	.04
39.88	38.61	37.33	36.05	34.76	33.46	32.16	30.84	29.52	28.19	26.85	25.49	24.12	22.74	21.34	19.92	18.48	17.01	15.51	13.97	12.37	10.71	8.95	7.01	4.71	.03
41.57	40.27	38.97	37.66	36.34	35.02	33.69	32.35	31.00	29.63	28.26	26.87	25.47	24.05	22.62	21.16	19.68	18.17	16.62	15.03	13.39	11.67	9.84	7.82	5.41	.02
44.31	42.98	41.64	40.29	38.93	37.57	36.19	34.81	33.41	32.00	30.58	29.14	27.69	26.22	24.73	23.21	21.67	20.09	18.48	16.81	15.09	13.28	11.34	9.21	6.63	.01
52.62	51.18	49.73	48.27	46.80	45.31	43.82	42.31	40.79	39.25	37.70	36.12	34.53	32.91	31.26	29.59	27.88	26.12	24.32	22.46	20.51	18.47	16.27	13.82	10.83	.001

Note. Problems with df>25 would rarely be worked by hand.

From: http://www.algebra.com/algebra/homework/Probability-and-statistics/Probability-and-statistics.faq.question.384379.html