CONCEPT: CHI-SQUARE TEST FOR LINKAGE

- A chi-square test can be used to identify the likelihood of gene linkage
  - □ **Chi-square test** is used to evaluate if your experimental values are different from the predicted values

$$\chi^2 = \Sigma \frac{(o - e)^2}{e}$$

EXAMPLE:

I want to know if genes A and B are linked, so I do an experiment where I cross two heterozygous organisms. I get 50 offspring, 31 parental types, and 19 recombinant types. Is it likely that A and B are linked?

1. What are the expected numbers?
   - If two genes are not linked then the recombination frequency is 50%. Therefore, there would be 50% parental types and 50% recombinant types. So out of 50 offspring, 50/2 = 25. There would be 25 parental and 25 recombinants.
2. Calculate the chi-square value

Phenotype	**Observed**	**Expected**	**$(o-e)^2/e$**
Parental	31	25	1.44
Recombinant	19	25	1.44
		Total	2.88

3. Determine the P value.
   a. Calculate degrees of freedom. DF=1
   b. Find chi-square value on row 1. It is between 2.71 and 3.84
   c. The appropriate p value is between 0.10 and 0.05 (10% to 5%)

Degrees of freedom (df)	x^2 value										
1	0.004	0.02	0.06	0.15	0.46	1.07	1.64	2.71	3.84	6.64	10.83
2	0.10	0.21	0.45	0.71	1.39	2.41	3.22	4.60	5.99	9.21	13.82
3	0.35	0.58	1.01	1.42	2.37	3.66	4.64	6.25	7.82	11.34	16.27
4	0.71	1.06	1.65	2.20	3.36	4.88	5.99	7.78	9.49	13.28	18.47
5	1.14	1.61	2.34	3.00	4.35	6.06	7.29	9.24	11.07	15.09	20.52
6	1.63	2.20	3.07	3.83	5.35	7.23	8.56	10.64	12.59	16.81	22.46
7	2.17	2.83	3.82	4.67	6.35	8.38	9.80	12.02	14.07	18.48	24.32
8	2.73	3.49	4.59	5.53	7.34	9.52	11.03	13.36	15.51	20.09	26.12
9	3.32	4.17	5.38	6.39	8.34	10.66	12.24	14.68	16.92	21.67	27.88
10	3.94	4.87	6.18	7.27	9.34	11.78	13.44	15.99	18.31	23.21	29.59
P value (Probability)	0.95	0.90	0.80	0.70	0.50	0.30	0.20	0.10	0.05	0.01	0.001

4. Do we accept or reject the null hypothesis?
    a. The null hypothesis states that the expected and observed values are not different. (This would mean that the genes would NOT be linked)
    b. Because the p values are greater than 0.05 (5%), so we accept the null hypothesis.

5. Therefore, we can say with 95% confidence the genes are NOT linked.
    a. Remember: This does not confirm linkage, it just states the likelihood

PRACTICE:

Black(B) rabbit coat colors are dominant to white(b) coat colors. Long hair (H) is dominant to short hair (h). A breeder crosses a rabbit homozygous for white, short hair with a black rabbit with long hair. The F_1 is backcrossed to the rabbit with white, short hair and the following progeny are produced. Use the chi-square test to answer the following questions.

Phenotype	**Offspring**
Black, Long	40
Black, Short	20
White, Long	24
White, Short	62
Total	146

1. What are the expected offspring numbers if the two genes are not linked, and therefore assort independently?
    a. 73 parental, 73 recombinant
    b. 146 parental, 0 recombinant
    c. 60 parental, 86 recombinant
    d. 102 parental, 44 recombinant

2. Calculate the chi-square value for the above problem.

    a. 23.00
    b. 5.89
    c. 0.02
    d. 0.467

3. In this example, how many degrees of freedom should be used?
    a. 1
    b. 2
    c. 3
    d. 4

4. Using the appropriate chi-square value and degrees of freedom, do the coat color and hair length genes assort independently?
    a. Yes, both genes assort independently
    b. No, both genes do not assort independently (meaning they are linked)

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