Lecture 22 Confidence Interval For The Proportion

BIO210 Biostatistics

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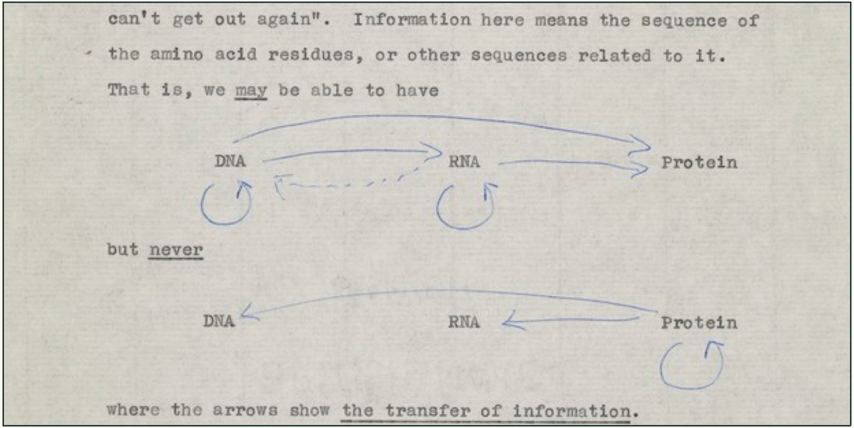
Population Parameters We Have Learnt

Population parameters	Sample statistics
μ	$\bar{x}$
σ^2	s^2
σ	s
π or p	p or $\hat{p}$



can't get out again". Information here means the sequence of the amino acid residues, or other sequences related to it. That is, we <u>may</u> be able to have

DNA RNA Protein

but <u>never</u>

DNA RNA Protein

where the arrows show <u>the transfer of information</u>.

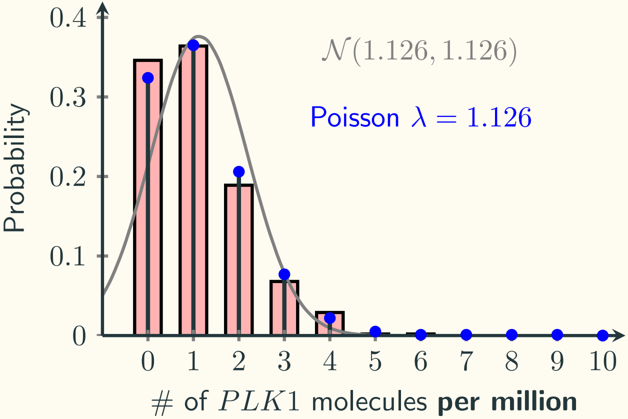
Credit: "Ideas on protein synthesis (Oct. 1956)". Wellcome Collection.

Sample Proportion Example

Gene expression (over-simplified RNA-seq): We know the probability of detecting *PLK1* is $\pi = 0.000001126088083$. If we take a random sample of $n = 1,000,000$ mRNA molecules, what is the sampling distribution of proportion of *PLK1*?

$$\mathcal{N}(\mu = 1.126 \times 10^{-6}, \sigma^2 = 1.126 \times 10^{-12})?$$

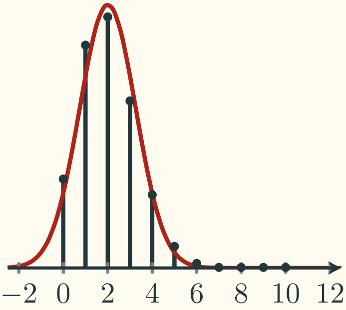
Results from 1,000 samples: $(n = 1,000,000)$



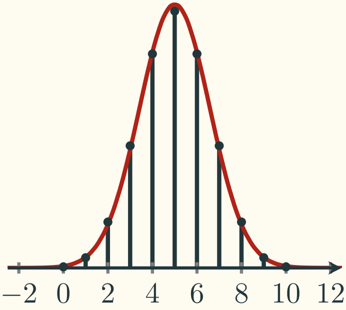
Approximation of The Binomial Distribution

$$B(n,p)\begin{cases} \dot{\sim}\ \mathcal{N}(\mu = np, \sigma^2 = npq) & \text{, when } np \geqslant 10 \text{ and } nq \geqslant 10 \\ \\ \dot{\sim}\ Pois(\lambda = np) & \text{, when } n \text{ is large, and } p \text{ is small,} \\ & \text{ such that } np \text{ is between } 0 \text{ and } 10. \\ \\ \sim B(n,p) & \text{, otherwise} \end{cases}$$

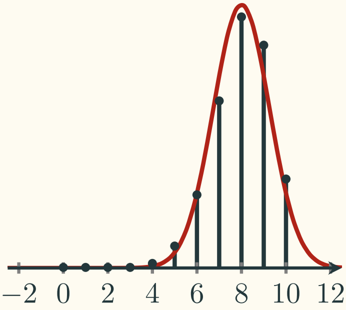
The Limitations on np and nq



$B(10, 0.2)$, $\mathcal{N}(2, 1.6)$



$B(10, 0.5)$, $\mathcal{N}(5, 2.5)$



$B(10, 0.8)$, $\mathcal{N}(8, 1.6)$

The Limitations on np and nq

- Binomial: all data are within $[0, n]$
- Normal: no bounds $(-\infty,\ +\infty)$ for data, but most are within $[\mu - 3\sigma,\ \mu + 3\sigma]$
- Intuitively: when $[\mu - 3\sigma,\ \mu + 3\sigma]$ is within $[0, n]$, the approximation works well!

$$
\begin{aligned}
\mu - 3\sigma &> 0 \\
np - 3\sqrt{npq} &> 0 \\
np &> 3\sqrt{npq} \\
n^2p^2 &> 9npq \\
np &> 9q \\
np &> 9(1-p) = 9 - 9p
\end{aligned}
$$

$$
\begin{aligned}
\mu + 3\sigma &< n \\
np + 3\sqrt{npq} &< n \\
n(1-p) &> 3\sqrt{npq} \\
n^2q^2 &> 9npq \\
nq &> 9p \\
nq &> 9(1-q) = 9 - 9q
\end{aligned}
$$

Interval Estimation For The Proportion

Goal: for a population containing an unknown proportion (π) of data of our interest, find a and b, such that $\mathbb{P}(a \leqslant \pi \leqslant b) = 0.95$.

$$\mathbb{P}(-1.96 \leqslant Z \leqslant 1.96) = 0.95$$

$$\mathbb{P}\left(-1.96 \leqslant \frac{p - \mu_P}{\sigma_P} \leqslant 1.96\right) = 0.95$$

$$\mathbb{P}\left(-1.96 \leqslant \frac{p - \pi}{\sqrt{\frac{\pi(1-\pi)}{n}}} \leqslant 1.96\right) = 0.95$$

$$\mathbb{P}\left(p - 1.96\sqrt{\frac{\pi(1-\pi)}{n}} \leqslant \pi \leqslant p + 1.96\sqrt{\frac{\pi(1-\pi)}{n}}\right) = 0.95$$

Confidence Interval For The Proportion

95% CI For The Sample Proportion

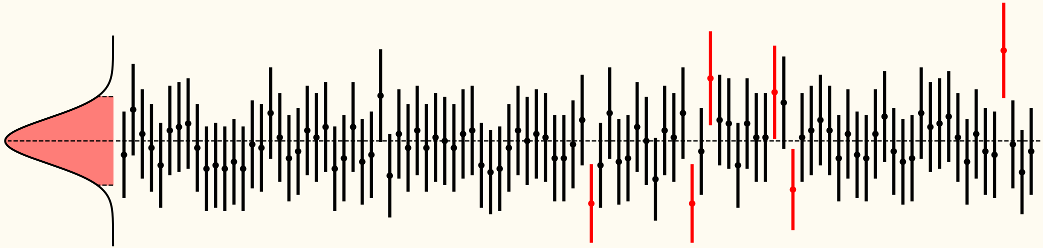
The Wald Interval:

$$\left[p - 1.96\sqrt{\frac{p(1-p)}{n}},\ p + 1.96\sqrt{\frac{p(1-p)}{n}}\ \right]$$

- **Not using t-distribution?** - You don't need to! Remember $\sigma_{\boldsymbol{P}} = \sqrt{\frac{\pi(1-\pi)}{n}}$, and when p is calculated to estimate π, then $\sigma_{\boldsymbol{P}}$ is automatically determined, unlike in the situation of the mean, where you have to do extra (independent) calculation of s to estimate σ, which causes the extra error.

Simulation of 95% CI For The Proportion

100 95% CI for the proportion, constructed using the Wald interval



Probability vs. Statistics

Probability:	Previous studies showed that the drug was 80% effective. Then we can anticipate that for a study on 100 patients, on average 80 will be cured and at least 65 will be cured with 99.99% chance.
Statistics:	We observe that 78/100 patients were cured by the drug. We will be able to conclude that we are 95% confident that for other studies the drug will be effective on between 69.88% and 86.11% of patients.

Sample Size Estimation Using Confidence Interval of The Proportion

Estimate Sample Size: We want to estimate the percentage of people cured by the drug. Suppose we could draw a truly random sample, and we want a 95% confidence interval estimation with a margin of error no more than $\pm 2\%$. What is the smallest sample size required to obtain the desired margin of error ?

$$95\% \text{ confidence interval: } p \pm 1.96\sqrt{\frac{p(1-p)}{n}}$$

Goal: find the smallest n such that it guarantees that $1.96\sqrt{\frac{p(1-p)}{n}} \leqslant 0.02$

Conditions For Interval Estimation For The Proportion

1. Random Samples

2. Normal Condition: the sampling distribution of p needs to be normal
   - $np \geqslant 10$
   - $nq \geqslant 10$

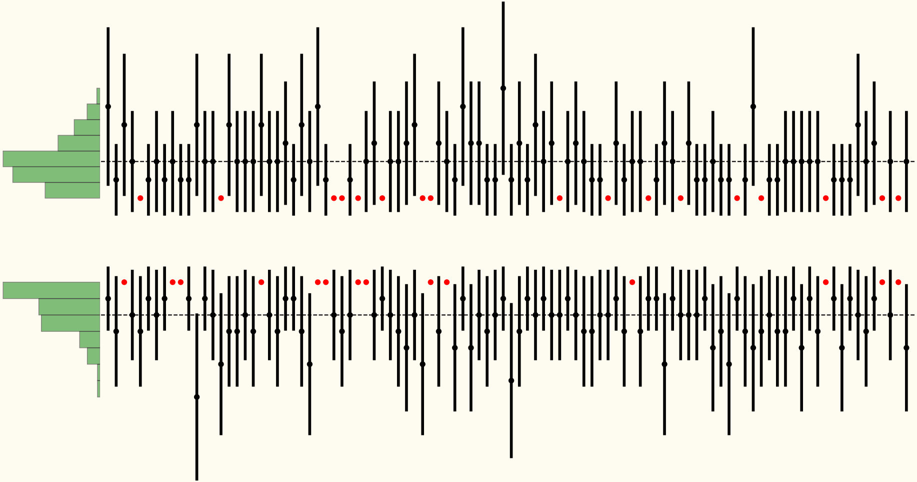
3. Independence ($n < 10\%$ population size)

Violation of The Conditions

100 simulated 95% CI using the Wald interval

$n = 200$

$p = 0.01$



$n = 200$

$p = 0.99$

What to do when the normal condition is not met?

- Wilson score interval
- Jeffreys interval
- Agresti–Coull interval
- Arcsine transformation
- Clopper–Pearson interval (the exact method)