Speaking more general...

Let a parameter $\theta$ of $f(X)$ $\{$such as $\mu \equiv E[X]$, $\sigma^2 \equiv E[(X-\mu)^2]$, ...$\}$

If $\exists$ an estimator $\hat{\theta} = \hat{\theta}(n, X_1, \dots, X_n)$ such that $\hat{\theta} \xrightarrow{P} \theta$ $\{$consistent$\}$ and $\sqrt{n}(\hat{\theta} - \theta) \xrightarrow{d} Z$, then

$$\boxed{\begin{array}{l} \hat{\theta} \xrightarrow{P} \theta \quad \text{that} \\ \text{AND} \\ \sqrt{n}(\hat{\theta}-\theta) \xrightarrow{d} Z \sim \xi \end{array} \xrightarrow[\text{method}]{\text{delta}} \sqrt{n}\left(h(\hat{\theta}) - h(\theta)\right) \xrightarrow{d} h'(\theta)^2 \cdot Z \quad \forall \text{ continuous } h}$$

If we consider a population parameter $\boxed{\theta \equiv E[g(X)]}$ with $g(X)$ s.t. $E[g(X)]$, $E[g(X)^2] < \infty$, then

(for WLLN, for CLT)

- WLLN : the plug-in estimator $\hat{\theta} \equiv \frac{1}{n}\sum_1^n g(X_i) \xrightarrow[n\to\infty]{P} E[g(X)] \equiv \theta$
- CLT : the plug-in estimator $\hat{\theta} \equiv \frac{1}{n}\sum_1^n g(X_i)$, $\sqrt{n}(\hat{\theta} - \theta) \xrightarrow[n\to\infty]{d} Z \sim N(0, V_g)$, $V_g \equiv Var(g(X)) \equiv E[(g(X)-\theta)^2]$

$$\boxed{\text{delta method: } \sqrt{n}\left(h(\hat{\theta}) - h(\theta)\right) \xrightarrow{d} Z \sim h'(\theta)^2 \cdot N(0, V_g) \equiv N(0, h'(\theta)^2 \cdot V_g) \equiv N(0, V_h),\ V_h \equiv h'(\theta)^2 \cdot V_g}$$

*1) To practically use the asymptotic distribution we need an estimation for $V_h$. It turns out that the plug-in estimator $\widehat{V_h} \equiv \widehat{h'(\theta)^2 \cdot V_g} \equiv \widehat{h'(\theta)^2} \cdot \widehat{V_g} = h'(\hat{\theta})^2 \cdot \widehat{V_g} \equiv h'\left(\frac{1}{n}\sum_1^n g(X_i)\right)^2 \cdot \frac{1}{n}\sum_1^n \left(g(X_i) - \frac{1}{n}\sum_1^n g(X_i)\right)^2 \xrightarrow{P} V_h$ ✓

*2) $h(\hat{\theta}) \overset{a}{\sim} N(h(\theta), V_h/n)$ and $t \equiv \dfrac{\sqrt{n}(\hat{\theta} - \theta)}{\sqrt{V_g}} = \dfrac{\sqrt{n}\left(h(\hat{\theta}) - h(\theta)\right)}{\sqrt{V_h}} \sim N(0,1)$