Let's apply this theory to explain the effect of FERROELECTRICITY.

In many insulators an applied electric field, $E$, causes internal stress which is $\sim E^2$

This phenomenon is known as **electrostriction**.

We don't want to discuss this, instead there are some interesting crystals where strain $\sim E$: pyroelectrics, ferroelectrics and piezoelectrics.

...are very interesting since they undergo the 2$\text{nd}$ order phase transition.

**NR. Symmetry consideration**: To have internally uncompensated electric fields: $\sum \vec{P}_i(r) = \vec{P}$

Below the transition $T_c$, crystal must transform into a new crystal symmetry which has no inversion symmetry, i.e. non-centrosymmetric.

**Side note**: The difference between FERRO- and PYRO-.

![Diagram]

Let's apply the Landau idea from $L_1$ and $L_2$ to $\text{BaTiO}_3$ — a "classic" FE

**WHAT ARE FERROELECTRICS?**
Free energy as usual can be written as:

\[ F(\eta, T) = F(P, T) = \]

Here \( P \) is polarization which is our order parameter since below \( T_c < P \neq 0 \).

\[ \frac{dF}{d\eta} = 0 \quad \Rightarrow \quad 2a(T - T_c)P + 2B P^3 = 0 \]

\[ P_M = \begin{cases} 0 & T > T_c \\ \left[ \frac{-a(T - T_c)}{2B} \right]^{1/2} & T < T_c \end{cases} \]

Insert \( P_M \) into \( F(P, T) \) we can get:

\[ F = \begin{cases} F_0(T) & T > T_c \\ F_0(T) - 4a(T - T_c) \cdot \left( \frac{-a(T - T_c)}{2B} \right)^2 & T < T_c \end{cases} \]

\[ = \begin{cases} F_0(T) & T > T_c \\ F_0(T) - a^2(T - T_c)^2 \cdot \frac{1}{4B} & T < T_c \end{cases} \]

Let's think how heat capacity changes at \( T_c \):

\[ C = T \frac{dS}{dT} = -T \frac{2F}{T^2} \]

\[ \frac{2F}{T^2} = \frac{-a^2}{2B} \]

\[ C = \begin{cases} \text{(constant)} & T > T_c \\ T \cdot \frac{a^2}{2B} & T < T_c \end{cases} \]