Organics (I) [Bougonoius]

- Provide quasi-1D and quasi-2D structure.

- Molecular crystals (chains) are built by stacking flat molecules. 
  ![Diagram](image)

  Each molecule is by itself closed shell 
  ➞ stacking results in band insulator.

- To build conductor, place 2 different species
  ![Diagram](image)

  ▲ First example: TTF-TCNQ (1973)
  ▲ Sharp metal-insulator transition at $T_c = 54 \, \text{K}$, 
    caused by Peierls instability

- Peierls Instability in 1D.
  ▲ Caused primarily by nesting
  ▲ Consider $e^-$-phonon coupling:
    $H = \sum_{k} \epsilon_k C_{k\sigma} C_{k\sigma}^\dagger$
    $H = \sum_{k} \epsilon_k C_{k\sigma} C_{k\sigma}^\dagger + \sum_i \omega_{b_0} b_{i\sigma}^\dagger b_{i\sigma} + \frac{1}{N_k} \sum_{k\sigma} \epsilon_{k\sigma} C_{k\sigma}^\dagger C_{k\sigma} \left(b_{k\sigma}^\dagger + b_{k\sigma}\right)$
    $\implies \chi_p(q, T) = T - \lambda \xi^0(q, T)$, $\lambda \sim \frac{1}{\pi k_F} \ln \left(\frac{\xi}{T}\right)$

  ▲ This gives a critical scale for fluctuations:
    $T_p^0 = 1.13 \, \xi^0 k_F$ $e^{-\frac{1}{\lambda}}$ $\lambda \sim \frac{q^2}{\omega_0}$

• Cooper Instability & Superconductivity
  \[ \chi_c(q=0,T) \approx \frac{1}{\pi T} \ln \left( \frac{1.13 T}{e} \right) \]
  \[ \chi_c(q=0,T) \approx \frac{2e^2(T)}{1 - \frac{1}{2} x \ln \left( \frac{1.13 T}{e} \right)} \rightarrow T_c^0 \approx 1.13 \omega_c e^{-2/L^2} \ll T_p \]

• Method to reduce Peierl in favor of Cooper
  ▲ Increase pressure
  ▲ Chemical route

• First stable organic metal: TMTSF - DMTCNQ
  ▲ Increased interchain coupling reduced nesting
  \[ \varepsilon_k \rightarrow \varepsilon'_k = \varepsilon_k - 2t_1 \cos(kx) - 2t_{12} \cos(2kx) \]

• Instead of stacking 2 species of organics, produce charge transfer using cation-radical \( X = PF_6, AsF_6, \ldots \)
  e.g. \((\text{TMTSF})_2 X \] \[ \bigcirc \square \]

△ In this material: metal-insulator transition at 12K, and the insulator is magnetic. ⇒ Coulomb more important than phonon

△ Under pressure, \((\text{TMTSF})_2 PF_6\) is a superconductor
  (the first organic superconductor)

• Around the same time the Fabre salt are synthesized: \((\text{TMTTF})_2\)
  ▲ \( S - S > Se - Se \) ⇒ more 1D.
  ▲ Charge gapped but spin gapless
  ⇒ these are Mott insulator
(TMTTF)$_2$X and (TMTSF)$_2$X can be combined into one phase diagram by combining "chemical pressure" & "physical pressure".

**Diagram:**

- **Experimental**
- **SP:** spin-Peierl
- **AF:** antiferromagnetic
- **SC:** superconductor
- **MI:** Mott insulator
- **CO:** charge order

The graph shows the phase transitions and regions denoted by these terms in the context of the phase diagram.