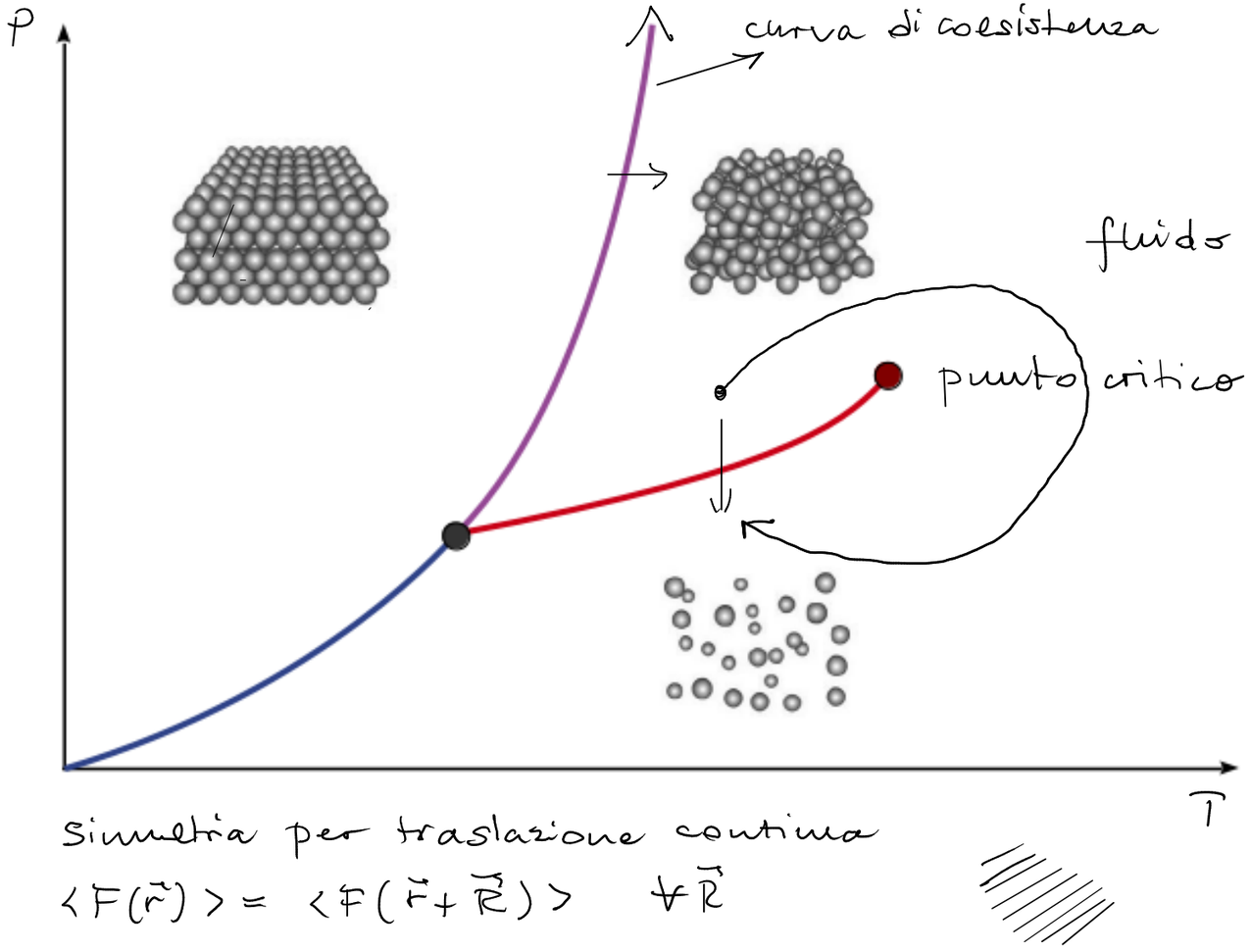
FORME DI DISORDINE

3cfdhpq

Diagramma di fase → ES.: Argon.



Simmetria per traslazione continua

$\langle F(\vec{r}) \rangle = \langle F(\vec{r}+\vec{R}) \rangle \quad \forall \vec{R}$

Fase cristallina : simmetria trasl. discreta

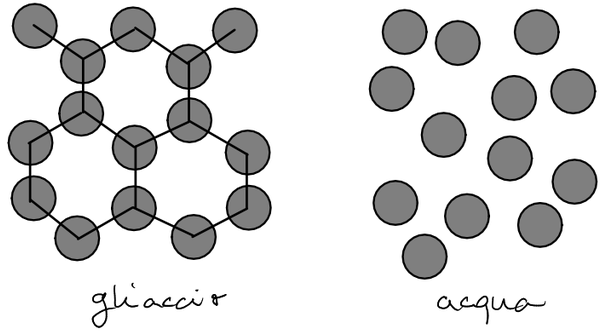
$\vec{R}_\ell = l_1\vec{a}_1 + l_2\vec{a}_2 + l_3\vec{a}_3$

$F(\vec{r}+\vec{R}_\ell) = F(\vec{r}) \quad \forall \vec{R}_\ell$

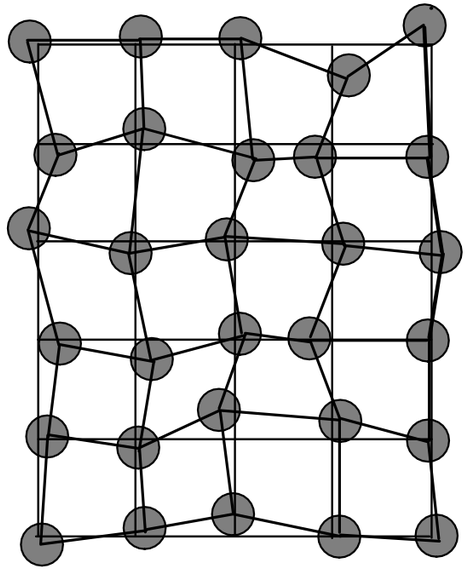
Fase liquido : no simmetria
traslazione discreta

Media d'ensemble $\langle \dots \rangle$

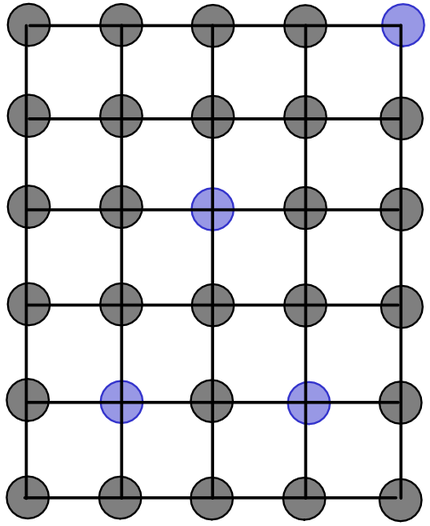
$\langle F \rangle \cong \dfrac{Tr\left[e^{-\beta H} F\right]}{Tr\left[e^{-\beta H}\right]}$ → media sul disordine



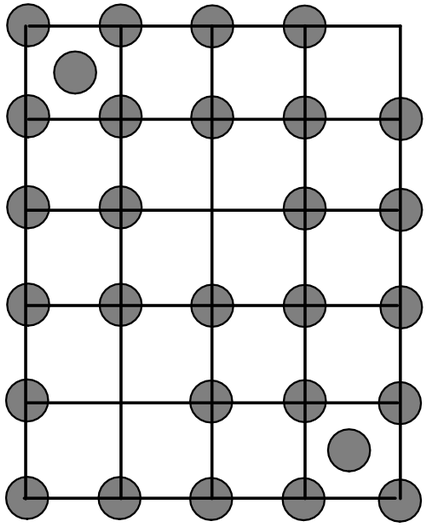
DISORDINE SOSTITUZIONALE



cristallo caldo
$T > 0$

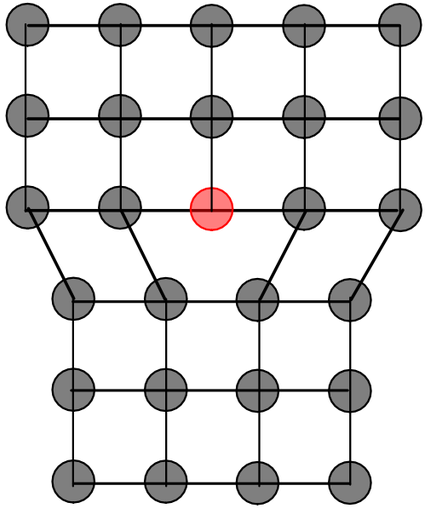


impurità A/B

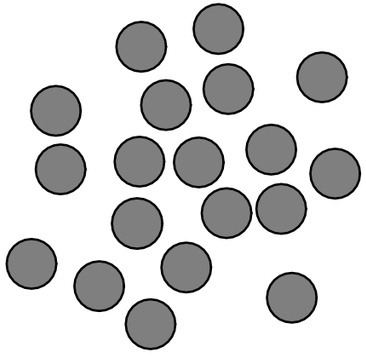


difetti puntuali

DISORDINE TOPOLOGICO



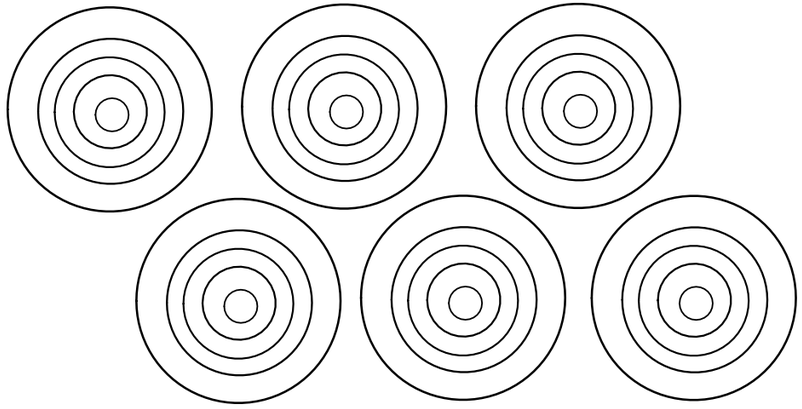
dislocazione



materiali amorfi

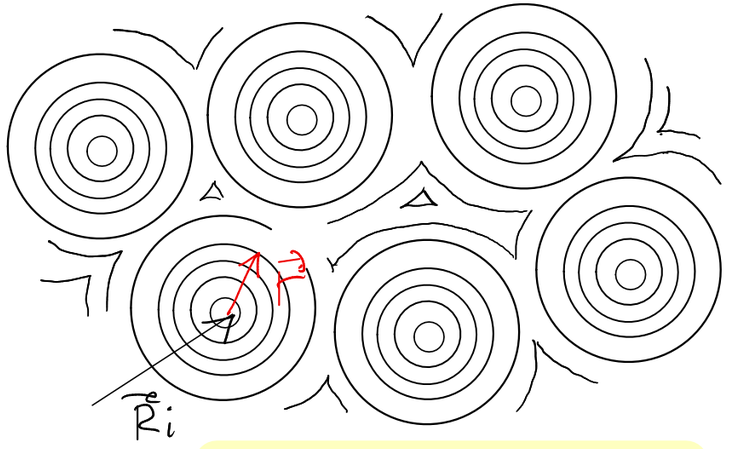
$F(\vec{r})$ → osservabile locale

[Ziman]



ordine cristallino

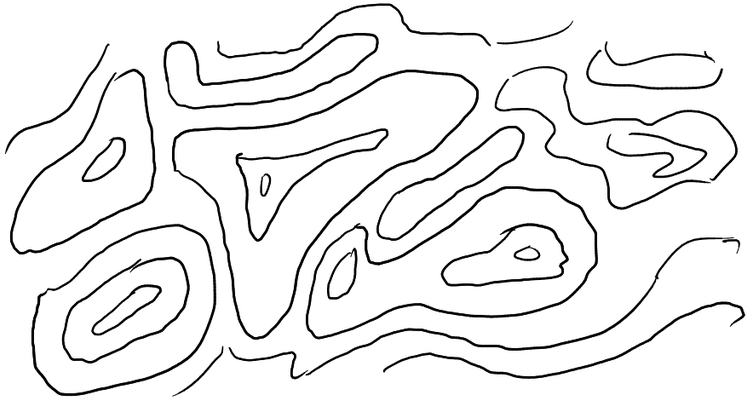
$F(\vec{r}+\vec{R}_\ell) = F(\vec{r}) \quad \forall \vec{R}_\ell$



disordine topologico

$F(\vec{r}+\vec{R}_i) \approx F(\vec{r}) \quad \forall \vec{R}_i$

$|\vec{r}| \lesssim r_c$



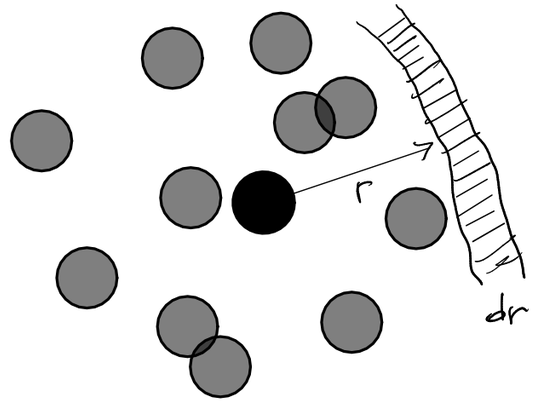
disordine continuo

- leggi di conservazione
- leggi costitutive

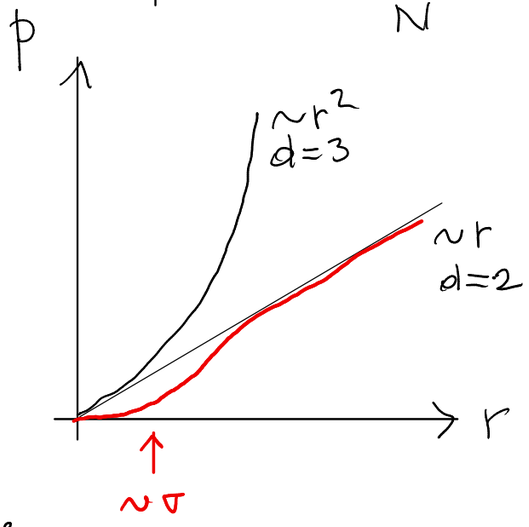
CORRELAZIONI

Ordine a corto raggio

Es: gas, leghe



$$p(r) = \frac{N(r)}{N}$$



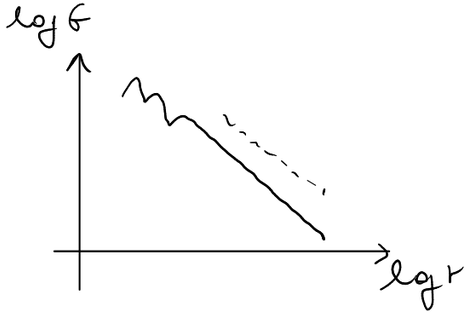
funzione di correlazione

$$G(\vec{r}', \vec{r}'')$$

Ordine a quasi-lungo raggio

Es: solidi cristallizzati

$$G(\vec{r}', \vec{r}'') \sim r^{-\gamma} \qquad \gamma > 0$$



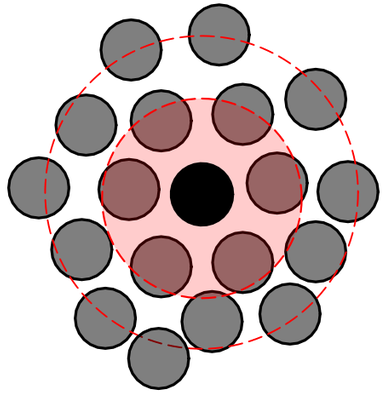
Ordine a lungo raggio

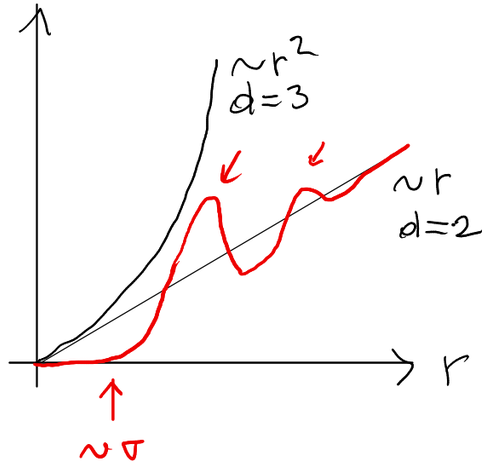
$$\begin{cases} G(\vec{r}_{e'}, \vec{r}_{e''}) \to \text{cost} \\ |\vec{r}_{e'} - \vec{r}_{e''}| \to \infty \end{cases}$$

Es: cristallo

Ordine a raggio intermedio

Es: liquidi





$$G(\vec{r}', \vec{r}'') \sim r^{-n} \exp(-r/\xi) \qquad n \geq 0$$

$\vec{r} = \vec{r}'' - \vec{r}'$

$\xi \equiv$ lunghezza di correlazione

$\xi \to \sigma \quad T \to \infty$; $\xi \to \infty \quad T \to T_c$

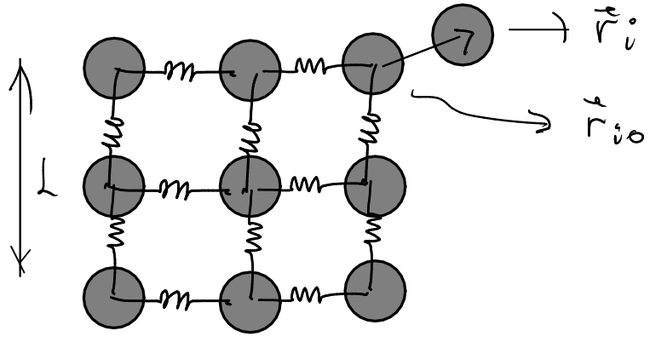
ORDINE E DIMENSIONALITÀ

'1930 : Peierls, Landau

'1960 : teor. Mermin – Wagner : Sotto ipotesi abb. generali sulla natura delle interazioni, non c'è ordine spontaneo a lungo raggio in $d=1$ e $d=2$

Esempi

1) Vibrazioni armoniche reticolo



$$|\Delta\vec{r}_i|^2 = |\vec{r}_i - \vec{r}_{i0}|^2$$

$$|\Delta\vec{r}|^2 = \frac{1}{N}\sum_{i=1}^{N} |\Delta\vec{r}_i|^2$$

Spost. quadratico medio

$$\langle |\Delta\vec{r}|^2 \rangle \sim \int \frac{d^d k}{\omega^2} \sim \int \frac{k^{d-2}}{k}\, dk$$

$\omega \simeq ck$

$$\sim \int k^{d-3}\, dk$$

$$\langle |\Delta\vec{r}|^2 \rangle \sim \ln L \quad d=2$$

2) Spin 1d

J accoppiamento primi vicini

↑ ↑ ↑ ↑ ↑ ↑

↑ ↑ ↑ | ↓ ↓ ↓

$\Delta U = J$ costo energetico

$\Delta S = k_B \ln N$ guadagno entropico

$$\Delta F = \Delta U - T\Delta S$$

$$= J - k_B T \ln N < 0$$

se $N \to \infty$

Scala atomica

$10^{-10} - 10^{-9}$

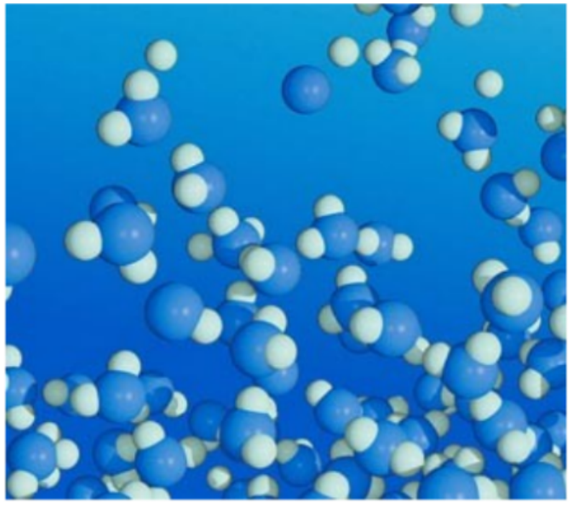
Scala mesoscopica

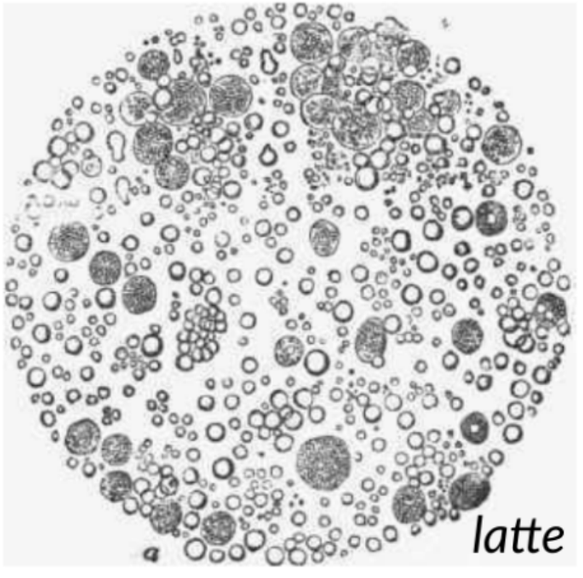
$10^{-7} - 10^{-5}$

Scala macroscopica

$10^{-2} - 10^{0}$

Lunghezza [m]





costituenti elementari ⟶ proprietà macro

↓

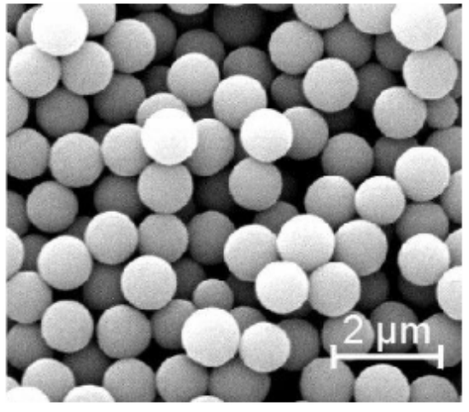
materia condensata DURA

colloidi, polimeri

↓

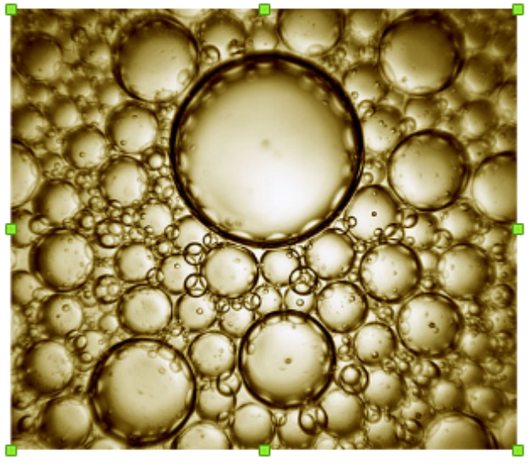
materia condensata SOFFICE

PMMA

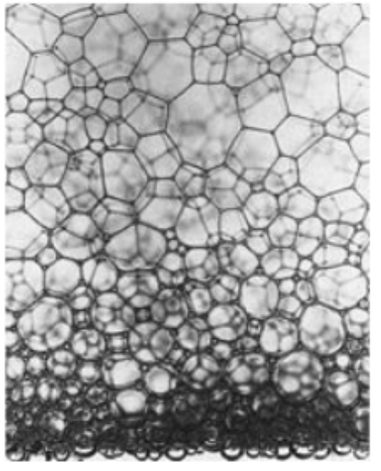


dispersione colloidale

mayo, yogurt



emulsioni



schiuma

particelle solide → sospese in un solvente

particelle liquide → sospese in un solvente

particelle gassose → sospese in un solvente