Title: Spontaneous Symmetry Breaking and Goldstone Theorem

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Abstract:

We discuss the concept of spontaneous symmetry breaking and illustrate it with a general example. We consider Wigner-Weyl and Nambu-Goldstone realisations of symmetry in the quantum theory. Next, we state Goldstone's theorem and sketch its proof. We discuss why quantum chromodynamics is not realised in the Wigner-Weyl mode.

Remote Experience for Young Engineers and Scientists 2023

Spontaneous Symmetry Breaking and Goldstone Theorem

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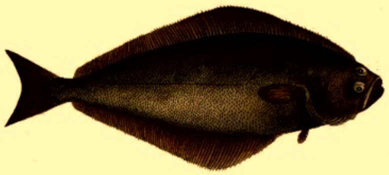
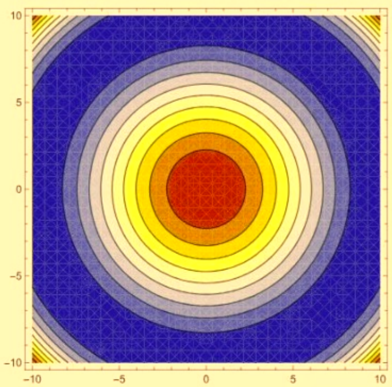
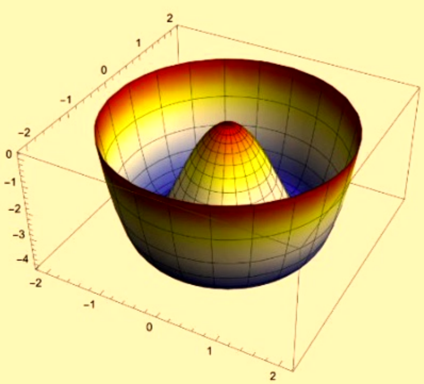
examples of spontaneous symmetry breaking



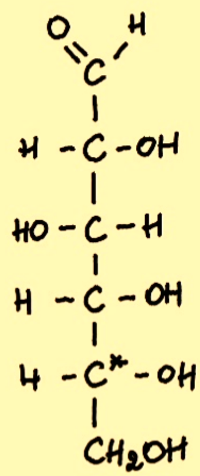
halibut

flounder

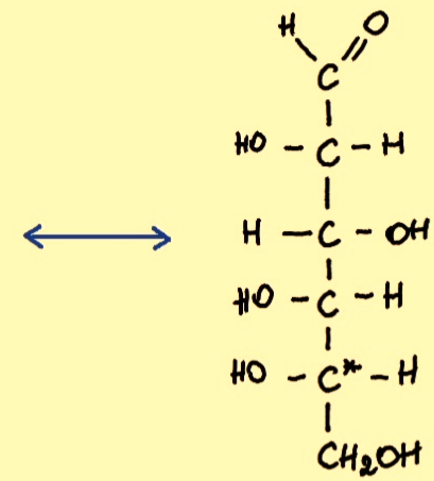




$$V(x,y) = (x^2+y^2)^2 - \mu(x^2+y^2)$$



D-glucose



L-glucose

Goldstone theorem

Nambu-Goldstone mode

$$\mathscr{U}(\alpha)\,|0\rangle = e^{i\alpha^a \mathcal{Q}^a}\,|0\rangle \neq |0\rangle \qquad \mathcal{Q}^a\,|0\rangle \neq 0$$

Every spontaneously broken continuous symmetry generator yields a massless boson in the spectrum of the theory.

The existence of a non-vanishing vacuum expectation value of the commutator

$$\langle 0|\,[\mathcal{Q}^a, \phi(x)]\,|0\rangle \neq 0$$

for a field in a continuous symmetry yields massless particle(s) in the theory.

SSB in quantum chromodynamics

$$\boxed{SU(3)_R \times SU(3)_L} \times U(1)_A \times U(1)_V$$

⇒ **flavour symmetry is spontaneously broken**

⇒ **the Goldstone boson: pion** π

⇒ **but** $m_\pi = 139 MeV$ **(compare to proton mass scale:** $m_p = 938 MeV$**)**

Thank You!