Symmetries of the nuclear Hamiltonian
(exact or almost exact)

1. **Translational invariance**
2. **Galilean invariance (or Lorentz invariance)**
3. **Rotational invariance**

} Continuous transformations (appear to be universally valid)

4. Time reversal
5. Parity (space reflection)
6. Charge independence and isobaric symmetry
7. Baryon and lepton number symmetry
8. Permutation between the two nucleons (imposed by the exclusion principle)

Dynamical symmetries
apply in certain cases, provide useful coupling schemes

1. Chiral symmetry (broken by a quark condensate; valid for massless quarks)
2. SU(4) symmetry (Wigner supermultiplet)
3. SU(2) symmetry (seniority)
4. SU(3) symmetry (Elliott model)

Symmetries in quantum mechanics

(see "Symmetry in Physics", J.P. Elliott and P.G. Dawber, The Macmillan Press, London)

- Wave equation for the Hamiltonian operator:

$$\hat{H}\Psi_k = E_k\Psi_k$$

- Group of transformations $\mathcal{G}$ whose elements G commute with H:

$$G\hat{H}G^{-1} = \hat{H}$$

- We say that H *is invariant* under $\mathcal{G}$ or totally symmetric with respect to the elements of $\mathcal{G}$
- What are the properties of $G\Psi_k$?
- Representation of the group (represents group elements as matrices so that the group operation can be represented by matrix multiplication)

$$\hat{G}\phi_p = \sum_{q=1}^{d} D^{\alpha}_{qp}(G)\phi_q$$

d: dimension of the representation

$D^{\alpha}_{qp}(G)$: matrix representation of the group

ϕ_q: basis

If all matrices D can be put into a block-diagonal form, the representation is irreducible