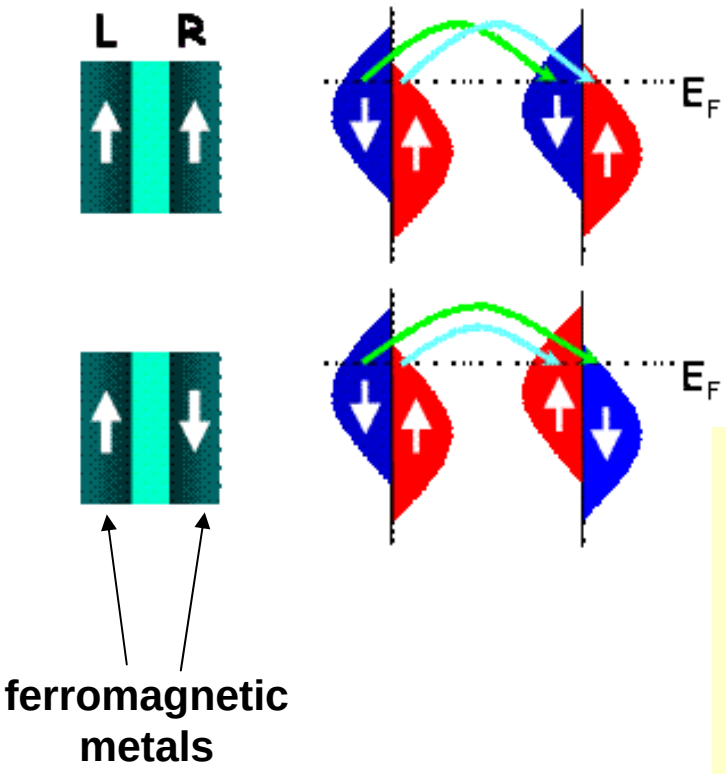
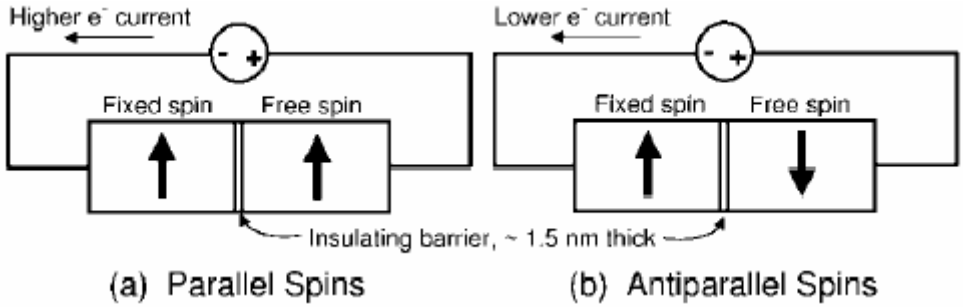
Magnetic tunnel junctions and tunnelling magneto-resistance





$$I_{\uparrow\uparrow} \propto n_L^{\uparrow} n_R^{\uparrow} + n_L^{\downarrow} n_R^{\downarrow}$$ - parallel magnetization

$$I_{\uparrow\downarrow} \propto n_L^{\uparrow} n_R^{\downarrow} + n_L^{\downarrow} n_R^{\uparrow}$$ - antiparallel magnetization

$$TMR = \frac{I_{\uparrow\uparrow} - I_{\uparrow\downarrow}}{I_{\uparrow\downarrow}} = \frac{2P_L P_R}{1 - P_L P_R}$$

where $P_L = \frac{n_L^{\uparrow} - n_L^{\downarrow}}{n_L^{\uparrow} + n_L^{\downarrow}}$ and $P_R = \frac{n_R^{\uparrow} - n_R^{\downarrow}}{n_R^{\uparrow} + n_R^{\downarrow}}$ are

the spin polarizations of the left and the right ferromagnets

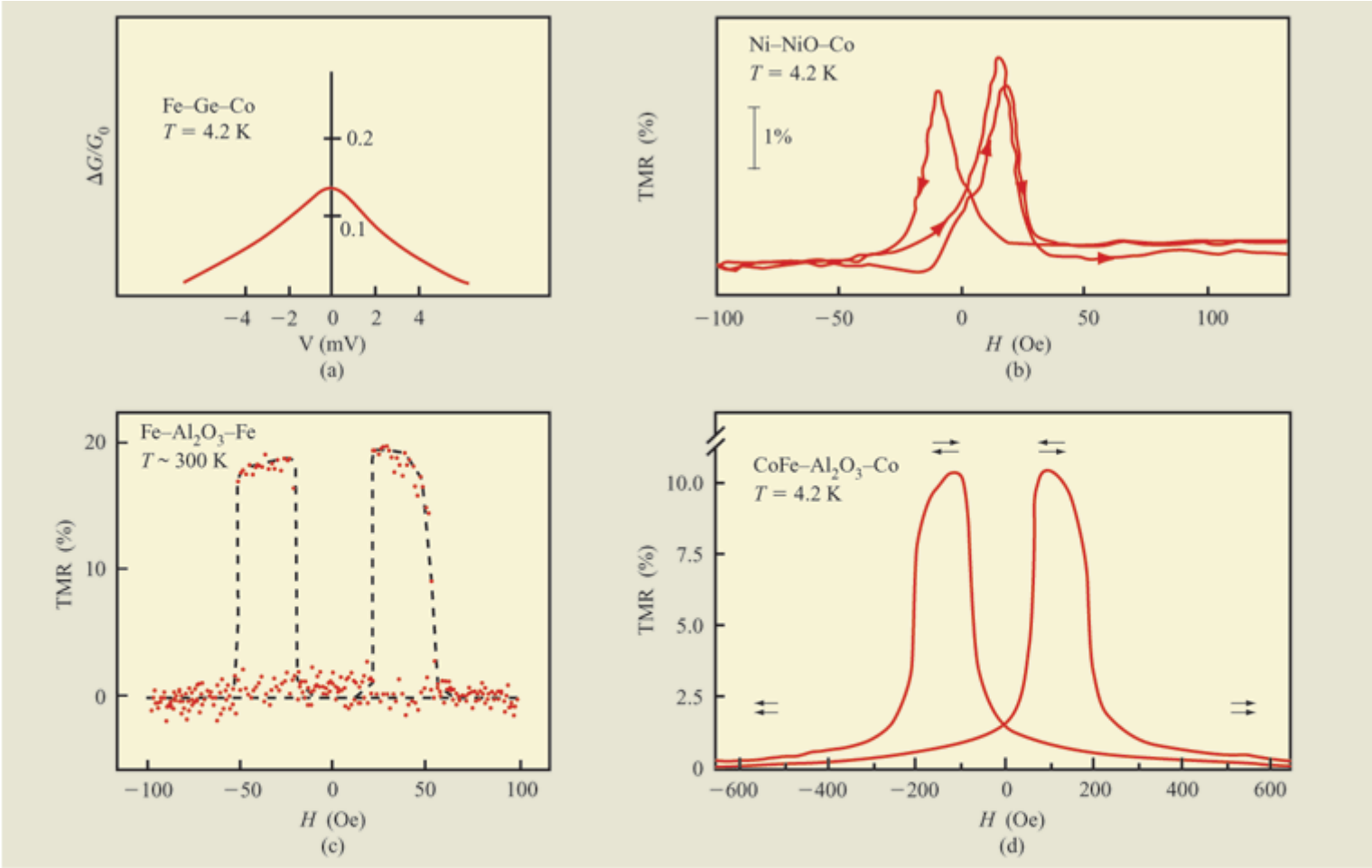
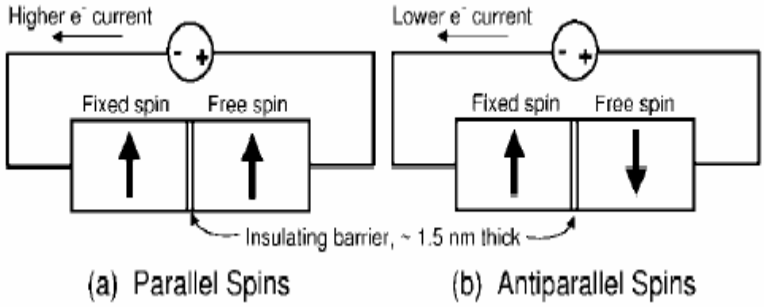
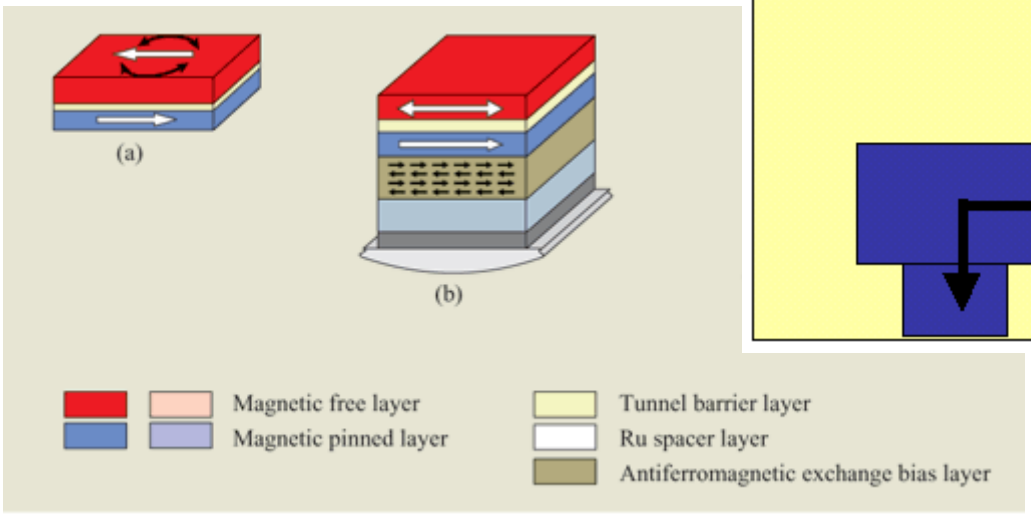


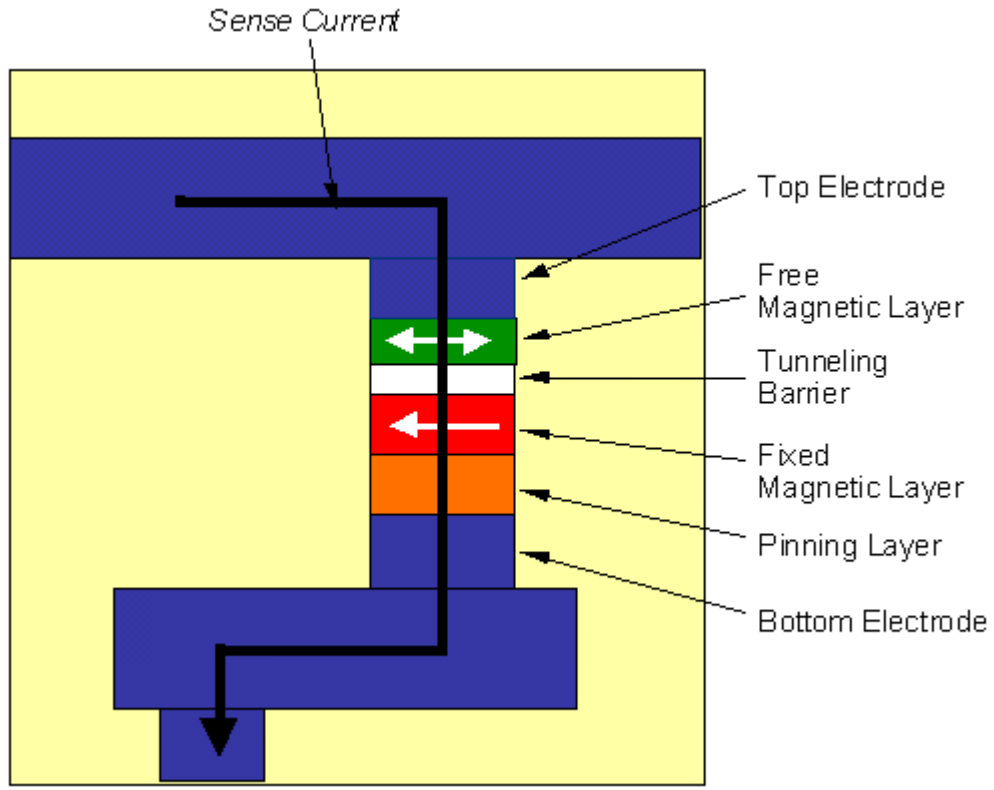
Figure 1

Early demonstrations of tunneling between ferromagnetic metals. (a) First demonstration of such tunneling — by Julliere in 1975 of tunneling at 4.2 K in an Fe–Ge–Co junction. Adapted from [11]; ©1975, with permission from Elsevier. (b) Demonstration by Maekawa and Gafvert in 1982 of tunneling at 4.2 K in a Ni–NiO–Co tunnel junction. Adapted from [15], with permission; ©1982 IEEE. (c) Demonstration by Miyazaki and Tezuka in 1995 of tunneling at 300 K in an Fe–Al_2O_3–Fe junction. Adapted from [26], with permission. (d) Demonstration by Moodera et al. in 1995 of tunneling at 295 K in a CoFe–Al_2O_3–Co junction. Adapted from [27], with permission; ©1995 American Physical Society.

Magnetic tunnel junctions: read-heads for magnetic memory storage devices

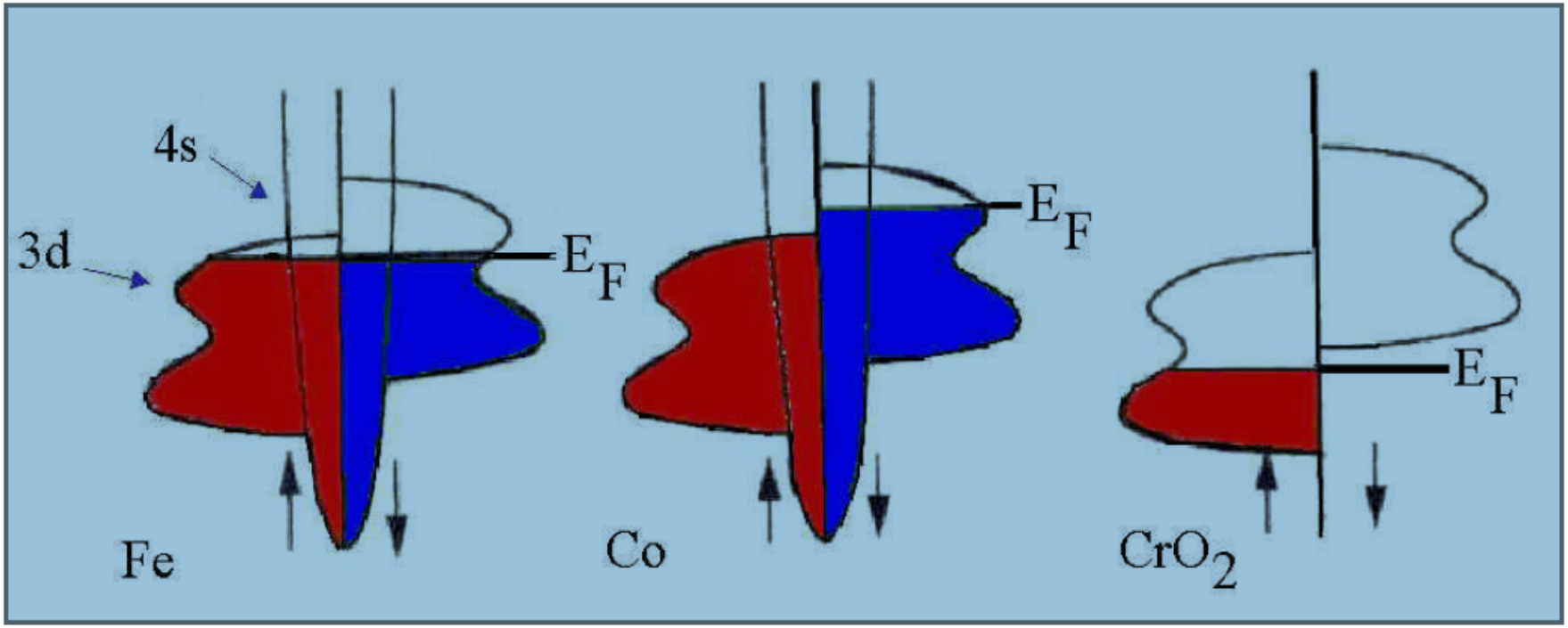






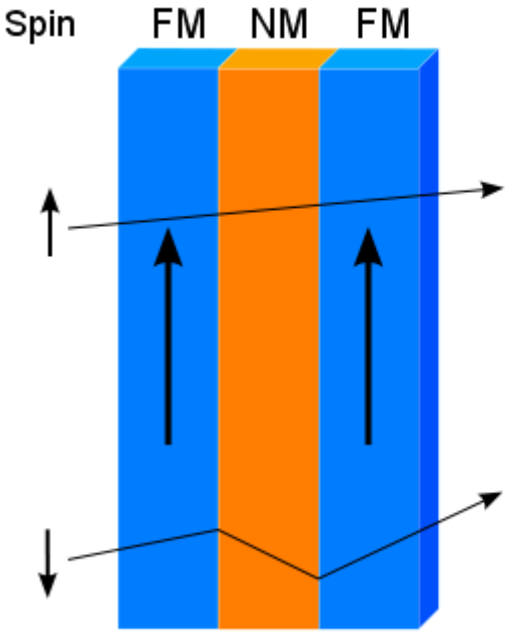
Half Metals

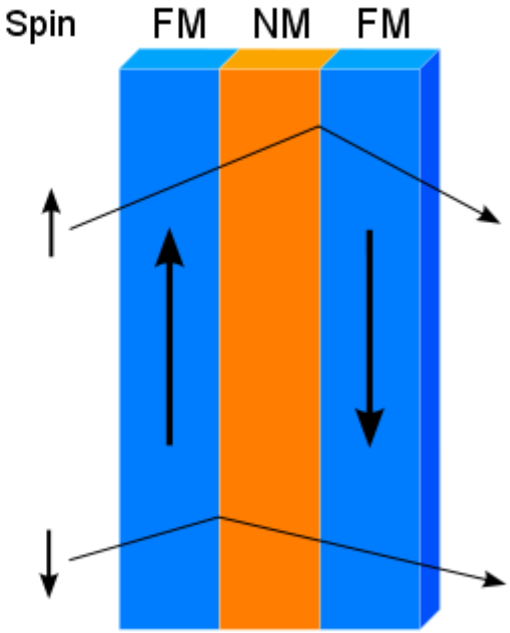
(Half Metallic Ferromagnets)

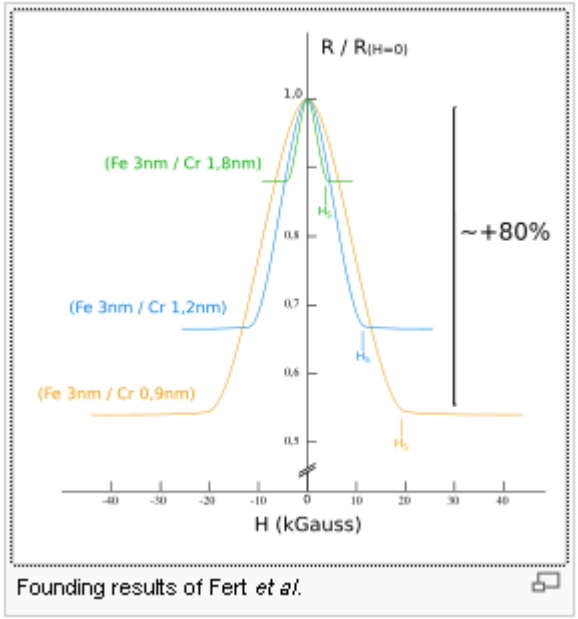


Half metals are ferromagnets whose density of states shows only one occupied spin-polarized sub-band at the Fermi energy E_F. Normal ferromagnets, like Fe and Co, have not only spin-polarized 3d electrons but also unpolarized 4s electrons at E_F. Half metals are compounds of more than one element and are mostly oxides or Heusler alloys.

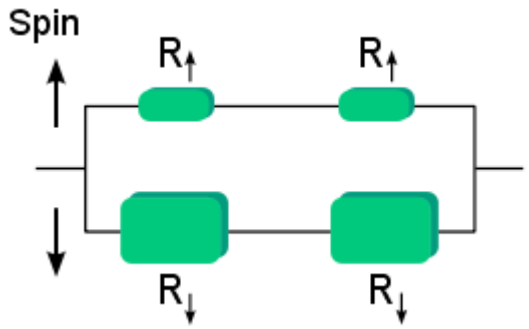
Giant magneto-resistance in ‘spin valves’: ferromagnet-metal-ferromagnet multi-layers; CPP (current perpendicular to the plane) devices

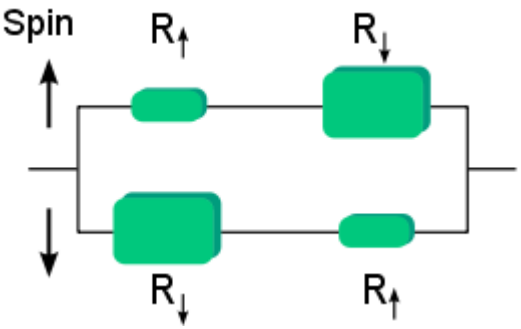






$$R_{antiparall\,el} > R_{parallel}$$





$$GMR = \frac{R_{antiparallel} - R_{parallel}}{R_{parallel}}$$

The Nobel Prize in Physics 2007

"for the discovery of Giant Magnetoresistance"

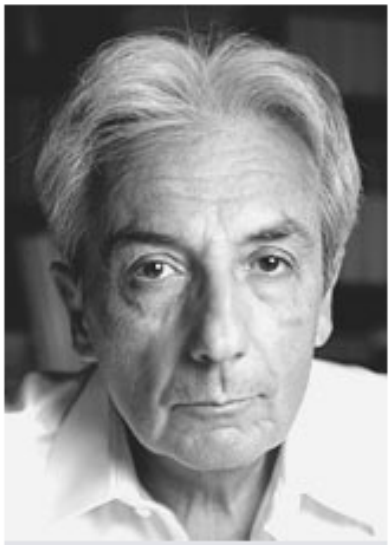


Photo: B. Fert, Invisuphoto

Albert Fert

◑ 1/2 of the prize

France

Université Paris-Sud;
Unité Mixte de Physique
CNRS/THALES
Orsay, France

b. 1938

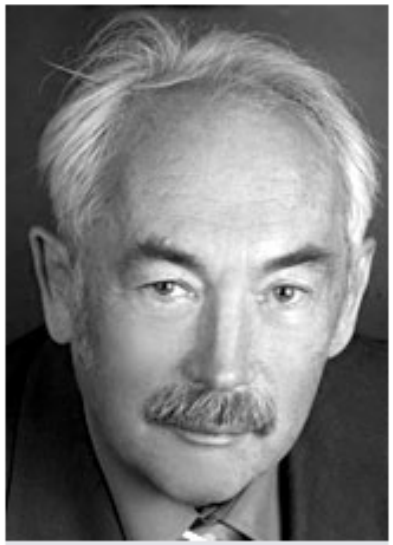


Photo: © Forschungszentrum Jülich

Peter Grünberg

◑ 1/2 of the prize

Germany

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Jülich, Germany

b. 1939