Property Pairs and Cause - Effect Relationships

Illustration

Language knows a lot of words for describing mechanical properties: brittle, hard, malleable, plastic, pliable, resilient, soft, springy, elastic, stiff, ... You understand all these words. You just don't know how to put a *number* on the property in questions and you might be uncertain about the *opposite* of a given property

- We force our students to "unlearn" some of what they individually associate with these words (and plenty of others like "energy", "work", "fatigue", "creep", or "heat") so we can instill a precise meaning that all of them share and that is usually expressible in numbers,
You might wonder why we do not simply introduce new scientific words that do not exist in everyday life. Well, we do. Quite frequently in fact. You just don't know about these words because, by definition, they do not appear in everyday language. Just wait until I hit you with enthalpy, eutectic, austenite, ledeburite, hypoeutectoid, interstitials or the logarithm dualis.
Anyway, here are two tables that may help to clear things up a bit:

Properties and Opposites		
Property	**Opposite**	**Remarks**
Brittle Can't be shaped by a hammer Glass, ceramic, cast iron	**Ductile** Can be shaped by a hammer Most metals, some plastic / polymers	May change with temperature ("Ductile to brittle transitions"; DTB) Cold / Hot Shortness: gets brittle if the temperature is too low / high.
Hard Needs large force to make an indent of a certain size	**Soft** Needs little force to make an indent of a certain size	For ductile materials like iron and steel hardness is just another word for "onset of plastic deformation"; or "beginning of dislocation" movement".
Stiff Materials with a large Young's modulus The *specific* stiffness *is* Young's modulus	**Resilient** Materials with a small Young's modulus	Stiffness has nothing whatsoever to do with hardness! There is no good word for the opposite; "resilient" is a compromise. You also could say: docile, or pliant. Resilience has a second meaning as: "ability to absorb energy when deformed elastically"
Talking about the stiffness of a blade or the resilience of a rubber matt mixes up the specific properties of the materials given by Young's modulus and the geometry of the object. A thick blade will be "stiffer" than a thin one made from the same material.		
Elastic deformation Complete recovery of shape after removal of (smaller) stress. Metal spring; rubber band	**Plastic deformation** Permanent change of shape after removal of (large) stress.	Ductility is the ability of a material to deform plastically after an initial elastic deformation.
Tensile being pulled; able to get longer	**Compressive** being pressed, able to get shorter	Cubes under tensile / compressive stress change into cuboids; all right angles are preserved.
Tensile stresses Forces per area trying to lengthen Force acts at right angle to surface	**Compressive stresses** Forces per area trying to shorten Force acts at right angle to surface	

Cause, Effect and relation		
Cause	**Effect**	**Remarks**
Forces (pulling, pushing, shearing, ...)	**Shape change** (Elongation, squeeze, folded, broken, ..	There are infinitely many ways forces can act on some piece of arbitrarily shaped material. The effect is always a shape change (however small) Identical forces cause different shape changes, depending on starting geometry. Forces are useless for calculations; we need *stress*
Stress σ Force (N) per area [cm^2]. [σ]=[N/cm^2]	**Strain** ϵ Strain=Elongation per length (no dimension) Number · 100=length change in %	Specific quantities. Necessary for calculations
Young's modulus definition: Simple: $\boldsymbol{\sigma = Y \cdot \epsilon}$ General: $\boldsymbol{Y = d\sigma / d\epsilon}$		Young's modulus is a *specific* property, characterizing a given material independent of its geometry / size. It describes the magnitude of the elastic strain caused by stress
$\boldsymbol{\sigma > \sigma_{yield}}$ Stress *larger* than some critical value *yield stress*: where the materials "gives" or *yields*	**Plastic deformation** or **Fracture**	σ_{crit} defines hardness for ductile materials and (loosely) "fracture toughness" for brittle materials