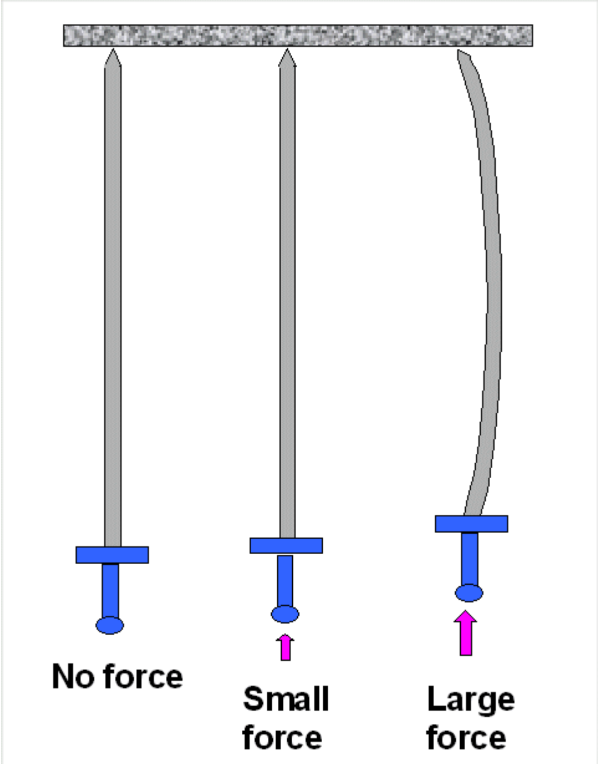
12.2.3 Sword Buckling

How do parameters of your sword influence "buckling", the shape-change if you push straight and at a right angle at an immobile hard object?

Your sword will respond to static load somewhere on its blade by some elastic deformation - as long as it doesn't break, chip or deform permanently. Bending the blade "sideways" is the first basic situation that comes to mind and I have dealt with that in the preceding sub-chapter. The second basic possibility is running your blade straight against something hard, causing it to **buckle**:



Basic "buckling beam" experiment

Applying force as shown above constitutes a compressive test, the opposite of tensile testing. I have treated compressive testing, including buckling, very briefly in the science part of chapter 3 but now we need to consider it in the backbone main section.

The long and short of buckling under compressive stress is:

- For forces (better would be stress=force per area, remember?) below a certain limit, the beam (or sword) deforms elastically by getting somewhat shorter as shown (exaggeratedly) in the middle situation above.
- For forces at or above a certain critical limit the beam (or sword) deforms elastically by buckling sideways as shown (in the right-hand situation above).
- Increasing the force beyond that critical limit makes the buckling more pronounced, followed by permanent bending (plastic deformation) and eventually fracture.
- Buckling occurs for all structures under compressive stress - like columns, towers or simply most of architecture. If your column or wall starts to buckle because it was designed too flimsy or the load gets too large because other columns holding up the structure were destroyed, it is all over! The World Trade Centers in 2001 bear witness to this.

It remains to determine how this "critical force" depends on parameters like the blade geometry and the material properties. It is not too difficult to calculate this for a simple geometry and I will do just that in a science module. Once more a simple equation that contains all (and more) of the points in what follows.

What would we guess - and what is true?

1. **Guess:** Thick columns are more stable than thin ones. So double the cross-sectional area and you double the critical force?
   Reality: No. The critical force is not proportional to the cross-sectional area but to I_A, the area moment of inertia. If you increase the area by a factor of two, the area moment of inertia increases much more than that. For a beam with square cross-section, for example, I_A increases with the square of the area!
2. **Guess:** Stiffer materials are less sensitive to buckling. So the critical force is proportional to Young's modulus **Y**?
   Reality: That is correct.

3. **Guess:** A long blade will buckle more easily than a short one. The buckling force thus might be inversely proportional to the length?
   Reality: Not really. The critical force decreases with the *square* of the length!

Will your sword buckle when you hit a target straight on? In particular your small sword with a tip region like a needle? If you know a bit of math, you can easily calculate it, or at least get a good approximation, by using the buckling equation.

- How about an experiment? Hold your sword tip against some unwielding object and slowly increase the "pressure" (=force). Observe when it suddenly buckles.
  When you then kill your wife since your sword ran right through her instead of buckling, you might be somewhat surprised if not sorry. Well - I meant *mechanically* unwielding, of course! Why didn't your sword buckle?
  Simple. Wives are typically not hard and unyielding objects (mechanically speaking). If the force it takes to *penetrate* a target is smaller than the critical force, you just cannot built up the critical force in the tip region. Even if your sword hits now a wall on the other aside of your (former) wife, it will not buckle anymore. Why? Because the wife impaled upon the blade is now part of the blade (again mechanically speaking) The cross-sections increases by quite a bit and the critical force is now much larger.