How does *vine* generate force ?

with Julien Derr (MSC) and Drazen Zanchi (ENS)

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Possibility to follow up with a PhD: Yes

Context Vines are defined as any plant with a growth habit of trailing or climbing stems. It can be twining if the shoots are growing in a helix and some studies have already described this mechanism[2, 3]; but some other species climb using tendrils (see figure 1) and their associated growth motion is violent (see QRcode video[4]). This is the later case that we propose to investigate in this internship.

Concepts and problematic Plants are sessile organisms. Their only way of moving is by regulating their growth which is by essence an irreversible process. The observation of the complex shapes emerging in plants gives particular insights on how growth is finely tuned both spatially and temporally. In the case of vines, one can naturally ask two questions:

- **How is the characteristic helical shape of the tendril formed ?**
  One could ask the link between growth and morphology, the interaction with the exterior world by contacts (thigmotropism), and the particular case of kinks (when the twist changes direction)
- **How is the force generated?**
  The very origin of the force itself is to understand, and then how does force evolve as a function of growing time.

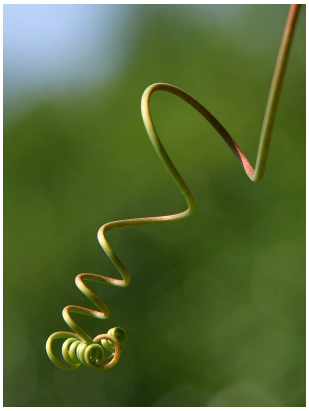

Figure 1: A vine tendril[1]

Proposed agenda In order to answer these questions, we propose to combine experimental and theoretical work, with the following steps:

1. **Observation** Tracking of the dynamics of growth by time lapse imaging with identification of the morphological steps in the free system[4] as well as under stress (traction for example, see the buckling event in figure 2 and the associated QRcode video).
2. **Set-up a force measurement system** force and torque sensors will be adapted to the vine geometry. Preliminary experiments have been done with a scale (figure 2).
3. **Experiments** will be of two kinds: constant force growth and constant distance growth.
4. **Physical modeling** building of a minimal mechanical model which reproduces the dynamics/growth/force generation

Figure 2: The tendrils pulls vertically, and the force is measured thanks to the scale

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[1] J. Sullivan. *Public Domain*. https://commons.wikimedia.org/w/index.php?curid=1015970.

[2] S. Isnard et al. "Tensioning the helix: a mechanism for force generation in twining plants". In: *Proceedings of the Royal Society of London B: Biological Sciences* (2009), rspb–2009.

[3] A. Goriely and S. Neukirch. "Mechanics of climbing and attachment in twining plants". In: *Physical review letters* 97.18 (2006), p. 184302.

[4] MSC laboratory. *Nutation of a vine tendril*. http://www.msc.univ-paris-diderot.fr/~plant-dynamics/vigne/.