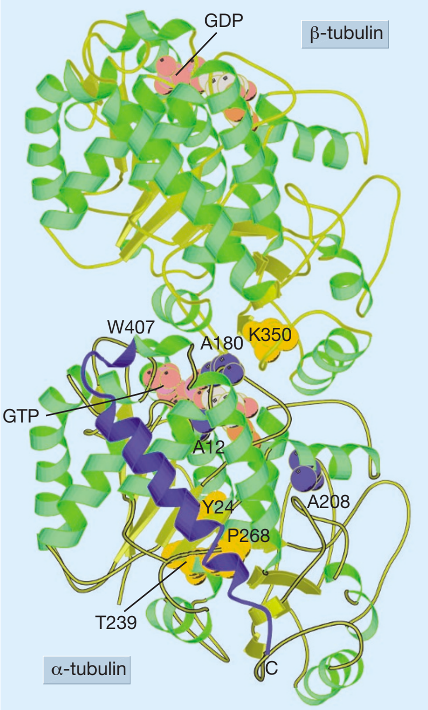

Figure 1 **A basis for twistiness? This structure of the α-tubulin/β-tubulin dimer shows the positions of amino acids that are known to be mutated in several plants or algae. Purple, mutations that affect twisting. The mutation of alanine (A) — or serine — to phenylalanine at position 180 in α-tubulin causes the *lefty* plants identified by Thitamadee *et al.*[2]. Mutation of alanine 12 to valine, or of alanine 208 to threonine, or deletion of tryptophan (W) 407, suppresses the left-handed twisting of *lefty* plants. Orange, mutations that cause plant resistance to dinitroaniline herbicides. (Y, tyrosine; P, proline; T, threonine; K, lysine.) Kindly provided by L. Amos, using coordinates from ref. 7.**

cause of the left-handed twisting of *lefty* plants. Similarly, microtubules in cells of the clockwise-twisting *spiral1* mutant plants form left-handed helices[3].

But Thitamadee *et al.*[2] delve deeper still, and find the precise protein affected by the *lefty* mutation: the α-subunit of the major microtubule protein tubulin. (The protein affected by the *spiral1* mutation is not known but might also be part of the microtubule network[3].) Tubulin is a dimer of α- and β-subunits and is dumb-bell-shaped; many dimers associate head-to-tail to form protofilaments. Generally, 13 protofilaments associate laterally in a staggered fashion to form a hollow tube — the microtubule — with an external diameter of 25 nanometres.

Thitamadee *et al.* find that the *lefty* mutation results in an amino-acid change in α-tubulin: the serine at position 180 in the amino-acid chain is replaced by phenylalanine. The amino acid at this position is obviously important as it is highly conserved, being either serine or alanine, across taxonomically distinct species. It is close to the interface between the α- and β-tubulin subunits and is in contact with the nucleotide guanine trisphosphate (GTP) (Fig. 1). The function of this GTP is unclear; unlike many such nucleotides, it is not hydrolysed to release energy and then replaced by another GTP. But it is possible that its presence favours the formation of the tubulin dimer.

So, mutations at or near this site might change the shape of the dimer, resulting in less stable microtubules or a change in microtubule shape. It would be interesting to see electron micrographs of microtubules from *lefty* plants. It is known that certain mutations in the FtsZ protein (the bacterial equivalent of tubulin) cause it to form a spiral instead of the normal closed ring and that this causes morphological abnormalities[4]. Perhaps the same happens in *Arabidopsis*, too. Whatever the case, though, the net result is that the microtubules in elongated cells of *lefty* plants are offset from the normal transverse orientation. Interestingly, the effects of the *lefty* mutation are overcome by mutations at other sites in α-tubulin[2]. Some of these (Fig. 1), which are near the α-tubulin/β-tubulin interface (changing alanine at position 208 to threonine) or near GTP (changing alanine at position 12 to valine), may 'tweak' the dimer back into its normal shape, and result in normal, straight *Arabidopsis* plants.

Thitamadee *et al.*'s results[2] suggest that microtubules can do the twist, and could be Kerner's "peculiar constitution of the living protoplasm". A perhaps confounding fact is that normal left- and right-twining plants, as well as the upright *Arabidopsis*, probably all have serine or alanine at position 180 in α-tubulin. So this may not be the precise amino acid that is different between twisting and non-twisting plants. But amino-acid changes in another region of the tubulin dimer might have a similar effect on microtubule structure, much as changes that cause herbicide resistance in plants occur in both α-tubulin and β-tubulin, and not all directly affect the herbicide-binding site[5]. Plant and animal tubulins do have preferred amino acids at certain sites[6]. It is possible, then, that in the origins of climbing plant species, selective pressure resulted in the conservation of one or more amino acids in the tubulin dimer that can cause twisting. This selective pressure could have come from an intense competition for light, for example in forests, where the ability to twist and climb would have been an advantage. ■

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Geology

A foot in the past

GEOL. SOC. AM.

The oldest fossils of footprints ever found on land suggest that animals may have emerged from the seas much earlier than had been thought. Lobster-sized, centipede-like animals made the prints shown here about 500 million years ago. Previous fossils had indicated that animals took this step around 40 million years later.

R. B. MacNaughton and colleagues analysed about 25 rows of footprints preserved in Cambrian–Ordovician aeolian sandstone in southeastern Ontario, Canada (*Geology* **30,** 391–394; 2002). They concluded that the ripples and fine layering in the sandstone are characteristic of wind-blown sand compacted over millennia, rather than underwater sediments, as had previously been believed.

The animals that made the tracks were about 50 cm long, had 16–22 legs, and may have dragged a tail behind them. They were probably euthycarcinoids — relatives of modern centipedes, and similar in appearance to overgrown woodlice.

Given the fossils' age, it is unlikely that the creatures lived on land. They probably ventured ashore to mate and lay eggs, to escape predators or to scavenge for food.

But if animals did forsake the seas 500 million years ago, they may have found little vegetation to eat. The only known fossils of land plants that are as old as these footprints are remains of algal mats. So the tracks appear to contradict the prevailing hypothesis that animals colonized the land to exploit leafy resources. A single finding is insufficient evidence, however, and sandstone rocks of this age are notoriously difficult to date. More examples will be needed before palaeontologists can rewrite the textbooks. **Tom Clarke**