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Received 23 January; accepted 3 June 1996.

Acknowledgements We thank R. Huber (Martinsried) for continuous encouragement and support of this work and M. Dörhöfer (Heidelberg) for excellent technical assistance. This work was supported by grants from the Deutsche Forschungsgemeinschaft.

1. Dumermuth, E. *et al. J. Biol. Chem.* **266**, 21381–21385 (1991).
2. Stöcker, W., Gomis-Rüth, F.-X., Bode, W. & Zwilling, R. *Eur. J. Biochem.* **214**, 215–231 (1993).
3. Bond, J.S. & Beynon, R.B. *Protein Science* **4**, 1247–1261 (1995).
4. Kessler, E., Takahara, K., Biniamov, L., Brusel, M., & Greenspan, D.S. *Science* **271**, 360–362 (1996).
5. Bode, W., Gomis-Rüth, F.-X., Huber, R., Zwilling, R. & Stöcker, W. *Nature* **358**, 164–167 (1992).
6. Stöcker, W. *et al. Protein Science* **4**, 823–840 (1995).
7. Matthews, B.W. *Acc. Chem. Res.* **21**, 333–340 (1988).
8. Baumann, U. *J. Mol. Biol.* **242**, 244–251 (1994).
9. Miyatake, H. *et al. J. Biochem.* **118**, 474–479 (1995).
10. Stöcker, W. & Zwilling, R. *Meth. Enzymol.* **248**, 305–325 (1995).
11. Yiotakis, A., LeCoq, A., Nicoleau, A., Labadie, J. & Dive, V. *Biochem. J.* **303**, 323–327 (1994).
12. Jirácek, J. *et al. J. Biol. Chem.* **265**, 21701–21706 (1995).
13. Tronrud, D.E., Holden, H.M. & Matthews, B.W. *Science* **235**, 571–574 (1987).
14. Bartlett, P.A. & Marlowe, C.K. *Science* **235**, 569–571 (1987).
15. Holland, D.R. *et al. Biochemistry* **31**, 11310–11316 (1992).
16. Baumann, U. Bauer, M., Létoffé, S., Delepelaire, P. & Wandersman, C. *J. Mol. Biol.* **248**, 653–661 (1995).
17. Baumann, U., Wu, S., Flaherty, K.M. & McKay, D.B. *EMBO J.* **12**, 3357–3364 (1993).
18. Auld, D.S. & Vallee, B.L. In: Hydrolytic enzymes, (A. Neuberger & K. Brocklehurst, eds) 201–255 (Elsevier Science Publishers, New York, NY, 1987).
19. Kraut, J. *Science* **242**, 533–540 (1988).
20. Gardell, S.J., Craik, C.S., Hilvert, D., Urdea, M. & Rutter, W.J. *Nature* **317**, 551–555 (1985).
21. Christianson, D.W. & Lipscomb, W.N. *Acc. Chem. Res.* **22**, 62–69 (1989).
22. Kim, H. & Lipscomb, W.N. *Biochemistry* **29**, 5546–5555 (1990).
23. Phillips, M.A., Fletterick, R. & Rutter, W.J. *J. Biol. Chem.* **265**, 20692–20698 (1990).
24. Beaumont, A. *et al. J. Biol. Chem.* **270**, 16803–16808 (1995).
25. Copié, V. *et al. Biochemistry* **29**, 9176–9184 (1990).
26. Gomis-Rüth, F.-X., Stöcker, W., Huber, R., Zwilling, R. & Bode, W. *J. Mol. Biol.* **229**, 945–968 (1993).
27. Brünger, A.T., Karplus, M. & Petsko, G.A. *Acta. Crystollogr.* A**45**, 50–61 (1989).
28. Engh, R.A. & Huber, R. *Acta Crystallogr.* A**47**, 392–400 (1991).
29. Jones, T.A. *J. Appl. Crystallogr.* **15**, 23–31 (1978).

Jellyroll boat

Photosynthetic organisms must harvest energy from sunlight and then convert it into chemical energy. A number of light harvesting complexes (LHCs) have evolved to sift solar radiation for photons to be passed on to the photosynthetic reaction centre. The structure of one such LHC from the sea-plankton *Amphidinium carterae*—peridinin-chlorophyll-protein (PCP)—is shown in the picture (Eckhard Hofmann *et al. Science* **272**, 1788–1791; 1996) and provides an explanation for its light-gathering capabilities.

The structure of PCP can be likened, appropriately, to that of a ship. The symmetrical N- and C-terminal domains consist of eight helices apiece (right and left respectively). Of the sixteen helices, eight—four on each side (in the centre, front and back)—form the spars of the hull, arranged in cross-section like a 'V'. The 40 Å polypeptide connecting the two domains runs along the base of the V (bottom) forming the keel. Two helices each cap the bow (right) and stern (left) and the remaining four form the planks of the deck (top), beneath which is found the cargo of lipids (two digalactosyl diacyl glycerol molecules, blue; evidence for PCP's presence in the thylakoid lumen) and pigments (two chlorophylls, green; eight peridinins, red). The hold is lined with hydrophobic residues cushioning the oily lipids and pigments from the surrounding solvent. The jargon for the topology of the domains is culinary, rather than nautical, each being described as having a 'jellyroll' fold. The PCPs are found in convoys of three both in crystals and, it is thought, in solution.

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

Energy is transferred between photosynthetic pigments by two mechanisms: short-range (<20 Å) coupling of delocalized excitons and long-range (up to 100 Å) Förster dipole-dipole interactions. The tight packing of four peridinins around each chlorophyll (closest approach, <4 Å) guarantees efficient excitonic energy transfer, whereas the disposition of the chlorophylls within PCP (separated by 17.4 Å) and between monomers in the trimer (40–50 Å) indicates energy transfer by Forster dipole-dipole interactions. **GR**