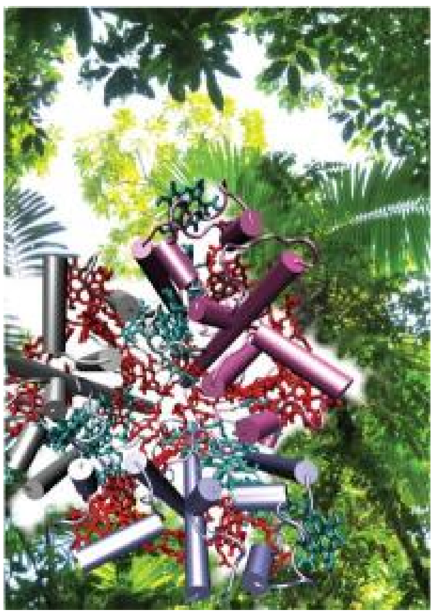
Scientists lay out plans for efficient harvesting of solar energy

September 23 2011



Half the green pigment (chlorophyll) in this Costa Rican rain forest is bound in the light-harvesting complex LHCII (shown in the inset). By studying these natural solar energy antennas, researchers have learnt new physical principles underlying the design of "circuits" that harvest and transport energy from the sun. Credit: Greg Scholes

Solar power could be harvested more efficiently and transported over long distances using tiny molecular circuits, according to research inspired by new insights into natural photosynthesis.

Incorporating the latest research into how plants, algae and some bacteria use quantum mechanics to optimise energy production via photosynthesis, scientists have set out how to design molecular "circuitry" that is 10 times smaller than the thinnest electrical wire in computer processors. Published in *Nature Chemistry*, the report discusses how tiny molecular energy grids could capture, direct, regulate and amplify raw solar energy.

Professor Gregory Scholes, lead author from the University of Toronto said: "Solar fuel production often starts with the energy from light being absorbed by an assembly of molecules. The energy is stored fleetingly as vibrating electrons and then transferred to a suitable reactor.

"It is the same in biological systems. In photosynthesis, for example, antenna complexes comprised of chlorophyll capture sunlight and direct the energy to special proteins that help make oxygen and sugars. It is like plugging those proteins (called reaction centres) into a solar power socket."

In natural systems energy from sunlight is captured by 'coloured' molecules called dyes or pigments, but is only stored for a billionth of a second. This leaves little time to route the energy from pigments to the molecular machinery that produces fuel or electricity.

The key to transferring and storing energy very quickly is to harness the collective quantum properties of antennae, which are made up of just a few tens of pigments.

Dr Alexadra Olaya-Castro, co-author of the paper from UCL's department of Physics and Astronomy said: "On a bright sunny day, more than 100 million billion red and blue "coloured" photons strike a leaf each second.

"Under these conditions plants need to be able to both use the energy that is required for growth but also to get rid of excess energy that can be harmful. Transferring energy quickly and in a regulated manner are the two key features of natural light-harvesting systems.

"By assuring that all relevant energy scales involved in the process of energy transfer are more or less similar, natural antennae manage to combine quantum and classical phenomena to guarantee efficient and regulated capture, distribution and storage of the sun's energy."

Summary of lessons from nature about concentrating and distributing solar power with nanoscopic antennae:

1. The basic components of the antenna are efficient light absorbing molecules. These photo-energy absorbers should be appropriately distributed to guarantee that there is an even probability of converting sun energy into vibrating electrons across the whole antennae.

2. Take advantage of the collective properties of light-absorbing molecules by grouping them close together. This will make them exploit quantum mechanical principles so that the antenna can: i) absorb different colours ii) create energy gradients to favour unidirectional transfer and iii) possibly exploit quantum coherence for energy distribution -several energy transfer pathways can be exploited at once.

3. Make sure that the relevant energy scales involved in the energy transfer process are more or less resonant. This will guarantee that both classical and quantum transfer mechanisms are combined to create regulated and efficient distribution of energy across short and long-range distances when many antennae are connected.

4. An antenna should transfer energy not as fast as possible but as fast as necessary. This means that regulatory mechanisms need to be integrated in the antenna. For instance, if necessary, combine light-absorbing

molecules with a few local "sinks" that dissipate excess of damaging energy.

More information: 'Lessons from nature about solar light harvesting' is published online in the *Nature Chemistry* today.

Provided by University College London