Almost all life on Earth is solar-powered.

Plants, algae, and some bacteria capture light energy from the sun and convert it to chemical energy in a series of reactions called photosynthesis.

These organisms produce carbohydrates from simple building blocks like water and carbon dioxide from the environment, and in the process they release oxygen.

Photosynthesis nourishes almost the entire living world.

Photosynthesis is a set of chemical reactions in which light energy is converted to chemical energy.

Light energy enables the movement of electrons from molecules that donate electrons to molecules that accept electrons, but which molecules?

Water is the first electron donor.

The carbon in carbon dioxide is the ultimate electron acceptor.

Carbon dioxide combines with other molecules to form carbohydrates, such as a three-carbon sugar called G3P.

Carbohydrates are used to make other organic molecules that plants use to grow and as a source of energy to fuel their lives.

An important byproduct of photosynthesis is oxygen.

We are going to zoom in on a cross section of a leaf to have a closer look at the center of action for photosynthesis.

A leaf has many different types of cells, such as mesophyll cells, epidermal cells, and vascular bundles.

Most cells in the middle of a leaf contain large numbers of chloroplasts.

Pigments in chloroplasts make these cells green.

Chloroplasts are the organelles where photosynthesis occurs.

Carbon dioxide from the air enters a leaf through small pores, called stomata, on the outer cell layer.

Oxygen formed during photosynthesis also exits the plant through the stomata.

The plant transports organic molecules produced in its leaf cells to other cells via the plumbing system found in vascular bundles.

Let’s take a closer look at a chloroplast, the organelle where photosynthesis takes place.

Photosynthesis consists of two sets of chemical reactions: the light reactions and the Calvin cycle.

They occur in different regions of the chloroplasts.

Chloroplasts contain stacks of membrane-lined discs called thylakoids, surrounded by a watery clear fluid, called stroma.

The light reactions are carried out by molecules in the thylakoid membranes and the Calvin cycle reactions by molecules in the stroma.

Let’s explore these regions and their functions in more detail.

In the thylakoid membranes, the light reactions transform light energy to chemical energy.

Light energy drives the formation of ATP molecules from ADP and of NADPH molecules from NADP+ and electrons.

Along the way, water molecules are split and oxygen is formed, which can be released into the atmosphere.

In the stroma, the Calvin cycle reactions use the chemical energy of ATP and NADPH to combine carbon dioxide from the air with organic molecules to form new molecules, like the sugar G3P.

ADP and NADP+ are recycled and may be used again in the light reactions.

A plant increases its biomass through the formation of these new organic molecules.

The thylakoid membranes contain specialized molecules that work together to perform the light reactions.

Light is absorbed by protein-pigment complexes called photosystems.

There are two photosystems: photosystem I and photosystem II.

The photosystems transform light energy to chemical energy by exciting and then shuttling electrons from molecule to molecule in a chainlike fashion on the thylakoid membrane.

This process is called an electron transport chain.

Let’s take a closer look to see how this process works.

First, photons of light hit chlorophyll, a light-absorbing pigment in photosystem II.

Electrons in the chlorophyll are excited to a higher energy level.

The excited electrons are passed to an electron carrier.

Meanwhile, water splits and releases electrons.

These electrons replace those lost at photosystem II.

The byproduct of this reaction is oxygen, which is eventually released into the air.

The other products are protons, or hydrogen ions, which are released into the inside of the thylakoid, or lumen.

The excited electrons move to the cytochrome complex.

Some of the energy from the electrons is used by the cytochrome complex to transport additional protons into the lumen.

The second electron carrier, a protein inside the lumen, receives the electrons and passes them to photosystem I.

These electrons have now lost most of the energy they gained from light in photosystem II.

Photons of light hit chlorophyll in photosystem I and excite the electrons again.

The electrons are then passed to the third electron carrier.

Finally, these electrons are either recycled or they interact with an enzyme and NADP+, the final electron acceptor of the light reactions, to form NADPH.

Some of the energy from light is now stored in the reduced molecule NADPH.

Some of the energy released from the transfer of electrons established a proton gradient across the thylakoid membrane.

Protons that accumulated in the lumen diffuse into the stroma through an enzyme called ATP synthase.

ATP synthase uses the potential energy of the proton gradient to combine ADP with inorganic phosphate to form ATP.

In this way, the potential energy is transformed into chemical energy stored as ATP.

ATP and NADPH now have stored energy from the light reactions.

This energy can be used in the Calvin cycle.

This light driven electron transport chain is usually continuous in the presence of sunlight.

It encompasses a series of chemical reactions that involve light absorption, energy conversion and electron transfer carried out by the photosystems and other enzymes on the membrane of the thylakoids.

The Calvin cycle takes place in the chloroplast's stroma, the watery clear fluid surrounding the thylakoids.

It's helpful to think of the Calvin cycle in three phases: fixation, reduction, and regeneration.

In phase one, inorganic carbon, in the form of carbon dioxide from the air, is incorporated into organic molecules, a process known as carbon fixation.

Three molecules of carbon dioxide react with three molecules of ribulose bisphosphate (RuBP) to produce six molecules of a three-carbon molecule called 3-PGA.

The enzyme rubisco catalyzes this reaction.

In the second phase, the organic molecules accept electrons, a process known as reduction.

The six molecules of 3-PGA use six molecules of ATP and six molecules of NADPH—which store energy from the light reactions—to generate six molecules of G3P. The G3P molecules contain more electrons and are higher in potential energy than 3-PGA.

One molecule of G3P exits the cycle.

It can be used to make other organic molecules.

In phase three, the regeneration phase, a large set of reactions use the other five molecules of G3P and energy from three molecules of ATP to produce three molecules of RuBP.

With RuBP reformed, the process can start again.

Notice that in the Calvin cycle, the energy from ATP and NADPH produced in the light reactions is used to generate one G3P molecule from three carbon dioxide molecules.

In this process, the electrons lost from NADPH are accepted by the carbons from carbon dioxide molecules, which are the ultimate electron acceptors of photosynthesis.

G3P, the net product from the Calvin cycle, can be used to generate other organic molecules, such as sucrose or starch.

Sucrose produced by leaf cells is transported through the vascular bundles to other parts of the plant, like stems and roots.

Leaf cells can also sometimes form starch for long-term energy storage.

Overall, the molecules generated by photosynthesis provide fuel and building materials that allow a plant to grow.

Globally, photosynthesis produces an estimated 150 billion metric tons of carbohydrates per year and is responsible for the oxygen in our atmosphere, making it one of the most important chemical processes for life on Earth.