REVIEW

Recent advances in understanding photosynthesis [version 1; peer review: 3 approved]

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Abstract

Photosynthesis is central to all life on earth, providing not only oxygen but also organic compounds that are synthesized from atmospheric CO₂ and water using light energy as the driving force. The still-increasing world population poses a serious challenge to further enhance biomass production of crop plants. Crop yield is determined by various parameters, *inter alia* by the light energy conversion efficiency of the photosynthetic machinery. Photosynthesis can be looked at from different perspectives: (i) light reactions and carbon assimilation, (ii) leaves and canopy structure, and (ii) source-sink relationships. In this review, we discuss opportunities and prospects to increase photosynthetic performance at the different layers, taking into account the recent progress made in the respective fields.

Keywords

light-dependent reactions, assimilation reactions, photosynthetic organisms

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Introduction

Photosynthesis is a process that all life on earth depends on. Photosynthetic organisms convert more than 10^9 metric tons of atmospheric CO_2 into **biomass** per year. With the global human population rising from ~ 7 billion now to 9–10 billion by 2050, the worldwide trend towards a more meat-rich human diet, the loss of harvest and grazing land, and the negative effects of global warming on crop production have put forward the question of whether this incredibly high amount of biomass production can be further increased.

Crop yield is determined by the available solar irradiation energy across the growing season ($0.487 S_p$), the genetically encoded properties of how the radiation is intercepted (ϵ_i), the efficiency by which the light energy is converted into biomass (ϵ_c), and what fraction of the total biomass is partitioned into the harvestable part of the plant (harvest index, ϵ_p). This results in the Monteith equation: $\text{yield} = 0.487 \cdot S_p \cdot \epsilon_i \cdot \epsilon_c \cdot \epsilon_p^{1-3}$.

The *Green Revolution* raised the yield potential of the major grain crops mainly by increasing the harvest index, which is now about 0.6. Breeders were also able to improve the light interception efficiency, which in modern cultivars is up to about 0.8–0.9. All available evidence suggests that additional grain yields by further increasing the harvest index or optimizing light interception are rather unlikely; they appear to be close to their biological limits already. In contrast, the best light conversion efficiency (ϵ_c) observed in field experiments (0.24 in C_3 - and 0.37 in C_4 -crops) is far below the theoretical maxima (0.46 in C_3 - and 0.6 in C_4 -plants) and thus not yet close to its biological limit. Enhancing, and in the long term re-designing, photosynthesis with respect to light energy conversion efficiency is therefore a prime target when aiming to increase crop yield^{3–6}.

In general, photosynthesis can be described as a cellular trait that uses light energy to convert atmospheric CO_2 into carbohydrates. At a higher level, photosynthesis is determined by the activity of leaves and by the canopy structure. And, finally, photosynthesis is related to the capacities of source and sink tissues, i.e. mature leaves and heterotrophic organs, respectively (Figure 1).

Here, we will discuss the process of photosynthesis from these various perspectives and address putative targets for the improvement of photosynthetic performance.

Photosynthesis as a cellular trait: (1) light-dependent reactions

Novel insights into the dynamic interactions of photosynthetic complexes

The light-dependent reactions involve five major multi-protein complexes: photosystem I (PSI), photosystem II (PSII), cytochrome b_6 , ATP synthase, and NADPH dehydrogenase (NDH). In particular, PSI can (transiently) form larger super-complexes with other complexes like cytochrome b_6 , NDH⁸, and PROTON GRADIENT 5 (PGR5)-PGR5-LIKE 1 (PGRL1)^{9,10}. More recently, interactions of PSI with PSII¹¹ and light-harvesting complex II (LHCII)¹² have been characterized. Traditionally, PSI and PSII are thought to be spatially dispersed. However, in cyanobacteria, a megacomplex consisting of PSII, PSI, and phycobilisomes was found¹³. Aro and co-workers reported that PSI and PSII complexes coexist with LHCs in *Arabidopsis*¹⁴. More recently, Tanaka and colleagues suggested that about half of PSIIs are physically connected to PSI complexes¹¹. The obtained results suggest that when PSII becomes excessively excited, it can divert excitation energy directly to PSI to avoid photo-damage. Conversely, photoinhibition of PSI can downregulate PSII via a mechanism that involves increased

Figure 1. The process of photosynthesis viewed from different perspectives.

reduction of the intersystem electron carrier system due to damage to the FeS clusters of PSI. This is associated with the activation of thylakoid phosphorylation-based mechanisms that increase energy flow towards PSI¹⁵.

Bassi and colleagues have recently generated plants with a PSI that lacks its natural LHCI antenna system¹². Despite the absence of LHCI, LHCII can still attach to PSI, and in fact each LHCI-less PSI complex binds one LHCII trimer, thus fully replacing the four Lhca proteins from LHCI by the three Lhcb proteins of LHCII. This demonstrates that LHCI is not necessary for excitation energy transfer from LHCII to PSI, as was previously suggested¹⁶. Intriguingly, the transfer of energy from LHCII to PSI appears to be more efficient than from LHCI, raising the question of why PSI uses LHCI instead of LHCII. A plausible explanation is that LHCI absorbs photons with lower energy than LHCII, avoiding competition between PSI and PSII for the same photons. Therefore, in low-intensity and far-red enriched light (like the one available under canopy cover), PSI is favored over PSII, avoiding over-reduction of plastoquinone and thus preventing photo-damage.

With respect to photosynthetic improvements, the structural flexibility of the photosynthetic complexes might allow the construction of novel combinations of photosystem cores and LHC antenna complexes. Indeed, it appears to be possible to design an entire set of such combinations that could be tested under different light regimes for their efficiency and use under controlled (such as in greenhouses) and natural (such as in the field) light conditions. In a complementary approach, conditional regulation of various light-harvesting genes might allow for tuned optimization in an ever-changing and challenging environment. Therefore, biotic interactions also need to be considered, taking into account, for instance, trade-offs between photosynthesis and herbivore resistance¹⁷.

Novel auxiliary components of photosynthetic light reactions

During the last few decades, the structural components of the light reactions, including the multi-protein complexes PSI and PSII, cytochrome b_6f , ATP synthase, and NDH, have been identified and extensively characterized at the gene, protein, and mutant level. In contrast, the inventory of the auxiliary components of the photosynthetic light reactions is far from being complete. Novel proteins involved in the biogenesis, repair, regulation, and protection of the photosynthetic machinery are continuously identified owing to genetic screens and functional genomics approaches and employing mainly the model species *Arabidopsis thaliana*, *Chlamydomonas reinhardtii*, and *Synechocystis* sp. PCC 6803. In Table 1, recently identified auxiliary proteins of the photosynthetic light reactions are listed. Adding their numbers to the ones of the factors already identified before (reviewed in 18), it becomes clear that the number of different proteins controlling the biogenesis and repair of the multi-protein complexes exceeds the one of structural subunits. While for PSI and NDH, and particularly PSII, substantial sets of assembly factors have been known for many years already, until recently only one auxiliary protein (ALB4¹⁹) involved in the biogenesis of the chloroplast ATP synthase (cpATPase) has been isolated. Three additional cpATPase assembly factors have now been identified:

CGL160^{20,21}, PAB²², and CGLD11/BFA3^{23,24}. CGL160 represents a protein of prokaryotic origin, whereas CGLD11/BFA3 and PAB are specific to photosynthetic eukaryotes. Interestingly, CGLD11/BFA3 is also targeted to mitochondria but not (yet) essential for the assembly of the mitochondrial ATP synthase²³. Similar pronounced evolutionary dynamics are displayed by PAM68L, which evolved from a PSII assembly factor to mediate the assembly of the chloroplast NDH complex in *Arabidopsis*²⁵.

The network of protein kinases and phosphatases involved in reversible thylakoid phosphorylation (reviewed in 26) and the two ferredoxin-plastoquinone reductase complexes involved in cyclic electron flow (reviewed in 27) are now relatively well characterized, and also several factors regulating the dynamics of thylakoid ultrastructure and the acclimation and protection of the photosynthetic machinery have been identified (reviewed in 28–30). Three recent examples are highlighted here: (i) the levels and phosphorylation states of CURT1 proteins were shown to control the formation of the appressed regions of thylakoids in the so-called grana stacks³¹; it remains to be elucidated how the activity of CURT1 is regulated under physiological conditions. (ii) The calcium sensor CAS was localized to thylakoids³², appears to regulate acclimation and cyclic electron flow in *C. reinhardtii*^{33,34}, and was more recently associated with retrograde signaling in *A. thaliana*³⁵; here, future research needs to clarify the role of chloroplasts in cellular calcium signaling and how CAS is involved in this process. (iii) Very recently, the chloroplast-splicing factor HPE1 was shown to be involved in the regulation of photosynthetic efficiency; in fact, plants without HPE1 readjust their light-harvesting pigments, thereby reducing antenna size, improving light capture, decreasing energy loss, mitigating photodamage, and enhancing photosynthetic quantum yield during photosynthesis³⁶.

As suggested before, the most promising targets for genetic engineering of the light reactions of photosynthesis—in terms of manipulating one or a few genes—are modifying light harvesting and regulators of photosynthetic electron flow³⁷. The resulting plants have the potential to exhibit more efficient photosynthesis under controlled conditions, e.g. in greenhouses, or in regions that cannot otherwise be extensively used for agriculture because of their short growing seasons. In fact, plants without the LHCII protein phosphatase TAP38 and concomitantly with hyperphosphorylated thylakoid proteins³⁸ or without HPE1³⁶ (see above) appear to be superior to normal plants under certain conditions, implying that the modification of single regulatory proteins might positively impact photosynthesis. Moreover, since evolutionary-based adaptation of plants might not cope with the relatively rapid progression of human-made climate change that we experience today, transgenic plants with altered acclimation capacity due to altered activity of accessory photosynthetic proteins might contribute to the generation of improved crop varieties. Proof of this concept was provided very recently. The parallel overexpression of three proteins involved in photoprotection (subunit S of PSII [PsbS], violaxanthin de-epoxidase [VDE], and zeaxanthin epoxidase [ZEP]) accelerated the photoprotective response to natural shading events in tobacco, resulting in increased plant dry matter productivity in fluctuating light and under field conditions³⁹.

Table 1. Overview of novel auxiliary components of photosynthetic light reactions identified in the last few years.

Function	Protein/Species	Reference
<i>Biogenesis and repair</i>		
PSII biogenesis	AtCtpA (<i>Arabidopsis thaliana</i>)	74
	TRX-m1, -m2 and -m4 (<i>A. thaliana</i>)	75
	RBD1 (<i>Chlamydomonas reinhardtii</i> , <i>Synechocystis</i> , <i>A. thaliana</i>)	76
	THF1 (<i>A. thaliana</i>)	77,78
	PsbN (Tobacco)	79
	AtTerC (<i>A. thaliana</i>)	80
	CyanoP (<i>Synechocystis</i>)	81
PSII repair	Psb28 (<i>Synechocystis</i>)	82,83
	Slr0151 (<i>Synechocystis</i>)	84,85
	MET1/TEF30 (<i>A. thaliana</i> , <i>C. reinhardtii</i>)	86,87
PSI biogenesis	PSA2 (<i>A. thaliana</i>)	88
	FtsH2 and FtsH5 (<i>A. thaliana</i>)	89
Chloroplast ATP synthase assembly	CGL160 (<i>A. thaliana</i>)	20,21
	PAB (<i>A. thaliana</i>)	22
	CGLD11/BFA3 (<i>A. thaliana</i>)	23,24
Assembly of NADPH dehydrogenase complex	PAM68L (<i>A. thaliana</i>)	25
	NdhP (<i>Thermosynechococcus elongatus</i>)	90
	CRR9 (<i>A. thaliana</i>)	91
<i>Regulation</i>		
Reversible thylakoid phosphorylation	PBCP (<i>A. thaliana</i>)	92
Thylakoid ultrastructure	CURT1 (<i>A. thaliana</i>)	31
Photoacclimation, cyclic electron flow, and retrograde signaling	CAS (<i>A. thaliana</i> , <i>C. reinhardtii</i>)	33–35
Light-harvesting pigments	HPE (<i>A. thaliana</i>)	36
<i>Protection</i>		
PSII protection	HHL1 (<i>A. thaliana</i>)	93
	MPH1 (<i>A. thaliana</i>)	94
PSI protection	FKBP16-1 (<i>A. thaliana</i>)	95

Photosynthesis as a cellular trait: (2) assimilation reactions

During photosynthesis, plants capture energy from sunlight and turn it into biochemical energy in the form of ATP and reducing equivalents, NADPH. In C_3 -plants, the first product of the CO_2 -fixing ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO), the C_3 -compound 3-phosphoglycerate, is transformed to a C_3 -sugar (triose phosphate) as part of the Calvin-Benson cycle using both ATP and NADPH as products of the light reaction. In most plants, triose phosphates are subsequently converted into sucrose as the

main photoassimilate exported from photosynthetically active leaves (the source tissue). The long-distance transport of photosynthates to heterotrophic organs (the sink tissue) serves to supply these organs with carbon and energy. In harvestable organs, carbon can be stored as, e.g., sucrose, starch, oil, or, in combination with nitrogen, protein.

In C_3 -plants, the category to which most of our crop plants belong to, RuBisCO is CO_2 limited and works, at best, at half of its maximal reaction velocity⁴⁰. The oxygenase activity of RuBisCO

initiates the wasteful process of photorespiration that finally results in the release of previously photoassimilated CO₂ and ammonia⁴¹. Multiple efforts have been or are still being undertaken to improve RuBisCO activity either directly⁴², albeit with very limited success so far⁶, or by targeting auxiliary proteins, for instance RuBisCO activase⁴³. Alternatively, by introducing CO₂ pumping devices into C₃-species, the limitations of RuBisCO are expected to be reduced. These CO₂ pumps are to operate via either a C₄ cycle⁴⁴ or inorganic carbon-concentrating devices of cyanobacterial origin⁴⁵. There were also attempts to reduce photorespiratory losses by introducing alternative salvage pathways^{46,47}. In addition, promising approaches have also been initiated to overcome bottlenecks in the Calvin-Benson cycle^{48,49}.

Photosynthesis: leaves as target for photosynthesis improvement

Leaves are the plant's organs that are dedicated to photosynthesis. Under high-light conditions, e.g. at midday, plants receive excess energy that they are not able to cope with. It was proposed earlier that photosynthetic efficiency could be maximized by improving the plants' canopy light distribution in a way that minimizes light saturation of the upper leaves and light starvation of the lower leaves⁶. This could be achieved by (i) varying the angle of the leaves in the canopy, (ii) altering the size of LHCs per photosystem, i.e. fewer LHCs in the upper leaves and larger LHCs in lower leaves, and/or (iii) extending the light absorption spectrum of photosynthetic pigments into the near-infrared region in the lower leaves in order to use this light quality more efficiently^{6,50,51}.

The leaves of the angiosperms vary greatly in size and shape, from single and entire to highly complex compound leaves⁵². However, the role and importance of leaf anatomy in contributing to the photosynthetic output of leaves is largely unexplored. It was suggested earlier that both leaf shape and leaf anatomy contribute to the photosynthetic output of leaves⁵³ and are therefore promising targets for improving photosynthesis⁵⁴. Genetic studies with rice support this notion by demonstrating that in rice the anatomy of leaves is closely associated with leaf photosynthesis^{55,56} and, moreover, with crop yield^{57,58}. Unfortunately, global genetic analyses, preferably with easily accessible genetic model plants, which aim to identify genes affecting the inner anatomy of leaves and concomitantly their photosynthetic output, are still missing.

One approach to tackle this issue would be to compare leaf form and anatomy in established model systems, e.g. *A. thaliana* and *Cardamine hirsuta*, which both belong to the Brassicaceae. In contrast to *A. thaliana*, *C. hirsuta* has complex leaves subdivided into leaflets. Major steps in understanding the genetic basis for variation in leaf shape both within and between species have already been made^{59–63}. Both species have been documented to be suitable for an easy identification of genes and their functions. In both species, genes could be identified that affect primarily leaf form and/or the structure and organization of palisade and spongy parenchyma tissues of the leaf. A second step would be to investigate how and to which degree these genes can be used to optimize the photosynthetic output of leaves. The forward genetic approaches

could rely on either mutagenesis or the available natural genetic diversity. Both photosynthesis and leaf differentiation are rather conserved in evolution, at least among the angiosperms. The transfer of knowledge from these model systems to the major crop species of this plant family, namely the Brassicas, should therefore be relatively straightforward.

Photosynthesis and the interaction with source-sink metabolism

Photosynthesis is part of a superordinate system, namely the whole plant. From the system's perspective, the production of goods and their utilization have to be coupled, i.e. previous to the storage of products derived from photosynthetic assimilation processes in sink tissues (i.e. in harvestable organs), and carbon and nitrogen have to be assimilated in the source tissue (i.e. in mature leaves). To increase biomass production, strengthening the capacities of both source and sink tissues have been aimed at, although with varying success^{64–71}. Molecular targets were mainly related to genes involved in sugar and starch metabolism. A promising approach was recently suggested comprising the simultaneous boosting of both source and sink capacities using the crop plant potato as an example⁷². Here, the moderate repression of the leaf ADP-glucose pyrophosphorylase, a key enzyme of transitory starch formation or, alternatively, the mesophyll-specific expression of a bacterial pyrophosphate to stimulate sucrose synthesis and to prevent sucrose breakdown were combined with plants that had an increased sink strength. An increase in sink strength was accomplished by tuber-specific overexpression of two plastidic transporters responsible for the import of carbon (glucose 6-phosphate⁷³) and energy (ATP⁷⁴), respectively, into starch-storing amyloplasts. Both procedures resulted in an enhanced allocation of sucrose from source to sink tissues at the expense of leaf starch accumulation. The combined push-pull approach resulted in doubling the tuber starch yield⁷². This way of proceeding is currently being transferred to cassava, an important staple food in developing countries (Bill & Melinda Gates Foundation, CASS, OPP1113365).

It remains to be elucidated whether or not the push-pull approach can be combined with recent knowledge on novel photosynthetic components, e.g. by novel combinations of photosystem cores and LHC antenna complexes or by modifying light harvesting and regulators of photosynthetic electron flow to improve photosynthetic efficiency (Table 1). In addition, the push-pull strategy could potentially be teamed up with approaches to alter leaf form and/or anatomy to further improve ϵ_c , i.e. photosynthetic performance and biomass production.

Competing interests

The authors declare that they have no competing interests.

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References

1. Monteith JL, Moss CJ: **Climate and the efficiency of crop production in Britain.** *Philos Trans R Soc Lond B Biol Sci.* 1977; **281**(980): 277–294.
[Publisher Full Text](#)
2. Long SP, Zhu X, Naidu SL, *et al.*: **Can improvement in photosynthesis increase crop yields?** *Plant Cell Environ.* 2006; **29**(3): 315–30.
[PubMed Abstract](#) | [Publisher Full Text](#)
3. Zhu X, Long SP, Ort DR: **Improving photosynthetic efficiency for greater yield.** *Annu Rev Plant Biol.* 2010; **61**: 235–61.
[PubMed Abstract](#) | [Publisher Full Text](#)
4. Zelitch I: **The close relationship between net photosynthesis and crop yield.** *BioScience.* 1982; **32**(10): 796–802.
[Publisher Full Text](#)
5. **F** Long SP, Marshall-Colon A, Zhu XG: **Meeting the global food demand of the future by engineering crop photosynthesis and yield potential.** *Cell.* 2015; **161**(1): 56–66.
[PubMed Abstract](#) | [Publisher Full Text](#) | **F1000 Recommendation**
6. **F** Ort DR, Merchant SS, Alric J, *et al.*: **Redesigning photosynthesis to sustainably meet global food and bioenergy demand.** *Proc Natl Acad Sci U S A.* 2015; **112**(28): 8529–36.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | **F1000 Recommendation**
7. **F** Iwai M, Takizawa K, Tokutsu R, *et al.*: **Isolation of the elusive supercomplex that drives cyclic electron flow in photosynthesis.** *Nature.* 2010; **464**(7292): 1210–3.
[PubMed Abstract](#) | [Publisher Full Text](#) | **F1000 Recommendation**
8. Peng L, Shimizu H, Shikanai T: **The chloroplast NAD(P)H dehydrogenase complex interacts with photosystem I in *Arabidopsis*.** *J Biol Chem.* 2008; **283**(50): 34873–9.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
9. DalCorso G, Pesaresi P, Masiero S, *et al.*: **A complex containing PGRL1 and PGR5 is involved in the switch between linear and cyclic electron flow in *Arabidopsis*.** *Cell.* 2008; **132**(2): 273–85.
[PubMed Abstract](#) | [Publisher Full Text](#)
10. **F** Hertle AP, Blunder T, Wunder T, *et al.*: **PGRL1 is the elusive ferredoxin-plastoquinone reductase in photosynthetic cyclic electron flow.** *Mol Cell.* 2013; **49**(3): 511–23.
[PubMed Abstract](#) | [Publisher Full Text](#) | **F1000 Recommendation**
11. Yokono M, Takabayashi A, Akimoto S, *et al.*: **A megacomplex composed of both photosystem reaction centres in higher plants.** *Nat Commun.* 2015; **6**: 6675.
[PubMed Abstract](#) | [Publisher Full Text](#)
12. **F** Bressan M, Dall'Osto L, Bargigia I, *et al.*: **LHCII can substitute for LHCI as an antenna for photosystem I but with reduced light-harvesting capacity.** *Nat Plants.* 2016; **2**: 16131.
[PubMed Abstract](#) | [Publisher Full Text](#) | **F1000 Recommendation**
13. Liu H, Zhang H, Niedzwiedzki DM, *et al.*: **Phycobilisomes supply excitations to both photosystems in a megacomplex in cyanobacteria.** *Science.* 2013; **342**(6162): 1104–7.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
14. Järvi S, Suorsa M, Paakkari V, *et al.*: **Optimized native gel systems for separation of thylakoid protein complexes: novel super- and mega-complexes.** *Biochem J.* 2011; **439**(2): 207–14.
[PubMed Abstract](#) | [Publisher Full Text](#)
15. **F** Tiwari A, Mamedov F, Grieco M, *et al.*: **Photodamage of iron-sulphur clusters in photosystem I induces non-photochemical energy dissipation.** *Nat Plants.* 2016; **2**: 16035.
[PubMed Abstract](#) | [Publisher Full Text](#) | **F1000 Recommendation**
16. Benson SL, Maheswaran P, Ware MA, *et al.*: **An intact light harvesting complex I antenna system is required for complete state transitions in *Arabidopsis*.** *Nat Plants.* 2015; **1**: 15176.
[PubMed Abstract](#) | [Publisher Full Text](#)
17. **F** Johansson Jänkänpää H, Frenkel M, Zulfugarov I, *et al.*: **Non-photochemical quenching capacity in *Arabidopsis thaliana* affects herbivore behaviour.** *PLoS One.* 2013; **8**(1): e53232.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | **F1000 Recommendation**
18. Jensen PE, Leister D: **Chloroplast evolution, structure and functions.** *F1000Prime Rep.* 2014; **6**: 40.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
19. Benz M, Bals T, Gügel IL, *et al.*: **Alb4 of *Arabidopsis* promotes assembly and stabilization of a non chlorophyll-binding photosynthetic complex, the CF₁CF₀-ATP synthase.** *Mol Plant.* 2009; **2**(6): 1410–24.
[PubMed Abstract](#) | [Publisher Full Text](#)
20. Fristedt R, Martins NF, Strenkert D, *et al.*: **The thylakoid membrane protein CGL160 supports CF₁CF₀-ATP synthase accumulation in *Arabidopsis thaliana*.** *PLoS One.* 2015; **10**(4): e0121658.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
21. Rühle T, Razeghi JA, Vamvaka E, *et al.*: **The *Arabidopsis* protein CONSERVED ONLY IN THE GREEN LINEAGE160 promotes the assembly of the membranous part of the chloroplast ATP synthase.** *Plant Physiol.* 2014; **165**(1): 207–26.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
22. Mao J, Chi W, Ouyang M, *et al.*: **PAB is an assembly chaperone that functions downstream of chaperonin 60 in the assembly of chloroplast ATP synthase coupling factor 1.** *Proc Natl Acad Sci U S A.* 2015; **112**(13): 4152–7.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
23. Grahl S, Reiter B, Gügel IL, *et al.*: **The *Arabidopsis* Protein CGLD11 Is Required for Chloroplast ATP Synthase Accumulation.** *Mol Plant.* 2016; **9**(6): 885–99.
[PubMed Abstract](#) | [Publisher Full Text](#)
24. Zhang L, Duan Z, Zhang J, *et al.*: **BIOGENESIS FACTOR REQUIRED FOR ATP SYNTHASE 3 Facilitates Assembly of the Chloroplast ATP Synthase Complex.** *Plant Physiol.* 2016; **171**(2): 1291–306.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
25. Armbruster U, Rühle T, Kreller R, *et al.*: **The photosynthesis affected mutant68-like protein evolved from a PSII assembly factor to mediate assembly of the chloroplast NAD(P)H dehydrogenase complex in *Arabidopsis*.** *Plant Cell.* 2013; **25**(10): 3926–43.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
26. Rochaix JD, Lemeille S, Shapiguzov A, *et al.*: **Protein kinases and phosphatases involved in the acclimation of the photosynthetic apparatus to a changing light environment.** *Philos Trans R Soc Lond B Biol Sci.* 2012; **367**(1608): 3466–74.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
27. Yamori W, Shikanai T: **Physiological Functions of Cyclic Electron Transport Around Photosystem I in Sustaining Photosynthesis and Plant Growth.** *Annu Rev Plant Biol.* 2016; **67**: 81–106.
[PubMed Abstract](#) | [Publisher Full Text](#)
28. **F** Gollan PJ, Tikkanen M, Aro E: **Photosynthetic light reactions: integral to chloroplast retrograde signalling.** *Curr Opin Plant Biol.* 2015; **27**: 180–91.
[PubMed Abstract](#) | [Publisher Full Text](#) | **F1000 Recommendation**
29. **F** Dietz KJ, Turkan I, Krieger-Liszka A: **Redox- and Reactive Oxygen Species-Dependent Signaling into and out of the Photosynthesizing Chloroplast.** *Plant Physiol.* 2016; **171**(3): 1541–50.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | **F1000 Recommendation**
30. Pribil M, Labs M, Leister D: **Structure and dynamics of thylakoids in land plants.** *J Exp Bot.* 2014; **65**(8): 1955–72.
[PubMed Abstract](#) | [Publisher Full Text](#)
31. **F** Armbruster U, Labs M, Pribil M, *et al.*: ***Arabidopsis* CURVATURE THYLAKOID1 proteins modify thylakoid architecture by inducing membrane curvature.** *Plant Cell.* 2013; **25**(7): 2661–78.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | **F1000 Recommendation**
32. Vainonen JP, Sakuragi Y, Stael S, *et al.*: **Light regulation of CaS, a novel phosphoprotein in the thylakoid membrane of *Arabidopsis thaliana*.** *FEBS J.* 2008; **275**(8): 1767–77.
[PubMed Abstract](#) | [Publisher Full Text](#)
33. Petroutsos D, Busch A, Janssen I, *et al.*: **The chloroplast calcium sensor CAS is required for photoacclimation in *Chlamydomonas reinhardtii*.** *Plant Cell.* 2011; **23**(8): 2950–63.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
34. **F** Terashima M, Petroutsos D, Hüdig M, *et al.*: **Calcium-dependent regulation of cyclic photosynthetic electron transfer by a CAS, ANR1, and PGRL1 complex.** *Proc Natl Acad Sci U S A.* 2012; **109**(43): 17717–22.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | **F1000 Recommendation**
35. Guo H, Feng P, Chi W, *et al.*: **Plastid-nucleus communication involves calcium-modulated MAPK signalling.** *Nat Commun.* 2016; **7**: 12173.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
36. **F** Jin H, Li M, Duan S, *et al.*: **Optimization of Light-Harvesting Pigment Improves Photosynthetic Efficiency.** *Plant Physiol.* 2016; **172**(3): 1720–31.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | **F1000 Recommendation**
37. Leister D: **How Can the Light Reactions of Photosynthesis be Improved in Plants?** *Front Plant Sci.* 2012; **3**: 199.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
38. Pribil M, Pesaresi P, Hertle A, *et al.*: **Role of plastid protein phosphatase TAP38 in LHCI dephosphorylation and thylakoid electron flow.** *PLoS Biol.* 2010; **8**(1): e1000288.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
39. **F** Kromdijk J, Glowacka K, Leonelli L, *et al.*: **Improving photosynthesis and crop productivity by accelerating recovery from photoprotection.** *Science.* 2016; **354**(6314): 857–61.
[PubMed Abstract](#) | [Publisher Full Text](#) | **F1000 Recommendation**
40. Spreitzer RJ, Salvucci ME: **Rubisco: structure, regulatory interactions, and possibilities for a better enzyme.** *Annu Rev Plant Biol.* 2002; **53**: 449–75.
[PubMed Abstract](#) | [Publisher Full Text](#)
41. Bauwe H, Hagemann M, Fernie AR: **Photorespiration: players, partners and origin.** *Trends Plant Sci.* 2010; **15**(6): 330–6.
[PubMed Abstract](#) | [Publisher Full Text](#)
42. **F** Carmo-Silva E, Scales JC, Madgwick PJ, *et al.*: **Optimizing Rubisco and its regulation for greater resource use efficiency.** *Plant Cell Environ.* 2015; **38**(9): 1817–32.
[PubMed Abstract](#) | [Publisher Full Text](#) | **F1000 Recommendation**
43. Parry MA, Andralojc PJ, Scales JC, *et al.*: **Rubisco activity and regulation as**

- targets for crop improvement. *J Exp Bot.* 2013; **64**(3): 717–30.
[PubMed Abstract](#) | [Publisher Full Text](#)
44. von Caemmerer S, Quick WP, Furbank RT: **The development of C₃ rice: current progress and future challenges.** *Science.* 2012; **336**(6089): 1671–2.
[PubMed Abstract](#) | [Publisher Full Text](#)
 45. Price GD, Pengelly JJ, Forster B, *et al.*: **The cyanobacterial CCM as a source of genes for improving photosynthetic CO₂ fixation in crop species.** *J Exp Bot.* 2013; **64**(3): 753–68.
[PubMed Abstract](#) | [Publisher Full Text](#)
 46. Peterhansel C, Maurino VG: **Photorespiration redesigned.** *Plant Physiol.* 2011; **155**(1): 49–55.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 47. Maier A, Fahnstich H, von Caemmerer S, *et al.*: **Transgenic Introduction of a Glycolate Oxidative Cycle into *A. thaliana* Chloroplasts Leads to Growth Improvement.** *Front Plant Sci.* 2012; **3**: 38.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 48. Raines CA: **Increasing photosynthetic carbon assimilation in C₃ plants to improve crop yield: current and future strategies.** *Plant Physiol.* 2011; **155**(1): 36–42.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 49. **F** Simkin AJ, McAusland L, Headland LR, *et al.*: **Multigene manipulation of photosynthetic carbon assimilation increases CO₂ fixation and biomass yield in tobacco.** *J Exp Bot.* 2015; **66**(13): 4075–90.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 50. Blankenship RE, Chen M: **Spectral expansion and antenna reduction can enhance photosynthesis for energy production.** *Curr Opin Chem Biol.* 2013; **17**(3): 457–61.
[PubMed Abstract](#) | [Publisher Full Text](#)
 51. Evans JR: **Improving photosynthesis.** *Plant Physiol.* 2013; **162**(4): 1780–93.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 52. Nicotra AB, Leigh A, Boyce CK, *et al.*: **The evolution and functional significance of leaf shape in the angiosperms.** *Funct Plant Biol.* 2011; **38**(7): 535–552.
[PubMed Abstract](#) | [Publisher Full Text](#)
 53. Nicotra AB, Cosgrove MJ, Cowling A, *et al.*: **Leaf shape linked to photosynthetic rates and temperature optima in South African *Pelargonium* species.** *Oecologia.* 2008; **154**(4): 625–35.
[PubMed Abstract](#) | [Publisher Full Text](#)
 54. Tholen D, Boom C, Zhu XG: **Opinion: prospects for improving photosynthesis by altering leaf anatomy.** *Plant Sci.* 2012; **197**: 92–101.
[PubMed Abstract](#) | [Publisher Full Text](#)
 55. **F** Takai T, Adachi S, Taguchi-Shiobara F, *et al.*: **A natural variant of *NAL1*, selected in high-yield rice breeding programs, pleiotropically increases photosynthesis rate.** *Sci Rep.* 2013; **3**: 2149.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 56. Adachi S, Nakae T, Uchida M, *et al.*: **The mesophyll anatomy enhancing CO₂ diffusion is a key trait for improving rice photosynthesis.** *J Exp Bot.* 2013; **64**(4): 1061–72.
[PubMed Abstract](#) | [Publisher Full Text](#)
 57. Fujita D, Trijatmiko KR, Tagle AG, *et al.*: ***NAL1* allele from a rice landrace greatly increases yield in modern *indica* cultivars.** *Proc Natl Acad Sci U S A.* 2013; **110**(51): 20431–6.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 58. Zhang G, Li S, Wang L, *et al.*: ***LSC4* from *Japonica* Cultivar, which is allelic to *NAL1*, increases yield of *indica* super rice 93-11.** *Mol Plant.* 2014; **7**(8): 1350–64.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 59. Barkoulas M, Hay A, Kougiomoutzi E, *et al.*: **A developmental framework for dissected leaf formation in the *Arabidopsis* relative *Cardamine hirsuta*.** *Nat Genet.* 2008; **40**(9): 1136–41.
[PubMed Abstract](#) | [Publisher Full Text](#)
 60. Piazza P, Bailey CD, Cartolano M, *et al.*: ***Arabidopsis thaliana* leaf form evolved via loss of KNOX expression in leaves in association with a selective sweep.** *Curr Biol.* 2010; **20**(24): 2223–8.
[PubMed Abstract](#) | [Publisher Full Text](#)
 61. **F** Bilsborough GD, Runions A, Barkoulas M, *et al.*: **Model for the regulation of *Arabidopsis thaliana* leaf margin development.** *Proc Natl Acad Sci U S A.* 2011; **108**(8): 3424–9.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 62. **F** Vlad D, Kierzkowski D, Rast M, *et al.*: **Leaf shape evolution through duplication, regulatory diversification, and loss of a homeobox gene.** *Science.* 2014; **343**(6172): 780–3.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 63. Cartolano M, Pieper B, Lempe J, *et al.*: **Heterochrony underpins natural variation in *Cardamine hirsuta* leaf form.** *Proc Natl Acad Sci U S A.* 2015; **112**(33): 10539–44.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 64. Leggewie G, Kolbe A, Lemoine R, *et al.*: **Overexpression of the sucrose transporter *SoSUT1* in potato results in alterations in leaf carbon partitioning and in tuber metabolism but has little impact on tuber morphology.** *Planta.* 2003; **217**(1): 158–67.
[PubMed Abstract](#)
 65. Leidreiter K, Heineke D, Heldt HW, *et al.*: **Leaf-specific antisense inhibition of starch biosynthesis in transgenic potato plants leads to an increase in photoassimilate export from source leaves during the light period.** *Plant Cell Physiol.* 1995; **36**(4): 615–624.
[Reference Source](#)
 66. Sweetlove LJ, Kossmann J, Riesmeier JW, *et al.*: **The control of source to sink carbon flux during tuber development in potato.** *Plant J.* 1998; **15**(5): 697–706.
[Publisher Full Text](#)
 67. Zhang L, Häusler RE, Greiten C, *et al.*: **Overriding the co-limiting import of carbon and energy into tuber amyloplasts increases the starch content and yield of transgenic potato plants.** *Plant Biotechnol J.* 2008; **6**(5): 453–64.
[PubMed Abstract](#) | [Publisher Full Text](#)
 68. Baroja-Fernández E, Muñoz FJ, Montero M, *et al.*: **Enhancing sucrose synthase activity in transgenic potato (*Solanum tuberosum* L.) tubers results in increased levels of starch, ADPGlucose and UDPGlucose and total yield.** *Plant Cell Physiol.* 2009; **50**(9): 1651–62.
[PubMed Abstract](#) | [Publisher Full Text](#)
 69. Ferreira SJ, Sonnewald U: **The mode of sucrose degradation in potato tubers determines the fate of assimilate utilization.** *Front Plant Sci.* 2012; **3**: 23.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 70. Li J, Baroja-Fernández E, Bahaji A, *et al.*: **Enhancing sucrose synthase activity results in increased levels of starch and ADP-glucose in maize (*Zea mays* L.) seed endosperms.** *Plant Cell Physiol.* 2013; **54**(2): 282–94.
[PubMed Abstract](#) | [Publisher Full Text](#)
 71. **F** Jonik C, Sonnewald U, Hajirezaei M, *et al.*: **Simultaneous boosting of source and sink capacities doubles tuber starch yield of potato plants.** *Plant Biotechnol J.* 2012; **10**(9): 1088–98.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 72. Kammerer B, Fischer K, Hilpert B, *et al.*: **Molecular characterization of a carbon transporter in plastids from heterotrophic tissues: the glucose 6-phosphate/phosphate antiporter.** *Plant Cell.* 1998; **10**(1): 105–17.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 73. Kampfenkel K, Möhlmann T, Batz O, *et al.*: **Molecular characterization of an *Arabidopsis thaliana* cDNA encoding a novel putative adenylate translocator of higher plants.** *FEBS Lett.* 1995; **374**(3): 351–5.
[PubMed Abstract](#) | [Publisher Full Text](#)
 74. Che Y, Fu A, Hou X, *et al.*: **C-terminal processing of reaction center protein D1 is essential for the function and assembly of photosystem II in *Arabidopsis*.** *Proc Natl Acad Sci U S A.* 2013; **110**(40): 16247–52.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 75. Wang P, Liu J, Liu B, *et al.*: **Evidence for a role of chloroplastic m-type thioredoxins in the biogenesis of photosystem II in *Arabidopsis*.** *Plant Physiol.* 2013; **163**(4): 1710–28.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 76. Calderon RH, García-Cerdán JG, Malnoë A, *et al.*: **A conserved rubredoxin is necessary for photosystem II accumulation in diverse oxygenic photoautotrophs.** *J Biol Chem.* 2013; **288**(37): 26688–96.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 77. **F** Huang W, Chen Q, Zhu Y, *et al.*: ***Arabidopsis* thylakoid formation 1 is a critical regulator for dynamics of PSII-LHCII complexes in leaf senescence and excess light.** *Mol Plant.* 2013; **6**(5): 1673–91.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 78. Wang Q, Sullivan RW, Kight A, *et al.*: **Deletion of the chloroplast-localized *Thylakoid formation1* gene product in *Arabidopsis* leads to deficient thylakoid formation and variegated leaves.** *Plant Physiol.* 2004; **136**(3): 3594–604.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 79. Torabi S, Umate P, Manavski N, *et al.*: **PsbN is required for assembly of the photosystem II reaction center in *Nicotiana tabacum*.** *Plant Cell.* 2014; **26**(3): 1183–99.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 80. Schneider A, Steinberger I, Strissel H, *et al.*: **The *Arabidopsis* Tellurite resistance C protein together with ALB3 is involved in photosystem II protein synthesis.** *Plant J.* 2014; **78**(2): 344–56.
[PubMed Abstract](#) | [Publisher Full Text](#)
 81. Knoppová J, Yu J, Konik P, *et al.*: **CyanoP is Involved in the Early Steps of Photosystem II Assembly in the Cyanobacterium *Synechocystis* sp. PCC 6803.** *Plant Cell Physiol.* 2016; **57**(9): 1921–31.
[PubMed Abstract](#) | [Publisher Full Text](#)
 82. Sakata S, Mizusawa N, Kubota-Kawai H, *et al.*: **Psb28 is involved in recovery of photosystem II at high temperature in *Synechocystis* sp. PCC 6803.** *Biochim Biophys Acta.* 2013; **1827**(1): 50–9.
[PubMed Abstract](#) | [Publisher Full Text](#)
 83. Dobáková M, Sobotka R, Tichý M, *et al.*: **Psb28 protein is involved in the biogenesis of the photosystem II inner antenna CP47 (PsbB) in the cyanobacterium *Synechocystis* sp. PCC 6803.** *Plant Physiol.* 2009; **149**(2): 1076–86.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 84. Yang H, Liao L, Bo T, *et al.*: **Sir0151 in *Synechocystis* sp. PCC 6803 is required for efficient repair of photosystem II under high-light condition.** *J Integr Plant Biol.* 2014; **56**(12): 1136–50.
[PubMed Abstract](#) | [Publisher Full Text](#)
 85. Rast A, Rengstl B, Heinz S, *et al.*: **The Role of Sir0151, a Tetratricopeptide Repeat Protein from *Synechocystis* sp. PCC 6803, during Photosystem II Assembly and Repair.** *Front Plant Sci.* 2016; **7**: 605.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 86. **F** Bhuiyan NH, Friso G, Poliakov A, *et al.*: **MET1 is a thylakoid-associated**

- TPR protein involved in photosystem II supercomplex formation and repair in *Arabidopsis*. *Plant Cell*. 2015; **27**(1): 262–85.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
87. **F** Muranaka LS, Rütgers M, Bujaldon S, *et al.*: **TEF30 Interacts with Photosystem II Monomers and Is Involved in the Repair of Photodamaged Photosystem II in *Chlamydomonas reinhardtii***. *Plant Physiol*. 2016; **170**(2): 821–40.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
88. Fristedt R, Williams-Carrier R, Merchant SS, *et al.*: **A thylakoid membrane protein harboring a DnaJ-type zinc finger domain is required for photosystem I accumulation in plants**. *J Biol Chem*. 2014; **289**(44): 30657–67.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
89. Järvi S, Suorsa M, Tadini L, *et al.*: **Thylakoid-Bound FtsH Proteins Facilitate Proper Biosynthesis of Photosystem I**. *Plant Physiol*. 2016; **171**(12): 1333–43.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
90. Wulffhorst H, Franken LE, Wessinghage T, *et al.*: **The 5 kDa protein NdhP is essential for stable NDH-1L assembly in *Thermosynechococcus elongatus***. *PLoS One*. 2014; **9**(8): e103584.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
91. Yamamoto H, Fan X, Sugimoto K, *et al.*: **CHLORORESPIRATORY REDUCTION 9 is a Novel Factor Required for Formation of Subcomplex A of the Chloroplast NADH Dehydrogenase-Like Complex**. *Plant Cell Physiol*. 2016; **57**(10): 2122–2132.
[PubMed Abstract](#) | [Publisher Full Text](#)
92. **F** Samol I, Shapiguzov A, Ingelsson B, *et al.*: **Identification of a photosystem II phosphatase involved in light acclimation in *Arabidopsis***. *Plant Cell*. 2012; **24**(6): 2596–609.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
93. Jin H, Liu B, Luo L, *et al.*: **HYPERSENSITIVE TO HIGH LIGHT1 interacts with LOW QUANTUM YIELD OF PHOTOSYSTEM II1 and functions in protection of photosystem II from photodamage in *Arabidopsis***. *Plant Cell*. 2014; **26**(3): 1213–29.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
94. Liu J, Last RL: **A land plant-specific thylakoid membrane protein contributes to photosystem II maintenance in *Arabidopsis thaliana***. *Plant J*. 2015; **82**(5): 731–43.
[PubMed Abstract](#) | [Publisher Full Text](#)
95. Seok MS, You YN, Park HJ, *et al.*: **AtFKBP16-1, a chloroplast luminal immunophilin, mediates response to photosynthetic stress by regulating Psal stability**. *Physiol Plant*. 2014; **150**(4): 620–31.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

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