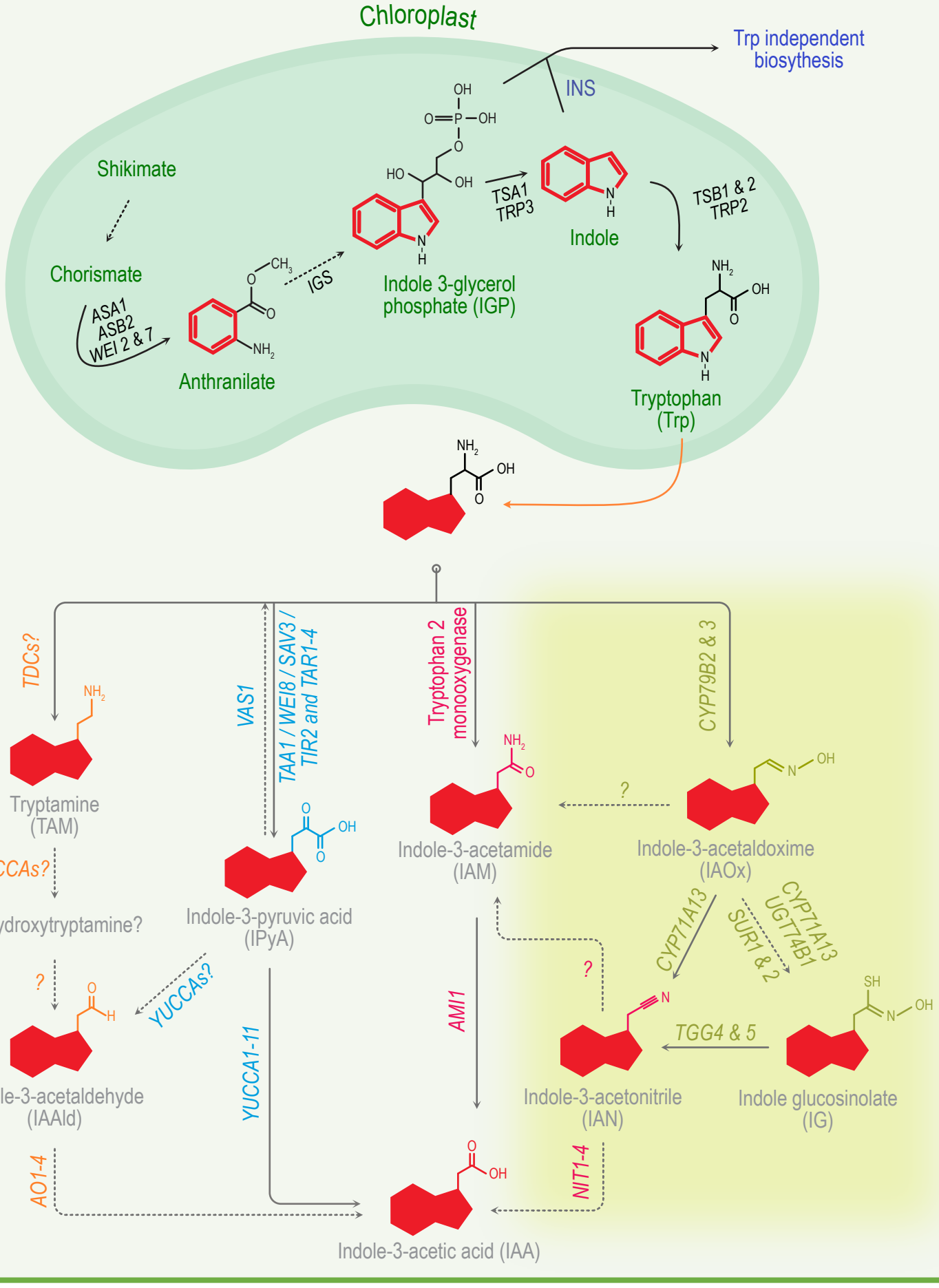
Auxin Biosyntheis

CEITEC Dr Helene Robert Boisivon group



Auxin Biosynthesis

The naturel auxin molecule is an indole-derived compound, indole-3-acetic acid, IAA. It is produced either from, or independently of, Tryptophan (Trp). Illustrated here are the known pathways of Trp-dependent IAA production in plants.

In chloroplast, Trp is produced from shikimate to chorismate, then to anthranilate by the anthranilate synthases WEI2/7 (or ASA1/ASB2) enzymes (Stepanova et al, 2005). WEI2 and WEI7 were uncovered in a genetic screen for identifying ethylene-mediated root growth regulators. Anthranilate is then converted into indole-3-glycerol phosphate (IGP) by multiple enzymes including IGS (Indole-3-glycerol phosphate synthase, Ouyang et al, 2001). Further conversion to indole and Trp is done by Trp synthase α (TSA1) and Trp synthase β (TSB1) (Tzin et al, 2010). The pathways for Trp-independent IAA production use IGP and Indole as substrates.

Four characterized pathways use Trp as precursor for IAA production. One of them, producing indole-3-acetaldoxime (IAOx), indole acetonitrile (IAN) and indole glucosinolate (IG), is specific to the Brassicaceae family (Sugawara et al, 2009). It is involved in the production of secondary metabolites such as glucosinolates and camalexin. IAOx is produced from Trp by cytochromes P450 CYP79B2 and CYP79B3 (Zhao et al, 2002). Glucosinolates biosynthetic genes include SUPERROOT SUR1 and SUR2, CYP71A13 and UGT74B1 (Douglas Grubb et al, 2004; Seo et al, 1998).

The first characterized enzymes in auxin biosynthesis were the iaaH and iaaM enzymes discovered in *Pseudomonas* and *Agrobacterium*. These enzymes encode a Trp-2-monooxygenase that converted Trp into indole-3-acetamide (IAM) and a hydrolase that modifies IAM into IAA. Orthologs of iaaH and iaaM have not be found in plants. The Trp-IAM-IAA pathway is catalized by a Trp-2-monooxygenase and the IAM hydrolase AMI1 (Pollmann et al, 2003). IAM may also be produced from IAOx and IAN.

The most prominent pathway for plant development is the two-step pathway involving indole-3-pyruvic acid (IPyA) as intermediate. The enzymes catalysing these reactions were isolated from genetic screens aiming at identifying regulators of organ development, ethylene response and shade avoidance. The first step is converting Trp into IPyA by the action of tryptophan aminotransferases (TAA1 and TARs). TAA1 was identified as WEAK ETHYLENE INSENSITIVE8 (WEI8, Stepanova et al, 2008), SHADE AVOIDANCE3 (SAV3, Tao et al, 2008) and TRANSPORT INHIBITOR RESPONSE2 (TIR2, Yamada et al, 2009). The second step is rate-limiting, catalyzed by the flavin-containing monooxygenases of the YUCCA proteins (YUC1-11, Zhao, 2012).

The last putative pathway involves tryptamine (TAM), as intermediate based on experiments performed in *Avena* (Lehman et al, 2010). The first step of the pathway is catalyzed by tryptophan decarboxylase (TDC), found in several plant species, but not yet in *Arabidopsis*. TAM is converted into N-hydroxytryptamine by hydroxylation of the amino group of TAM, supposedly by members of the YUCCA family (Zhao et al, 2001). However, N-hydroxytryptamine has not been detected in plants so far. Other research indicate that TAM may be directly converted into indole-3-acetaldehyde (IAAld) (Quittenden, 2009). Besides, IAAld may be also produced from IPyA by the YUCCAs as observed in rhizobacteria (Mano and Nemoto, 2012). IAAld is finally oxidized by aldehyde oxidases (AO) into IAA.

@R_Boisivonlab

Prepared and figure drawn based on Olatunji et al, 2017.

Douglas Grubb, C., et al. Arabidopsis glucosyltransferase UGT74B1 functions in glucosinolate biosynthesis and auxin homeostasis. Plant J. 2004, 40, 893–908.

Lehmann, T.; Hoffmann, M.; Hentrich, M.; Pollmann, S. Indole-3-acetamide-dependent auxin biosynthesis: A widely distributed way of indole-3-acetic acid production? Eur. J. Cell Biol. 2010, 89, 895–905.

Mano, Y.; Nemoto, K. The pathway of auxin biosynthesis in plants. J. Exp. Bot. 2012, 63, 2853–2872.

Olatunji D., Geelen, D. and Verstraeten, I. Control of Endogenous Auxin Levels in Plant Root Development. Int. J. Mol. Sci. 2017, 18, 2587.

Ouyang, J.; Shao, X.; Li, J. Indole-3-glycerol phosphate, a branchpoint of indole-3-acetic acid biosynthesis from the tryptophan biosynthetic pathway in Arabidopsis thaliana. Plant J. 2001, 24, 327–333.

Pollmann, S.; Neu, D.; Weiler, E.W. Molecular cloning and characterization of an amidase from *Arabidopsis thaliana* capable of converting indole-3-acetamide into the plant growth hormone, indole-3-acetic acid. Phytochemistry 2003, 62, 293–300.

Quittenden, L.J. , Davies, N.W., Smith, J.A., Molesworth, P.P., Tivendale, N.D. and Ross J.J. Auxin biosynthesis in pea: characterization of the tryptamine pathway. Plant Physiol. 2009, 151, 1130-1138.

Stepanova, A.N. et al. A Link between ethylene and auxin uncovered by the characterization of two root-specific ethylene-insensitive mutants in Arabidopsis. *The Plant cell*, 2005, 17, 2230–2242.

Stepanova, A.N., et al. TAA1-mediated auxin biosynthesis is essential for hormone crosstalk and plant development. Cell 2008, 133, 177–191.

Seo, M. et al. Higher activity of an aldehyde oxidase in the auxin-overproducing superroot1 mutant of Arabidopsis thaliana. Plant Physiol. 1998, 116, 687–693.

Sugawara, S. et al. Biochemical analyses of indole-3-acetaldoxime-dependent auxin biosynthesis in Arabidopsis. Proc. Natl. Acad. Sci. USA 2009, 106, 5430–5435.

Tao, Y., et al. Rapid synthesis of auxin via a new tryptophan-dependent pathway is required for shade avoidance in plants. Cell 2008, 133, 164–176.

Tzin, V.; Galili, G. New insights into the shikimate and aromatic amino acids biosynthesis pathways in plants. Mol. Plant 2010, 3, 956–972.

Yamada, M., et al. The TRANSPORT INHIBITOR RESPONSE2 gene is required for auxin synthesis and diverse aspects of plant development. Plant Physiol. 2009, 151, 168–179.

Zhao, Y.D., et al. A role for flavin monooxygenase-like enzymes in auxin biosynthesis. Science 2001, 291, 306–309.

Zhao, Y.D., et al. Trp-dependent auxin biosynthesis in Arabidopsis: Involvement of cytochrome P450s CYP79B2 and CYP79B3. Genes Dev. 2002, 16, 3100–3112.

Zhao, Y. Auxin biosynthesis: A simple two-step pathway converts tryptophan to indole-3-acetic acid in plants. Mol. Plant 2012, 5, 334–338