SFRZE

2022

6) Interaction of auxins and light in plant growth and development

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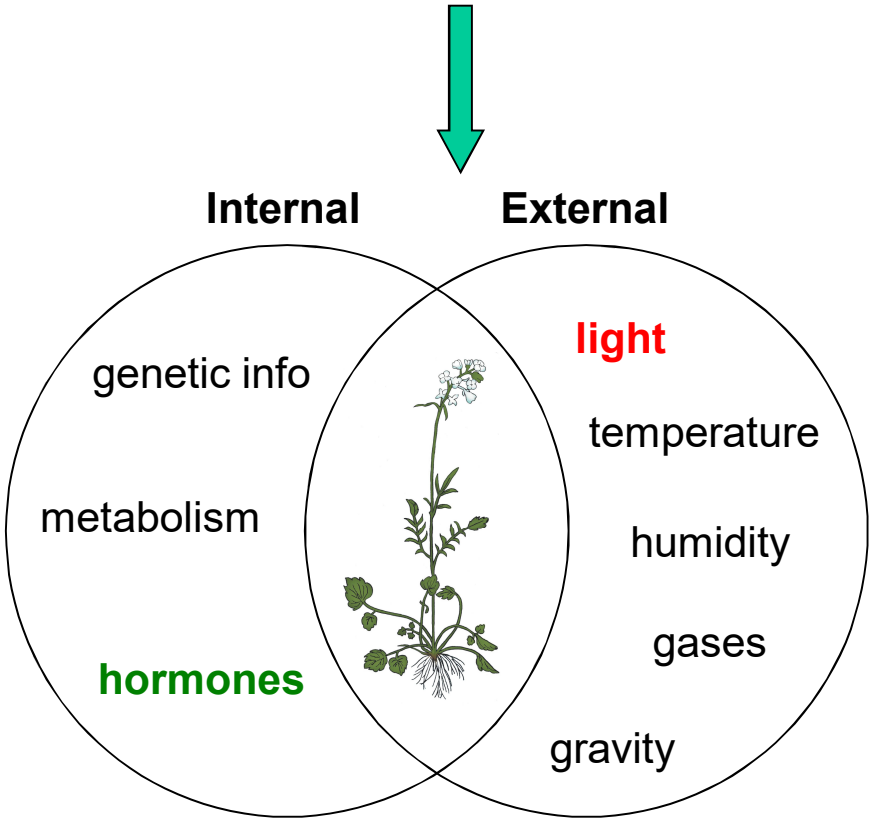
Development of organism is regulated by signals (factors)

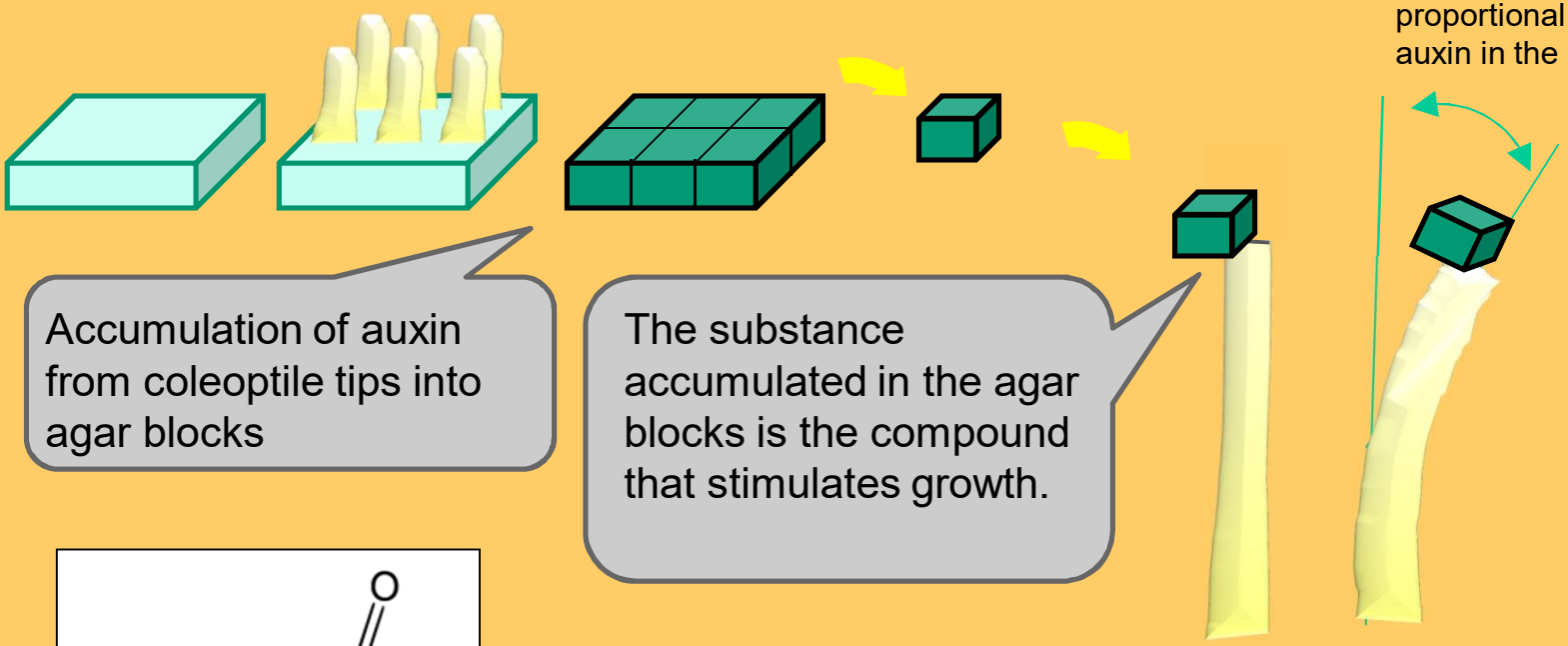


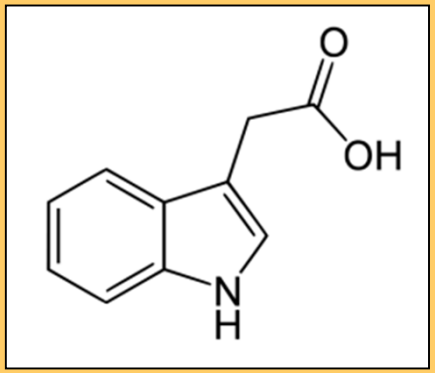
Arabidopsis

Tomato

Maize

In 30th auxin has been isolated and it was shown that it stimulates growth.





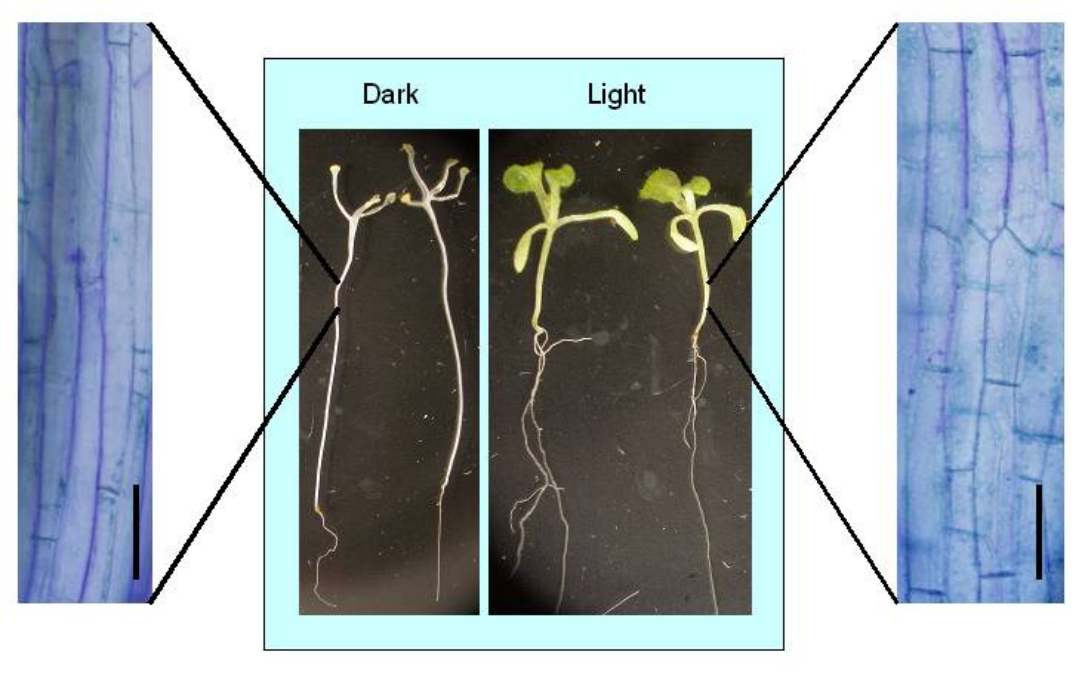
IAA - Indole-3-acetic acid

This experiment showing auxin-induced growth stimulation was used as a basis for auxin purification.

Redrawn from Went, F.W. (1935) Auxin, the plant growth-hormone. Bot. Rev. 1: 162-182.

Growth in the dark
(etiolated growth, skotomorphogenesis)

„*Skoto*“ = tma



Auxin

↓

Cell expansion

↓

Elongation growth

⇄

?

Light

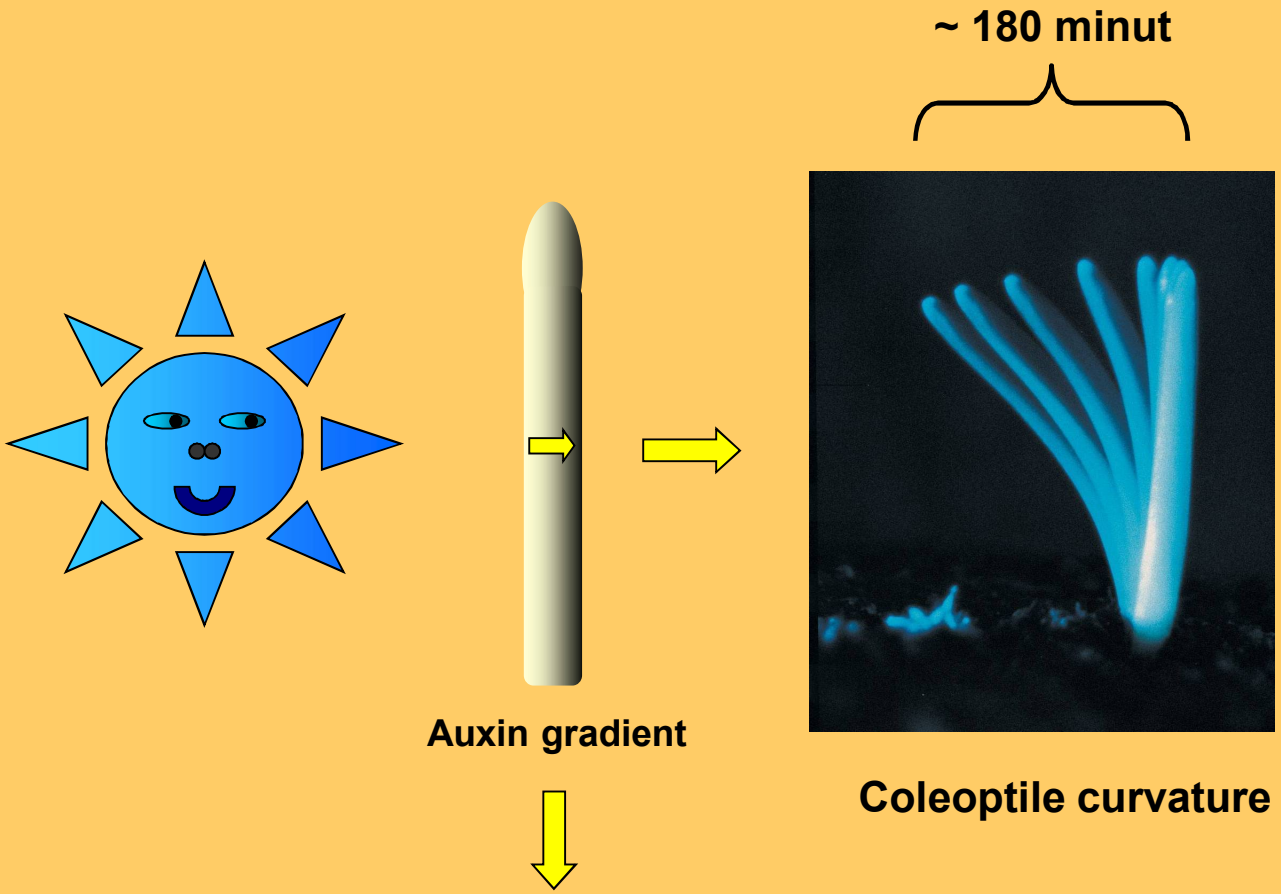
↓

Cell expansion is inhibited

⊥

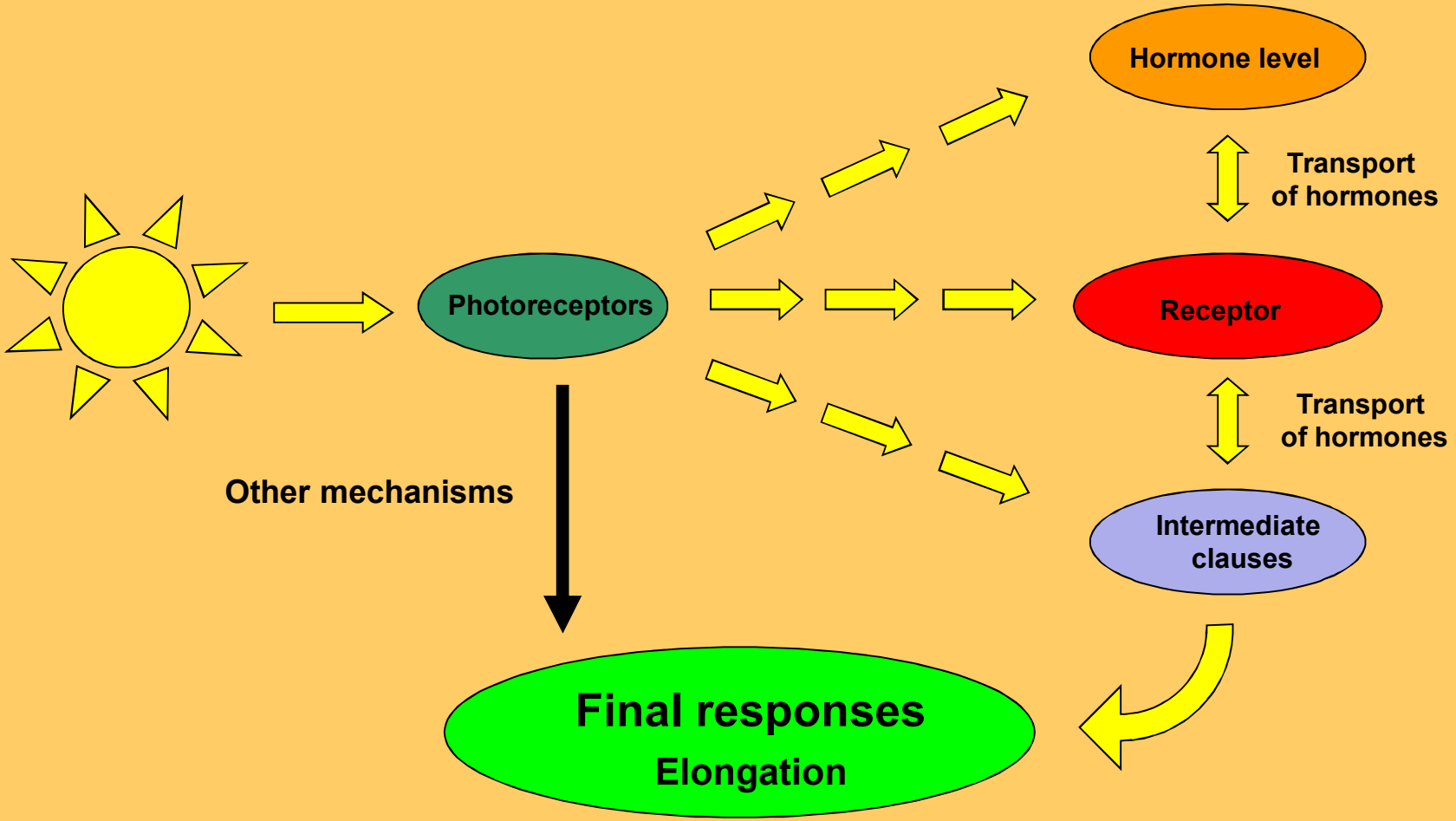
Elongation growth

Auxin-induced elongation during phototropism

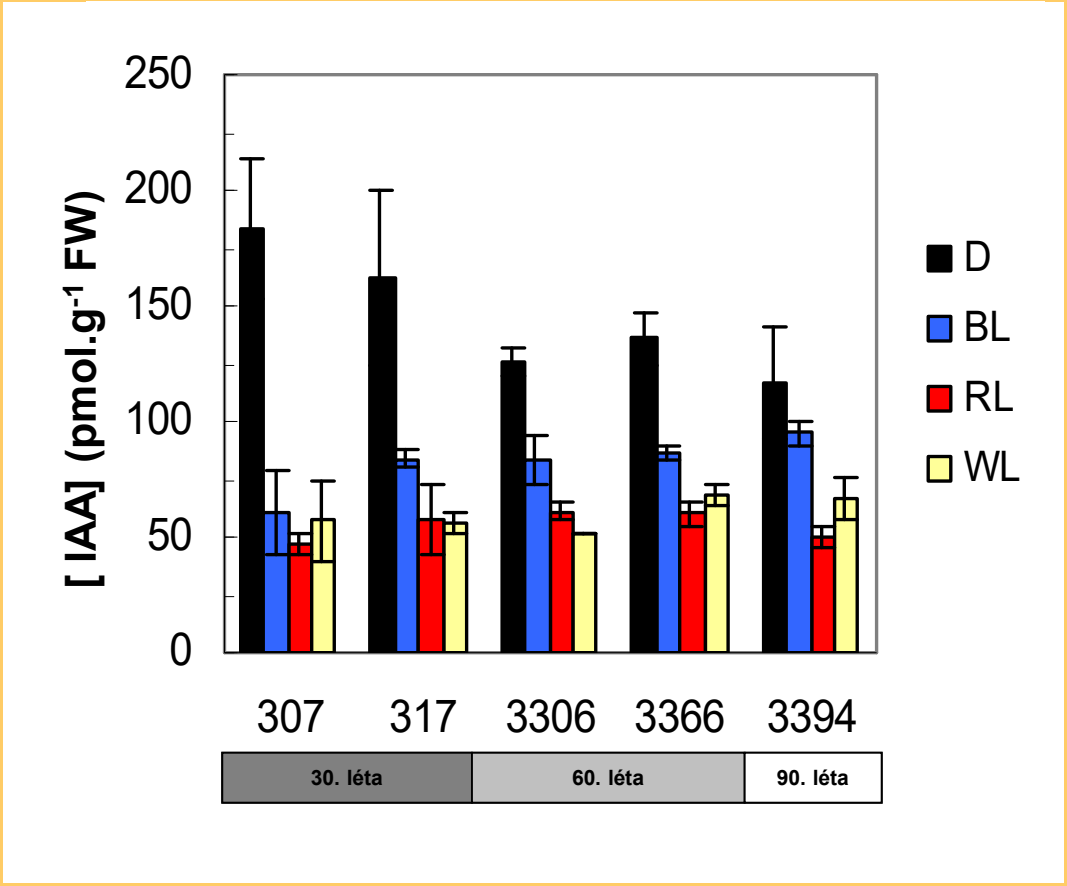


Auxin stimulates cell expansion on the shaded side of the coleoptile => coleoptile curvature

Light and auxin interaction levels



A. Light-induced growth control by regulators of endogenous auxin levels



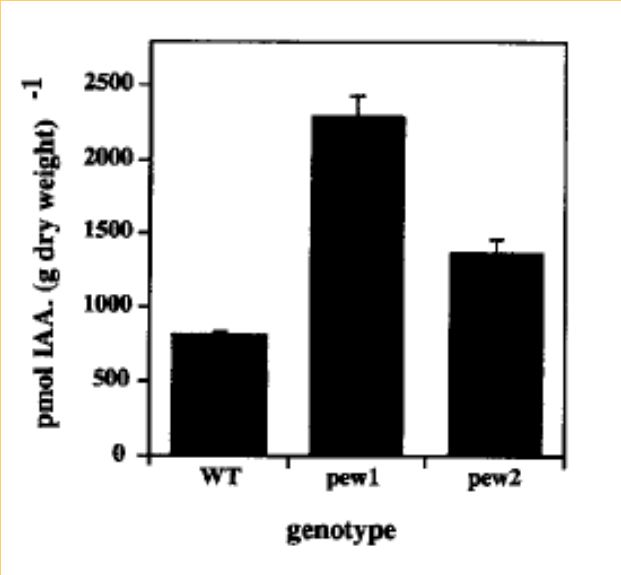
Changes in IAA auxin level in maize mesocotyls as a function of hybrid and light conditions.

307

Sensitivity to light
Leaf angle

3394

Tobacco: mutants *pew1* and *pew2* – defect in the chromophore synthesis

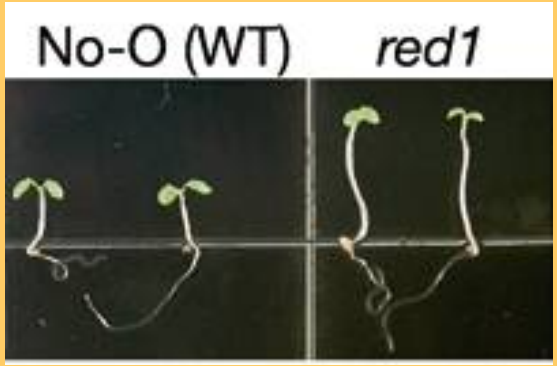


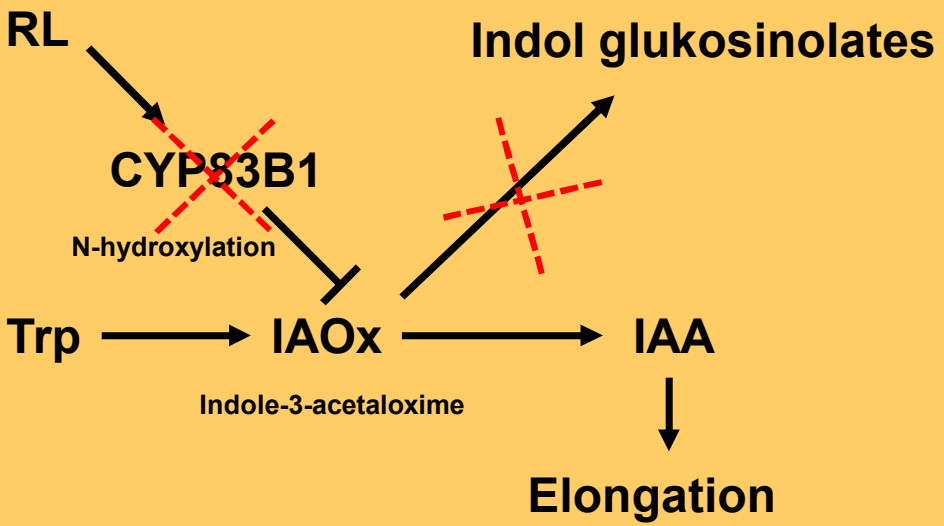
Reduced sensitivity to light

[IAA] ↑

Kraepiel Y et al. (1995) Planta 197: 142 146

***Arabidopsis*:** mutant *red1* – defect in enzyme CYP83B1 (P450 monooxygenasa – hydroxylates IAOX)

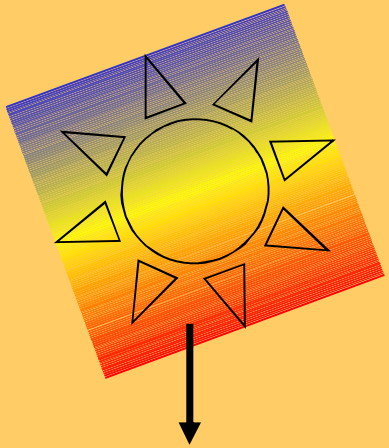




Hoecker U et al. (2004) Planta (2004) 219: 195–200

General principle: more light => less auxins => weaker growth

Normal R:FR = 1,2

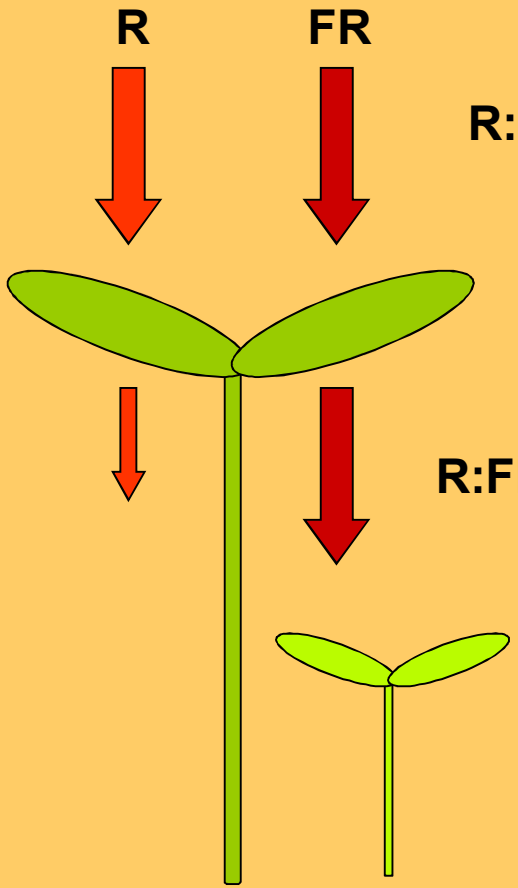


phyA, phyB, CRY1

[Auxin]

Elongation

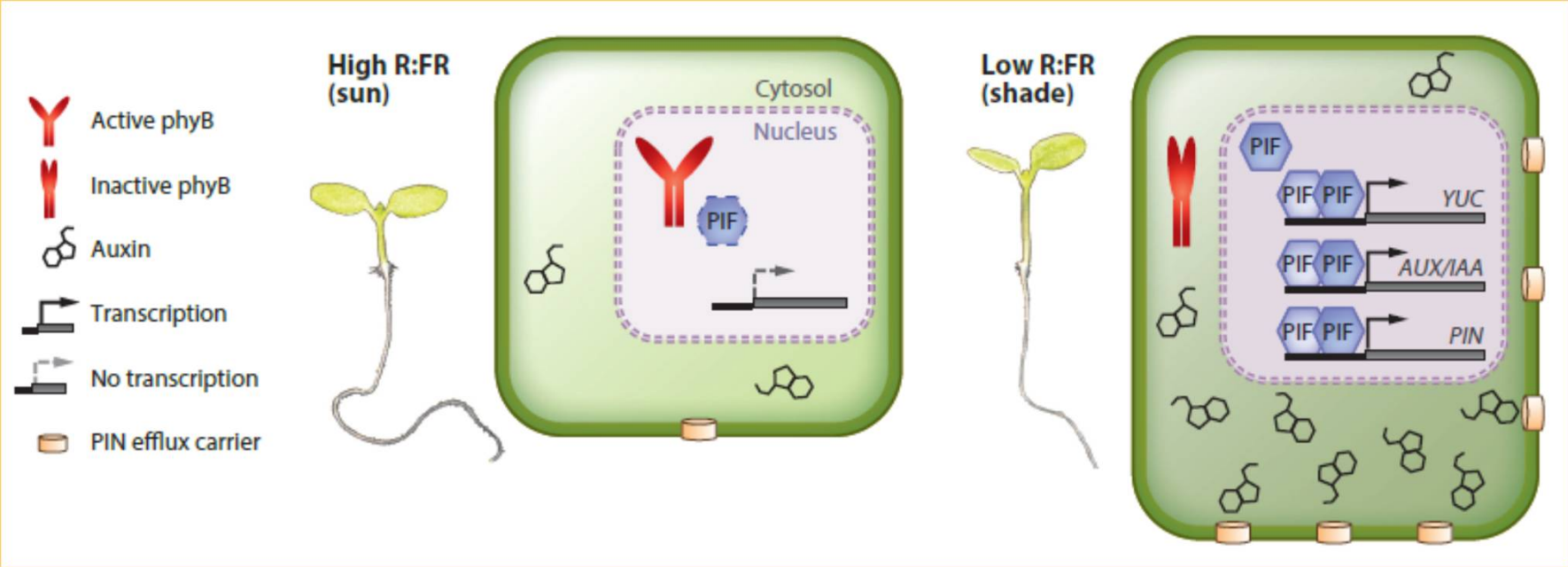
Shade avoidance = plant response to shade



[Auxin]

Elongation

De Wit M et al. (2016) Annu Rev Plant Biol 67: 22.1-22.25



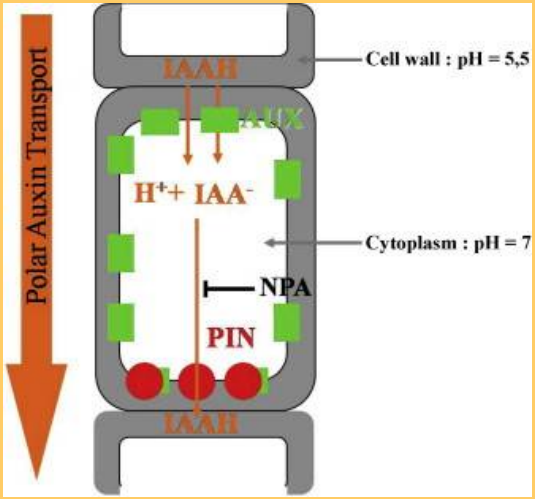
High R:FR => activation of phyB => transport to nucleus => inactivation of PHYTOCHROME-INTERACTING FACTOR 4 (PIF4), PIF5 and PIF7 => inhibition of PIF-dependent transcription

Low R:FR => inactivation of phyB => PIF acumulation => regulation of PIF-dependent transcription of targer genes: *YUCCA*, *AUXIN/IAA* and regulation if auxin transport proteins PIN-FORMED (PIN).

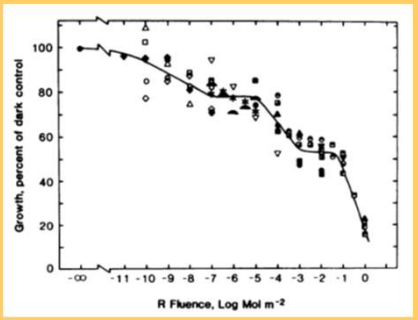
Cell expansion

B. Elongation growth as a consequence of light-regulated auxin transport

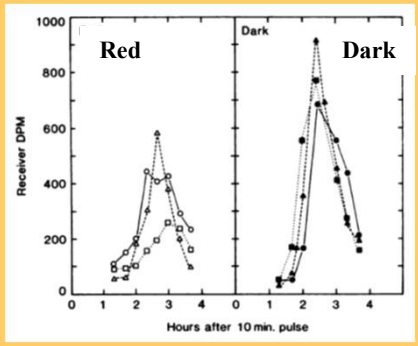
Maize



Bohn-Courseau I (2010)

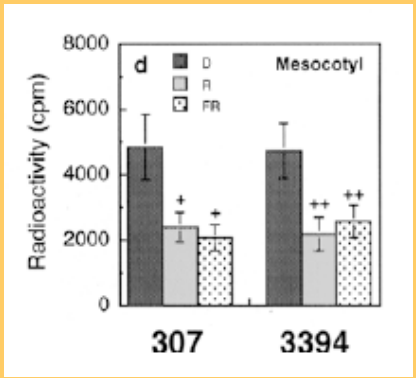


Maize coleoptile elongation is inhibited by increasing RL intensity.



RL reduces the accumulation of radioactive auxin in the maize mesocotyl.

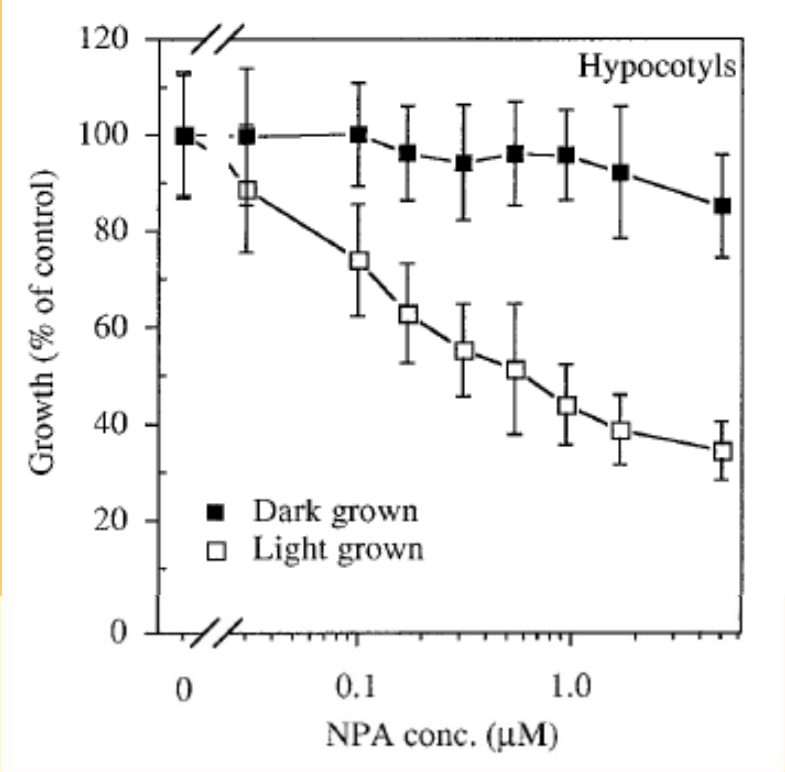
Jones AM et al. (1991) Plant Physiol. 97: 352-358



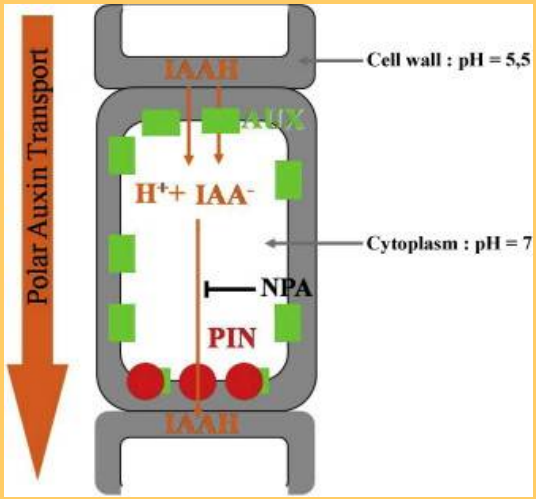
RL and FR reduce polar auxin transport in maize mesocotyl.

Fellner M et al. (2003) Planta 216: 366-376

Arabidopsis



Jensen PJ et al. (1998) Planta 116: 455-462



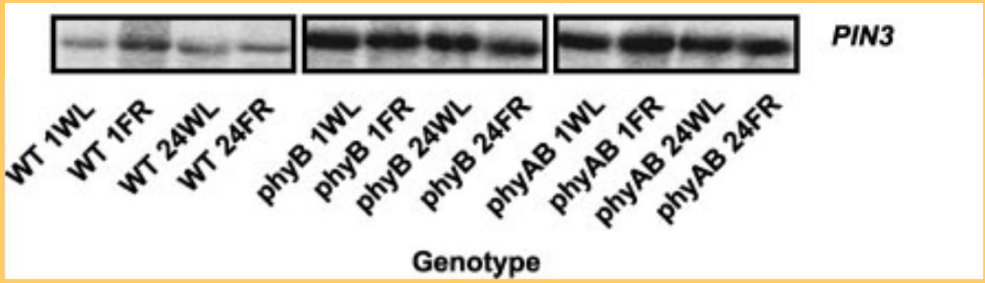
1) Etiolated hypocotyls are insensitive to NPA; de-etiolated hypocotyls are sensitive to NPA.

2) The effect of NPA is reduced in plants with a defect in light perception (plants with mutations in photoreceptors).

Photoreceptor-controlled inhibition of hypocotyl growth involves regulation of polar transport.

Mutation in phyA and phyB results in amplified expression of *PIN3* and *PIN7*

Overexpression of phyA and B results in reduction of expressio of *PIN3* a *PIN7*



Devlin et al. (2003) Plant Physiol 133: 1617–1629

phyA, phyB

⊣

PIN3, PIN7 expression

↓

Auxin transport

↓

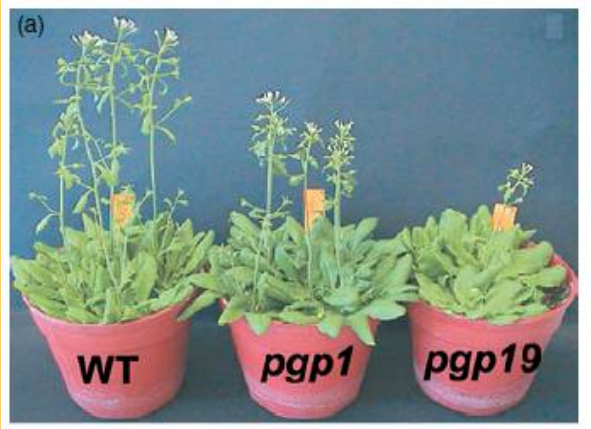
Elongation

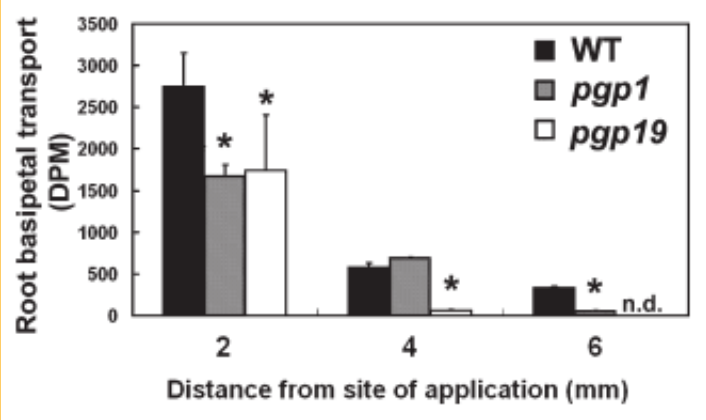
The de-etiolation process is associated with a reduction in polar auxin transport. This reduces auxin-induced elongation.

Reduction of polar auxin transport by light is mediated by phytochromes.

Auxin transporters ABCB

Auxin transport is also regulated by ABCB proteins (ABC = ATP-Binding Cassette; transmembrane glycoprotein transporters; formerly PGP or MDR proteins)

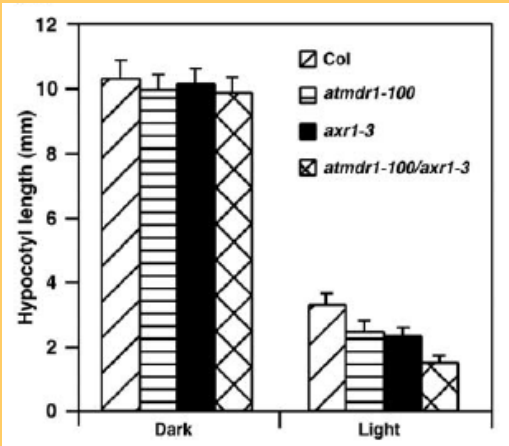




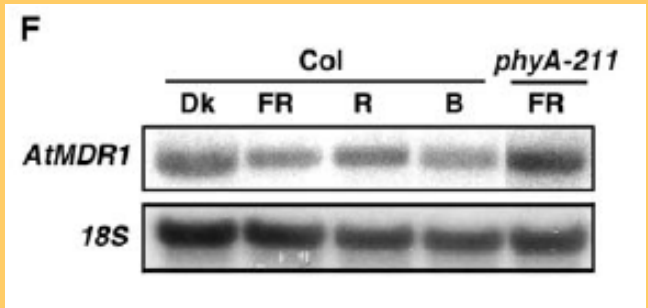
Overexpression of ABCB1 => hypokotyl elongation

ABCB1 knockout => hypokotyl shortening

Geissler M et al. (2005) Plant J 44: 179-194



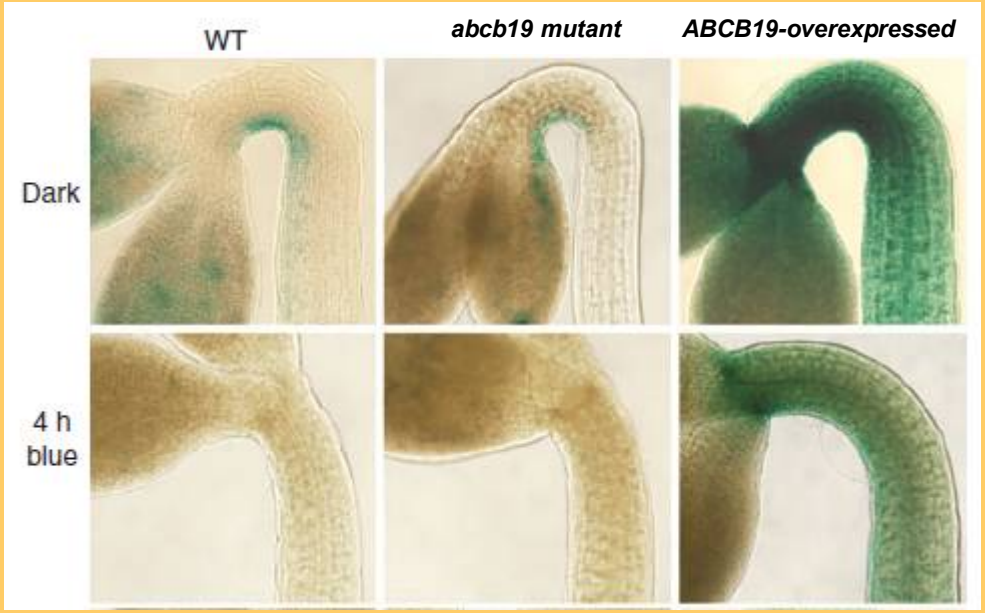
abcb1 **knockout mutants have strongly inhibited growth under light.**



Expression of ABCB1 is reduced by light.

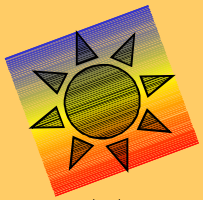
Lin R and Wang H (2005) Plant Physiol 138: 949-964

Expression of *ProDR5:GUS*



[IAA]↓ [IAA]↑

Hypocotyl growth



CRY1 phyB

ABCB19

[Auxin]

Hypocotyl growth

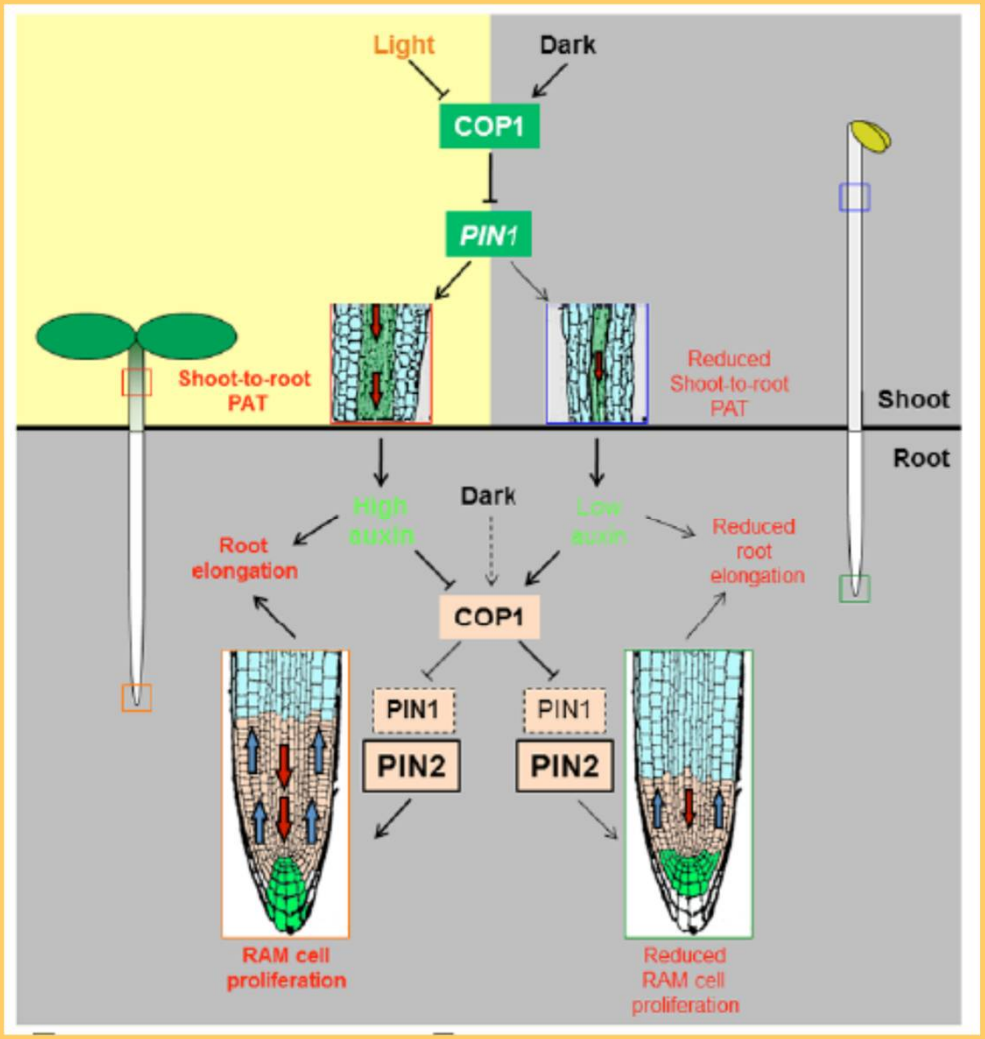
Wu et al. (2010) Plant Journal 62: 179-191

But!

Light enhances polar auxin transport in the *Arabidopsis* hypocotyl by blocking COP1, a negative regulator of the PIN1 auxin transporter. The results explain the stimulation of root growth in the light and the inhibition of root growth in the dark.

However, the data contradict earlier results showing that light inhibits polar auxin transport.

Further research into the mechanism of polar auxin transport is necessary



Sassi M et al. (2012) Development 139: 3402-3412

C. Signal elements common to light signal paths and auxins

1) Common genes regulated by auxin and light

Primary genes for growth and development

GH3 **– expression stimulated by auxin during 5 min; genes functioning in IAA conjugation; expressio of *GH3* reflects amount of endogenous auxin**

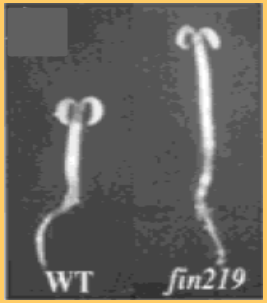
Aux/IAA **– expression stimulated by auxin during 6 – 60 min; the resulting protein lives for about 7 minutes.**

SAUR **– expression stimulated by auxin during 2 – 5 min; the expression does not require the synthesis of new proteins; genes do not contain introns, they encode very similar peptides of unknown function.**

GH3 – like genes

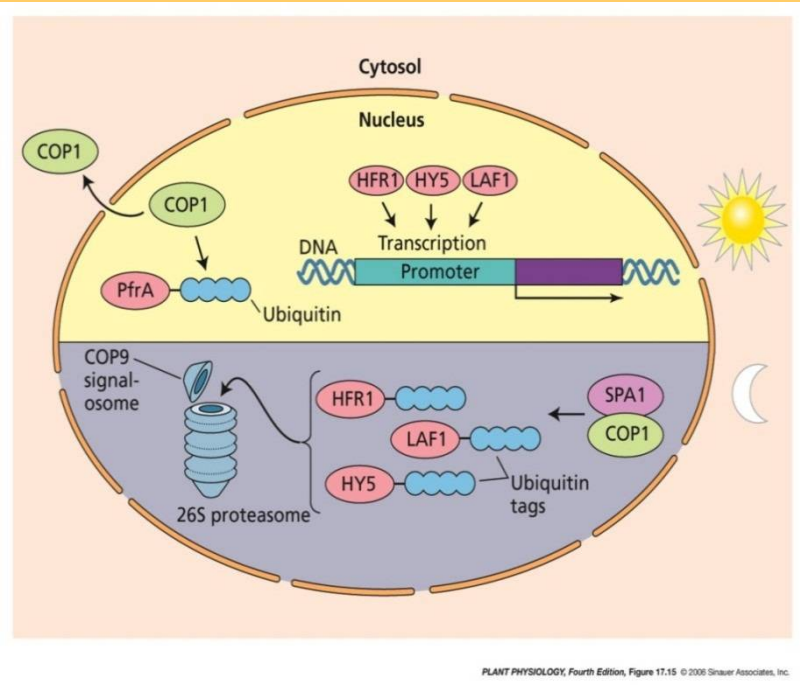
FIN219 **– quickly-induced by auxin**
fin219 **– long hypocotyl in the FR**

FR phenotype



Dark phenotype

FR
↓
phyA
↓
[FIN219]
⊥
COP1
⊥
HY5



Hsieh H-L et al. (2000) Genes and Development 14: 1958-1970

Aux/IAA genes

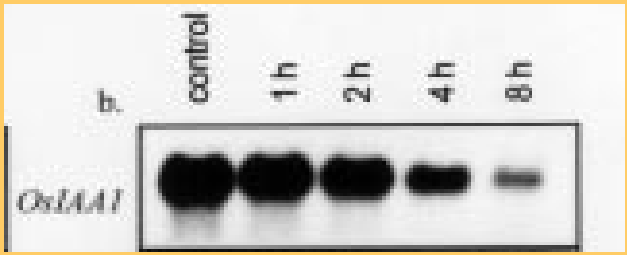
Expression of *Aux/IAA* genes is stimulated by auxin but inhibited by light.

Application of 30 μM IAA.

Light

Auxin → OsIAA

Elongation

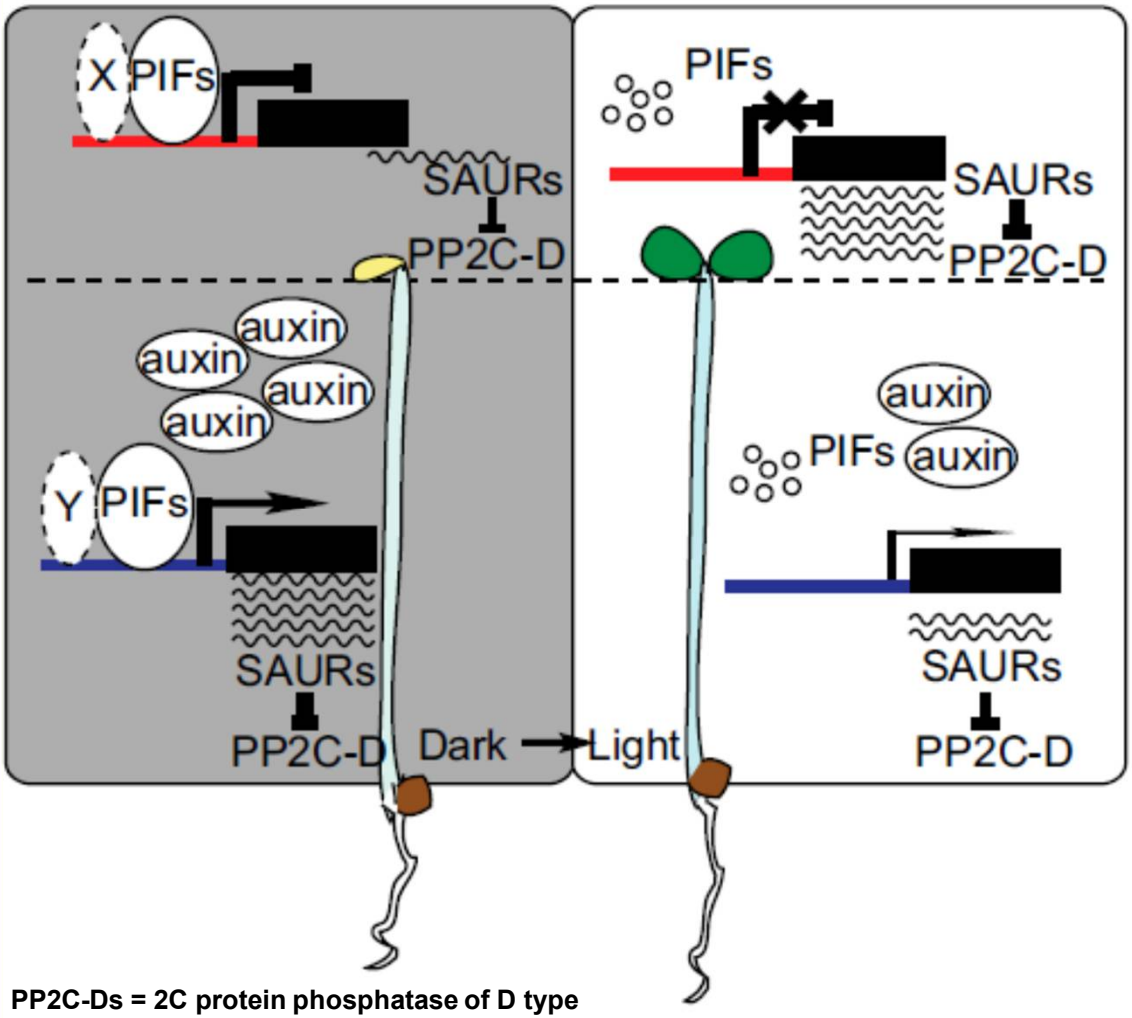


Thakur JK et al. (2001) DNA Res 8:193–203

SAUR genes

Lack of information

Sun N et al. (2016) PNAS 113: 60716076



PP2C-Ds = 2C protein phosphatase of D type

Cotyledons

Dark – low expression of SAUR => small, closed cotyledons

Light – high expression of SAUR => big, open cotyledons

Hypocotyl

Dark – high expression of SAUR => higher elongation of hypocotyl

Light – low expression of SAUR => Reduced elongation of hypocotyl

PIFs bind directly to genes encoding SAUR proteins and differentially regulate their expression in cotyledons and hypocotyls

Světlo mění hladinu auxinů a stabilitu PIF => odlišná regulace exprese SAUR v dělohách a hypokotylech.

2) Elements of a signaling pathway shared by auxin and light

TIR1 system

A – auxin

TIR1 – F-box subunit of E3-ubiquitin ligase; auxin receptor

AUX/IAA – repressor of transcription of auxin-induced genes

ARF – transcription factor (aktivator of gene expression)

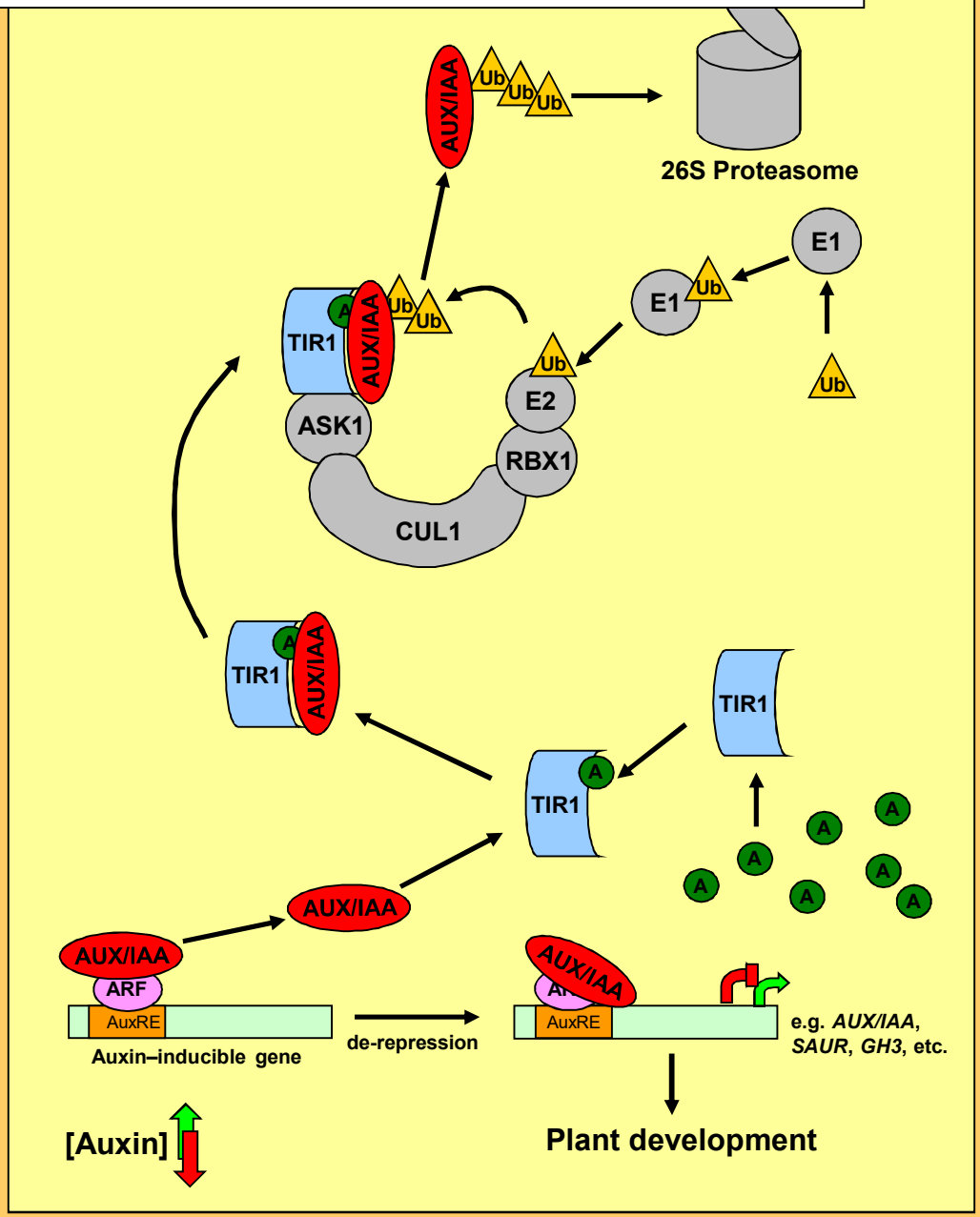
Auxin-induced genes contain AuxRE = auxin-responsive element

Similar mechanisms for other F-box proteins:

COP1 – CONSTITUTIVE PHOTOMORPHOG. 1

COI – CORONATINE INSENSITVE 1

ZTL – ZEITLUPE, etc.

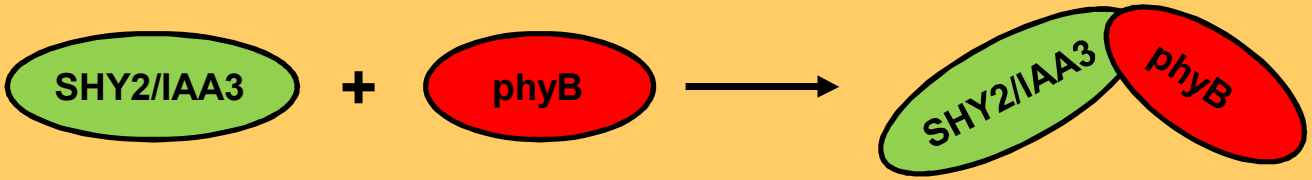


Mechanism of control of Aux/IAA activity by light.

Light → phyA, phyB → Transcription of *SHY2/IAA3*

1) Light → phyA → Phosphorylation of *Aux/IAA*

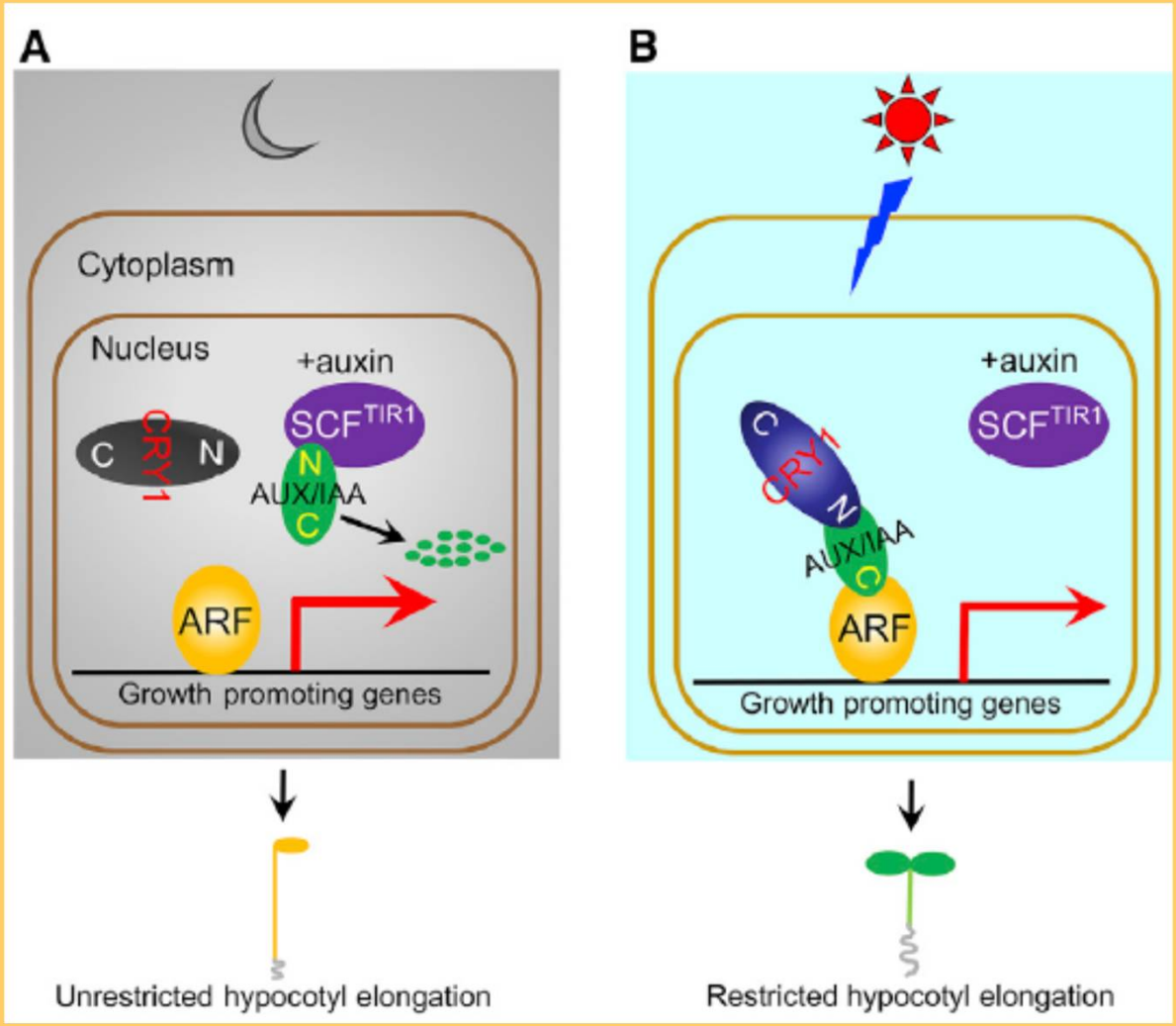
Colon-Carmona A et al. (2000)
Plant Physiology124: 1728–1738

2) 

Tian Q et al. (2003) Plant Journal 36: 643-651

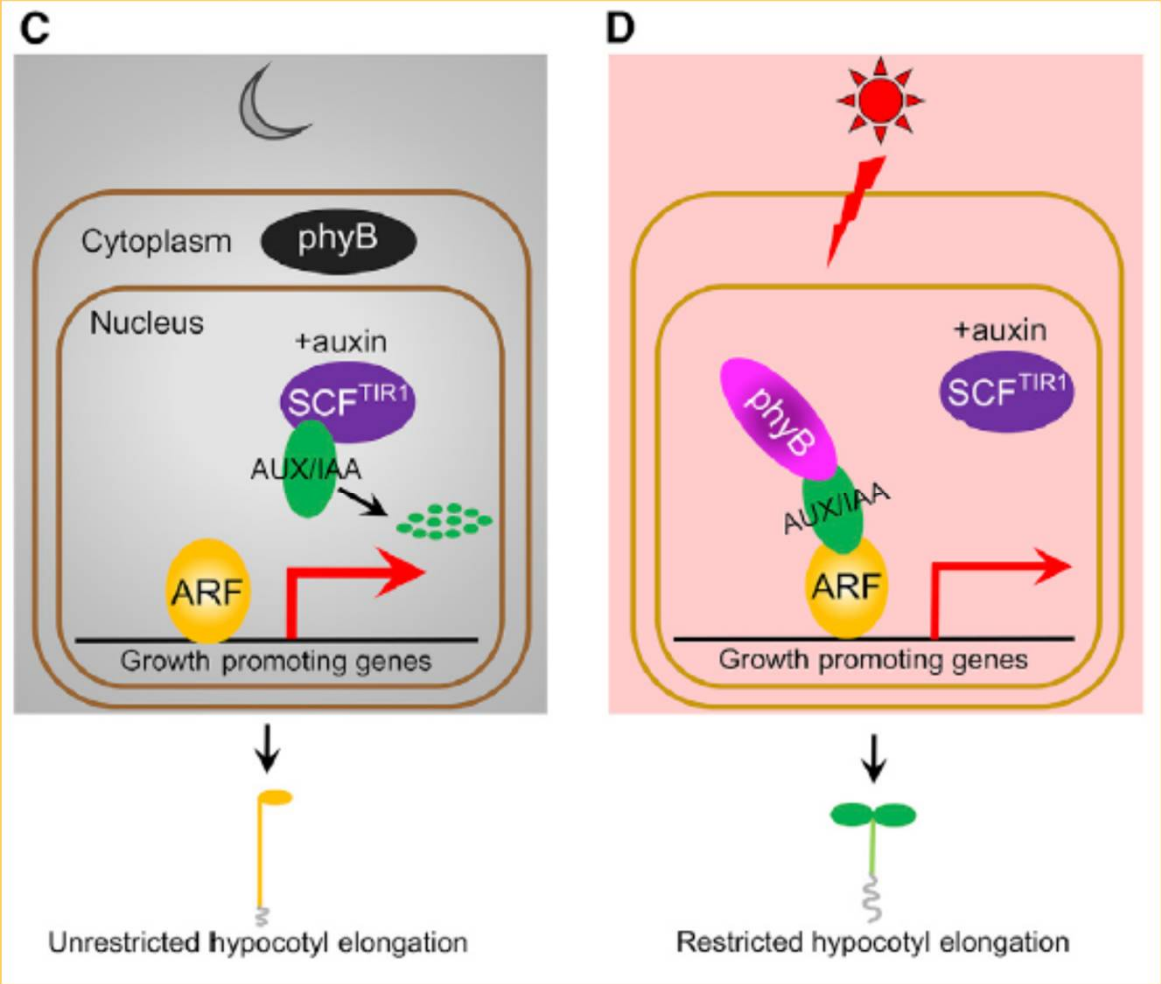
Phytochromes influence expression of *Aux/IAA*.

Xu F et al. (2017) Molecular Plant 11: 523-541



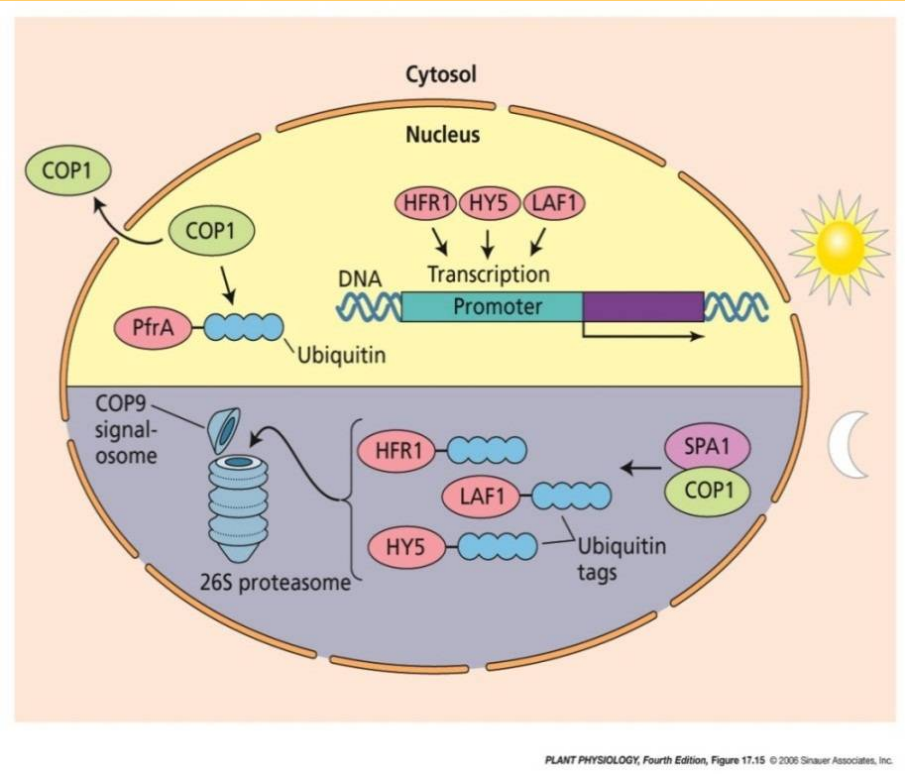
Blue light

Xu F et al. (2017) Molecular Plant 11: 523-541



Red light

Transcription factor of HY5



HY5 binds to promoter of *AUX/IAA* and *ARF* genes

hy5* – low exprese of genes *AUX/IAA

Light

↓

phyA, phyB

↓

HY5

↓

AUX/IAA

⊣

Auxin signaling

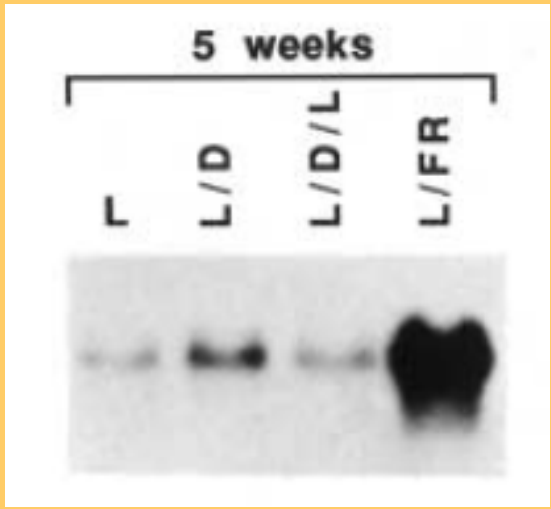
↓

Hypocotyl elongation

Sellaro et al. (2011) Plant J 68: 919–928

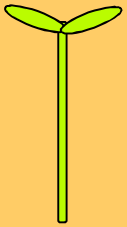
Transcription factor ATHB2

ATHB-2 expression is induced by low R:FR (shading) through phyB and phyE.

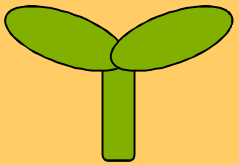


Carabelli M et al. (1993) Plant J 4: 469-479

***OE-ATHB2* plants = *phy* mutants:**



Antisense plants *athb-2:*



ATHB-2

The formation of lateral roots is induced by auxin

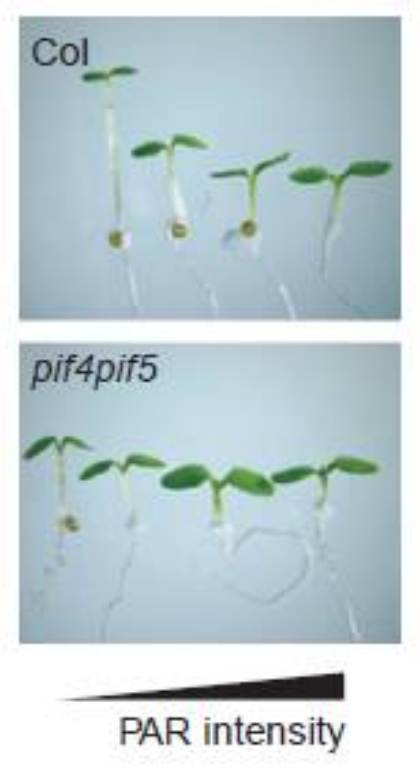
ATHB2 expression induced by low R:FR leads to reduced polar auxin transport and reduced expression of auxin-induced genes.

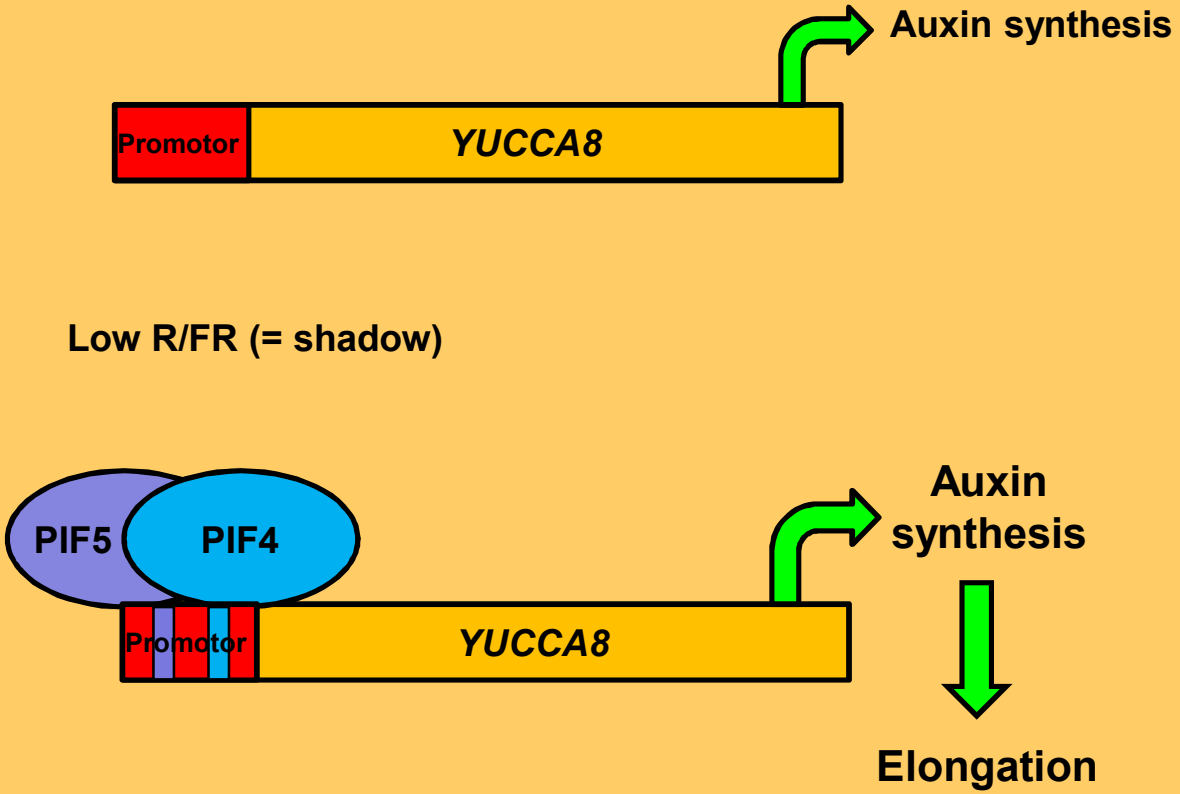
ATHB-2 is a connecting element of the light and auxin signaling pathway

Transcription factor PIF4, PIF5

Positive regulators of shade avoidance response => they are expressed at low R/FR (= shading)

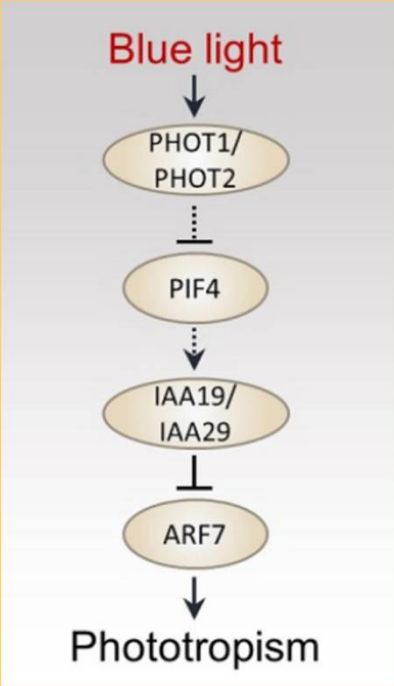
***YUCCA* genes – positive regulators of auxin synthesis**

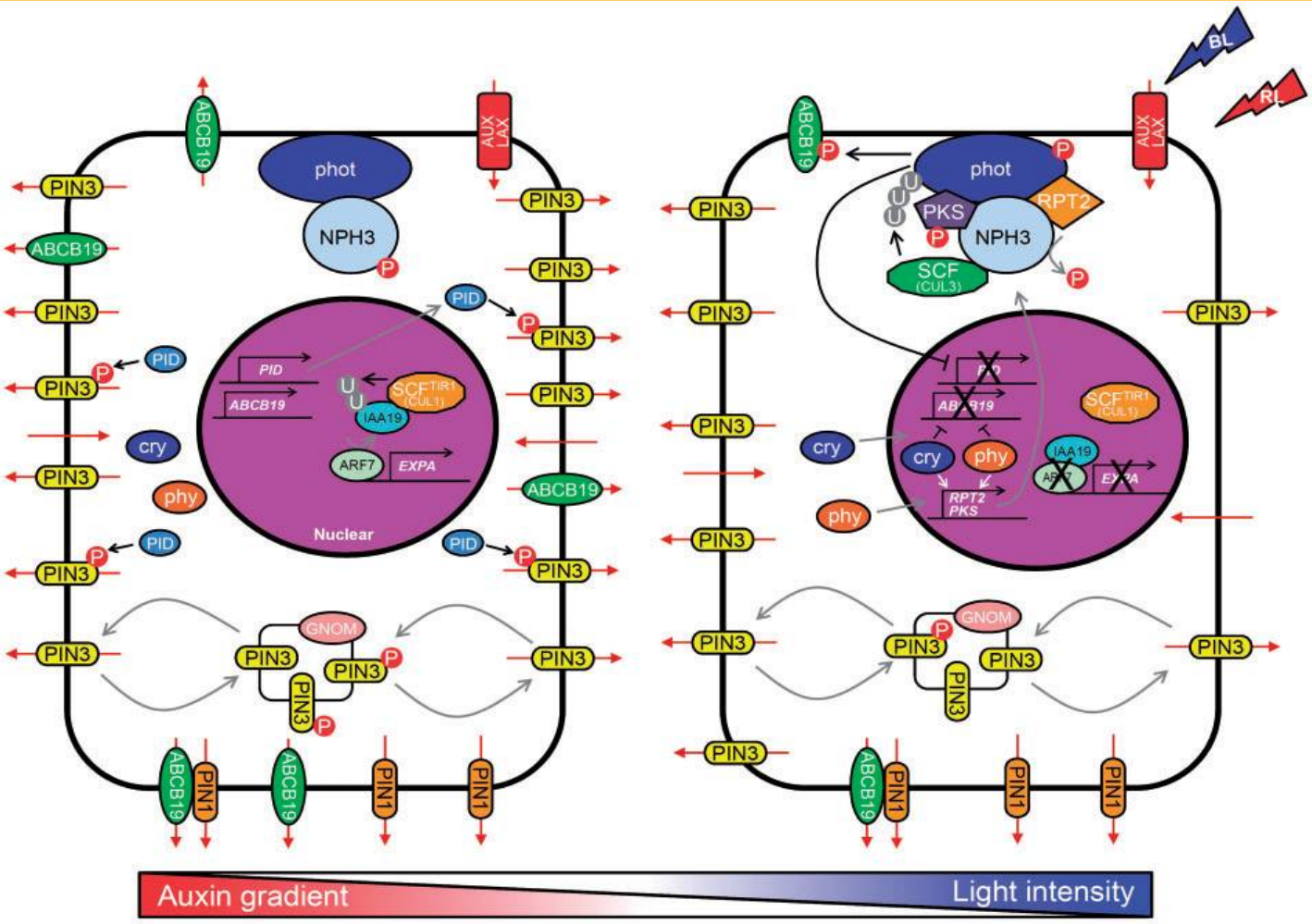




Hornitschek P et al. (1993) Plant J 71: 699-711

Choi H and Oh E (2016) Mol Cells 39: 587-593



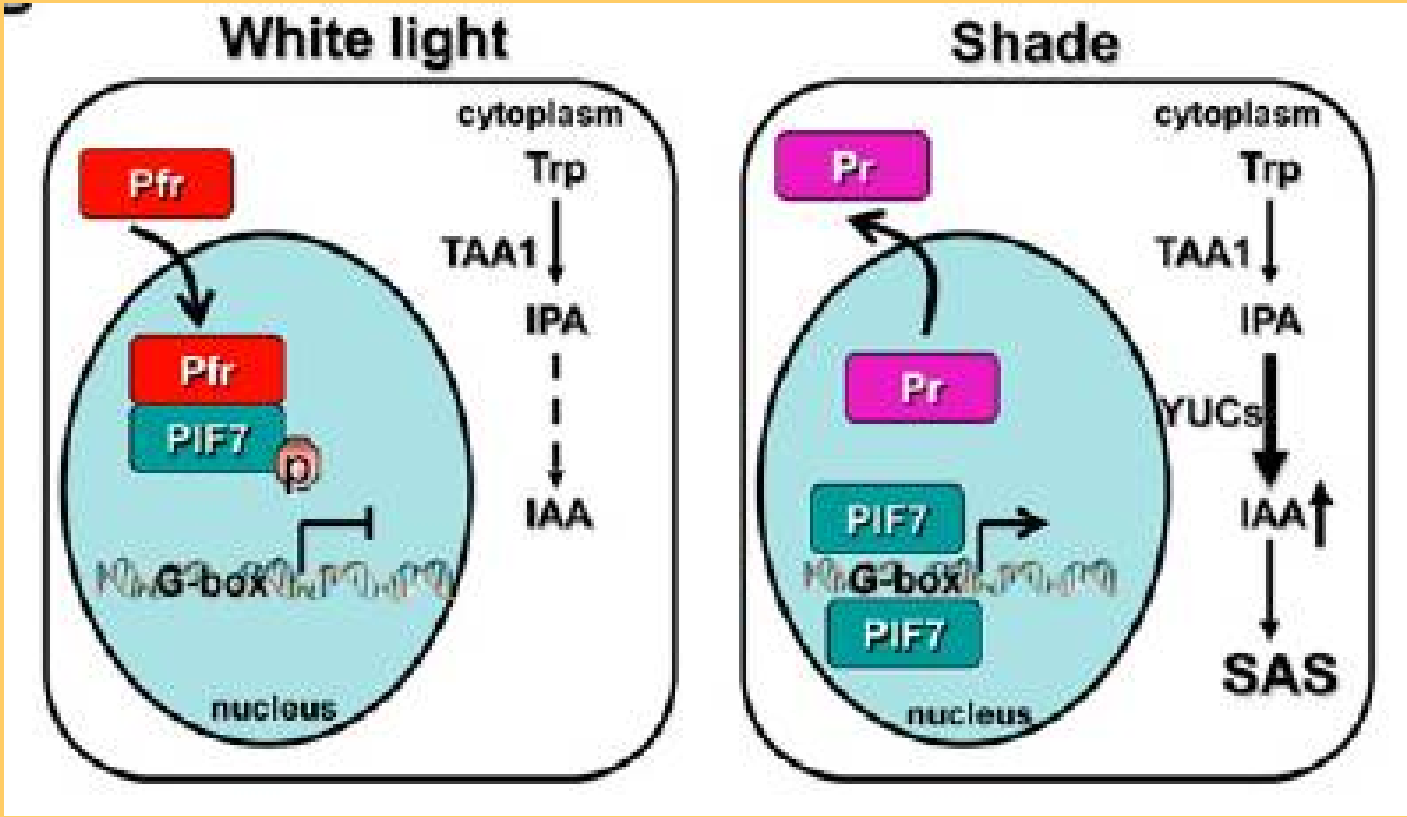


Low intensity of BL: PIF4 not expressed => IAA19/IAA29 not very active => ARF7 expressed => cell expansion

High intensity of BL: PIF4 expressed => IAA19/IAA29 active => ARF7 not expressed => lacking of cell expansion

Transcription factor PIF7

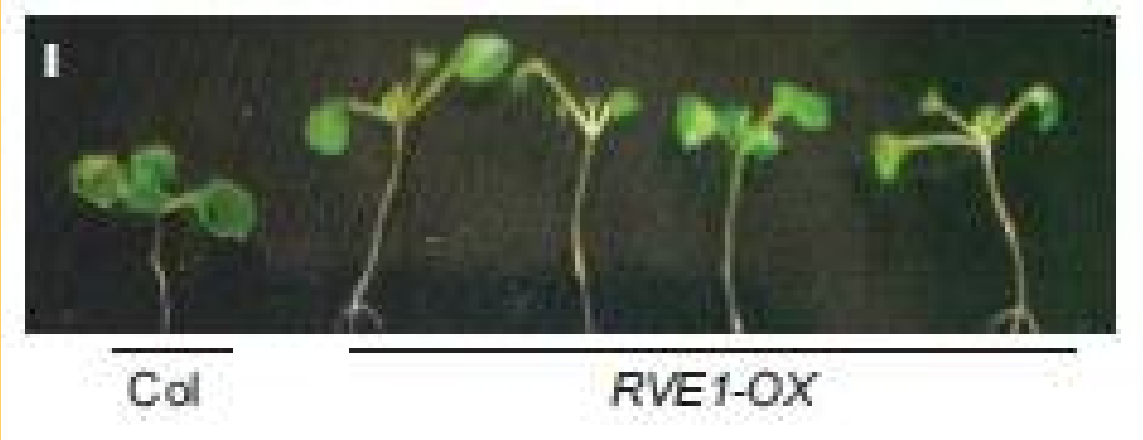
Li L et al. (2012) Genes Dev 26: 785-790

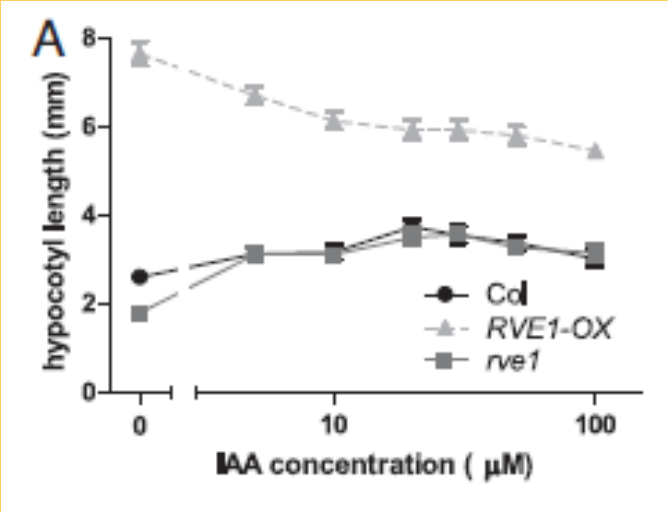


At low R/FR (= shadow), dephosphorylated PIF7 binds to the G-box of YUCCA8 and YUCCA9 genes involved in auxin synthesis and induces their expression. The increased synthesis of auxins then leads to the elongation of the plant.

Transcription factor REVEILLE 1 (RVE1)

Rawat R et al. (2009) PNAS 106: 16883 - 16888





Light

↓

RVE1

↓

YUCCA8

↓

[Auxin]

↓

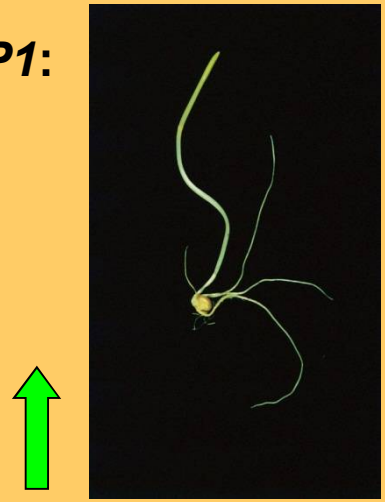
Elongation

ABP system

Jones AM et al. (1991) Plant Physiol 97: 352-358

Expression of *ABP1*:

Growth in the dark

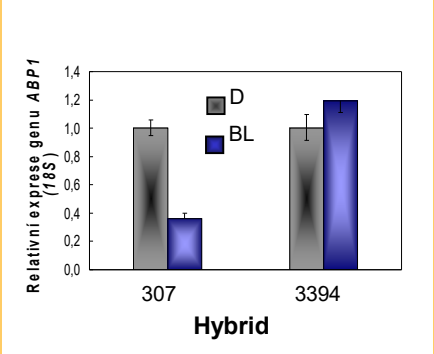


Growth in the light

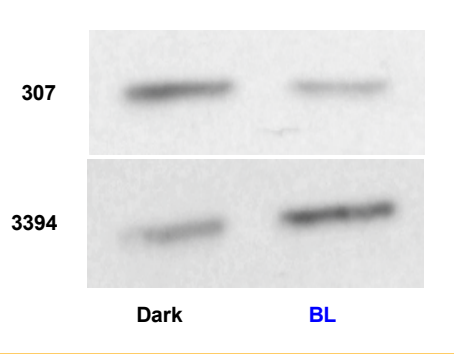
Im KH et al. (1991) Maydica 45: 319-325

Light regulates expression of genes and/or proteins ABP1 and ABP4 in maize

BL inhibits expression of *ABP1* in coleoptíle of older maize hybrid 307.

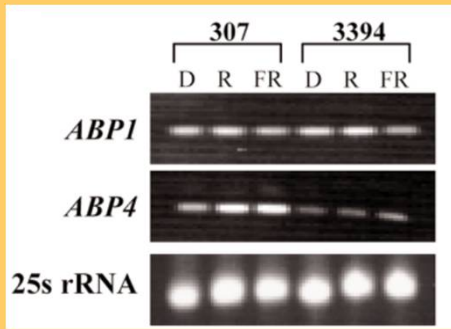


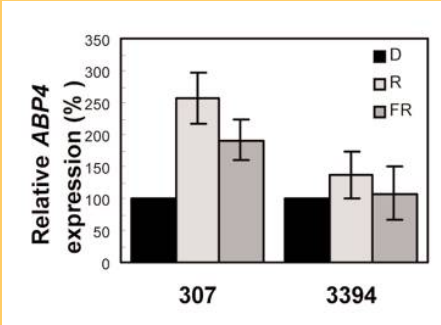
BL reduces amount of ABP1 protein in mesocotyl of older maize hybrid 307



Čudejková M et al. (2012)
Current Topics in Plant Biology 13: 21-34

R and FR stimulate expression of *ABP4* in mesocotyl of older maize hybrid 307.
Expression of *ABP4* is not induced by light in the modern hybrid 3394.





Fellner M et al. (2006) Plant Signaling and Behavior 1: 201-211