

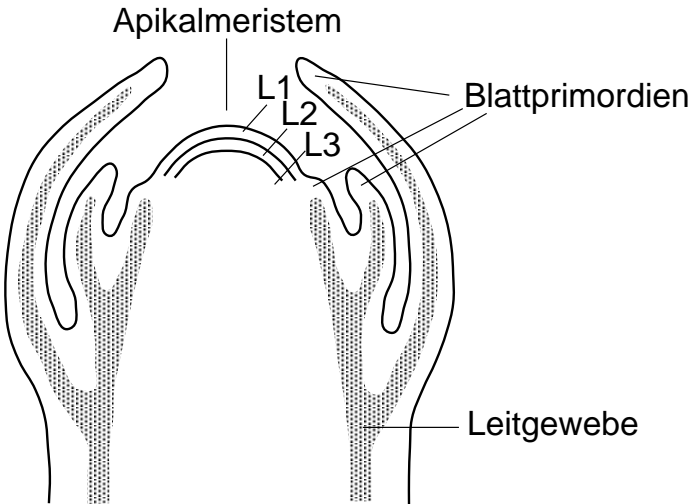
# Folien

## *"Blühinduktion und Blütenmorphogenese"*

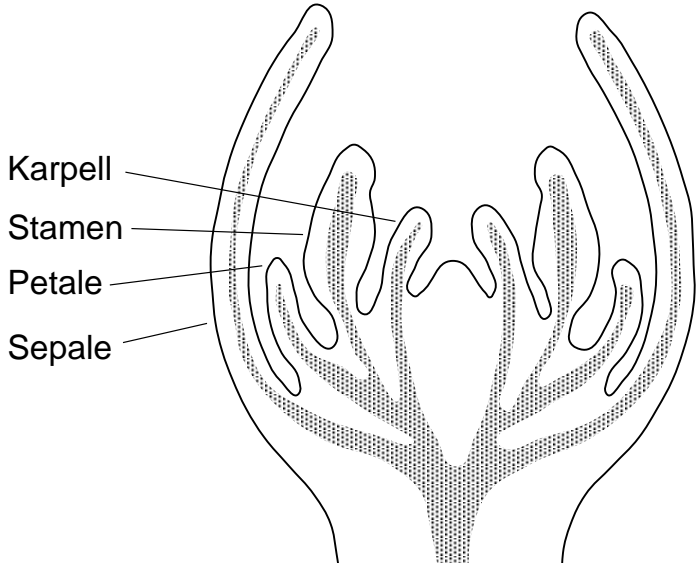
Vorlesung "Entwicklungsbiologie der Pflanzen"  
(SS 2006)

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Institut für Entwicklungs- und  
Molekularbiologie der Pflanzen  
Heinrich-Heine-Universität  
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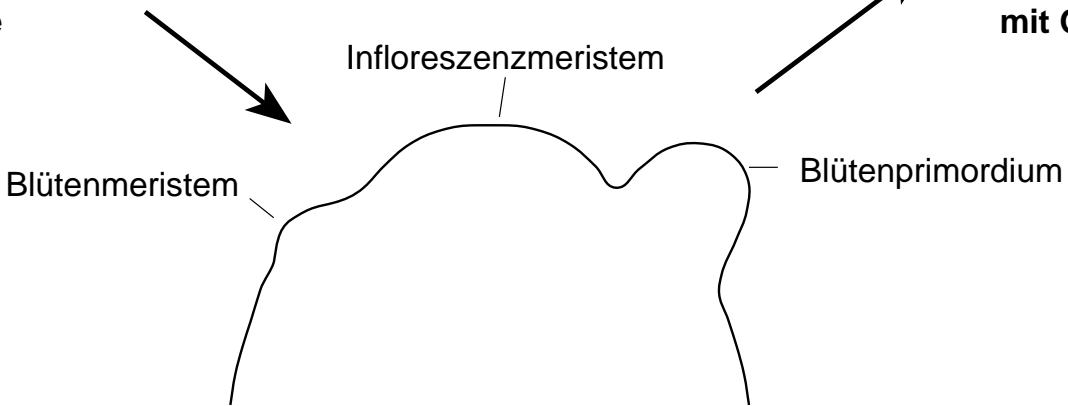
# Vom vegetativen Sproßapikalmeristem zur Bildung der Blüte



**Der Sproßapex in der vegetativen Phase**



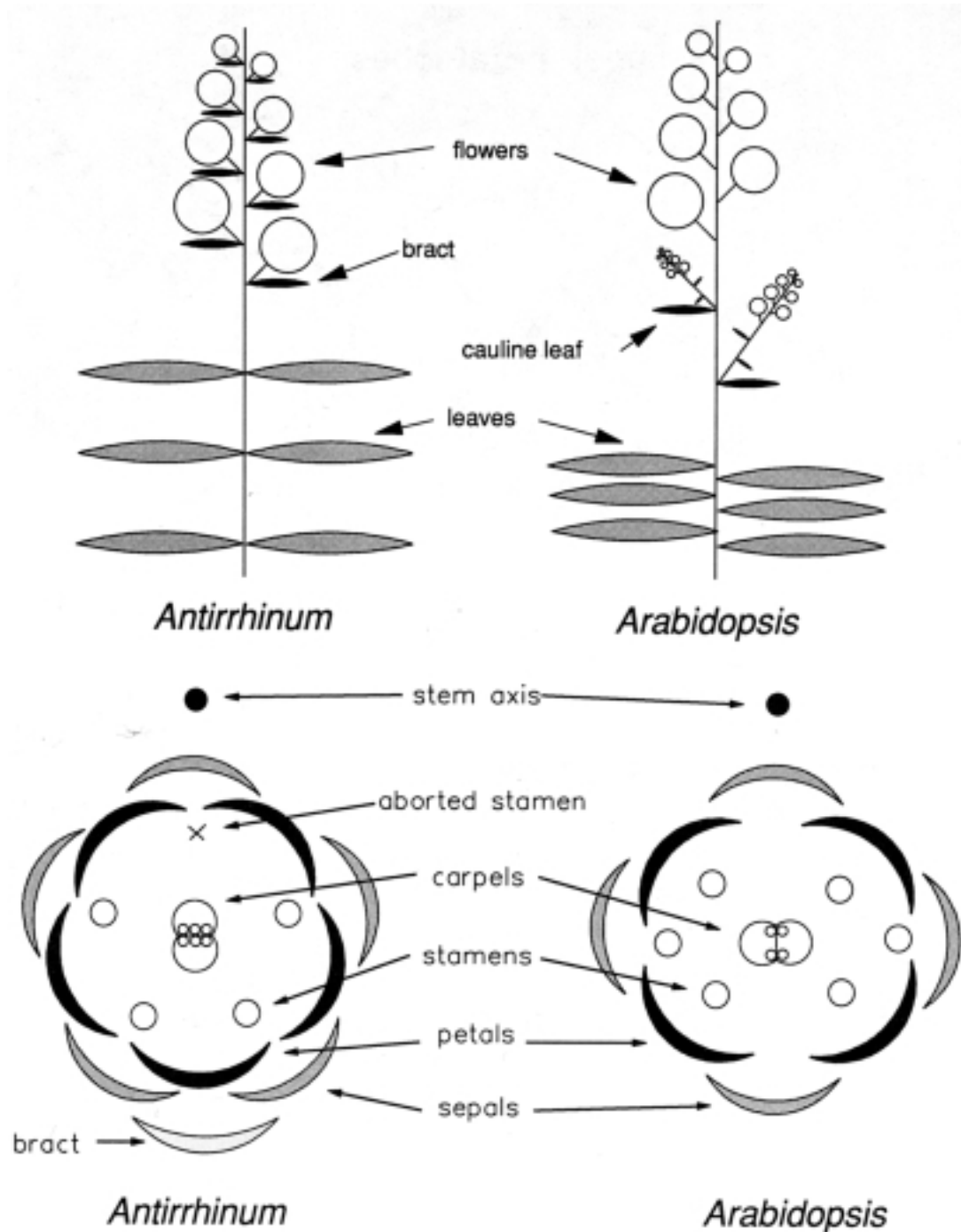
**Sich entwickelnde Blüte mit Organprimordien**



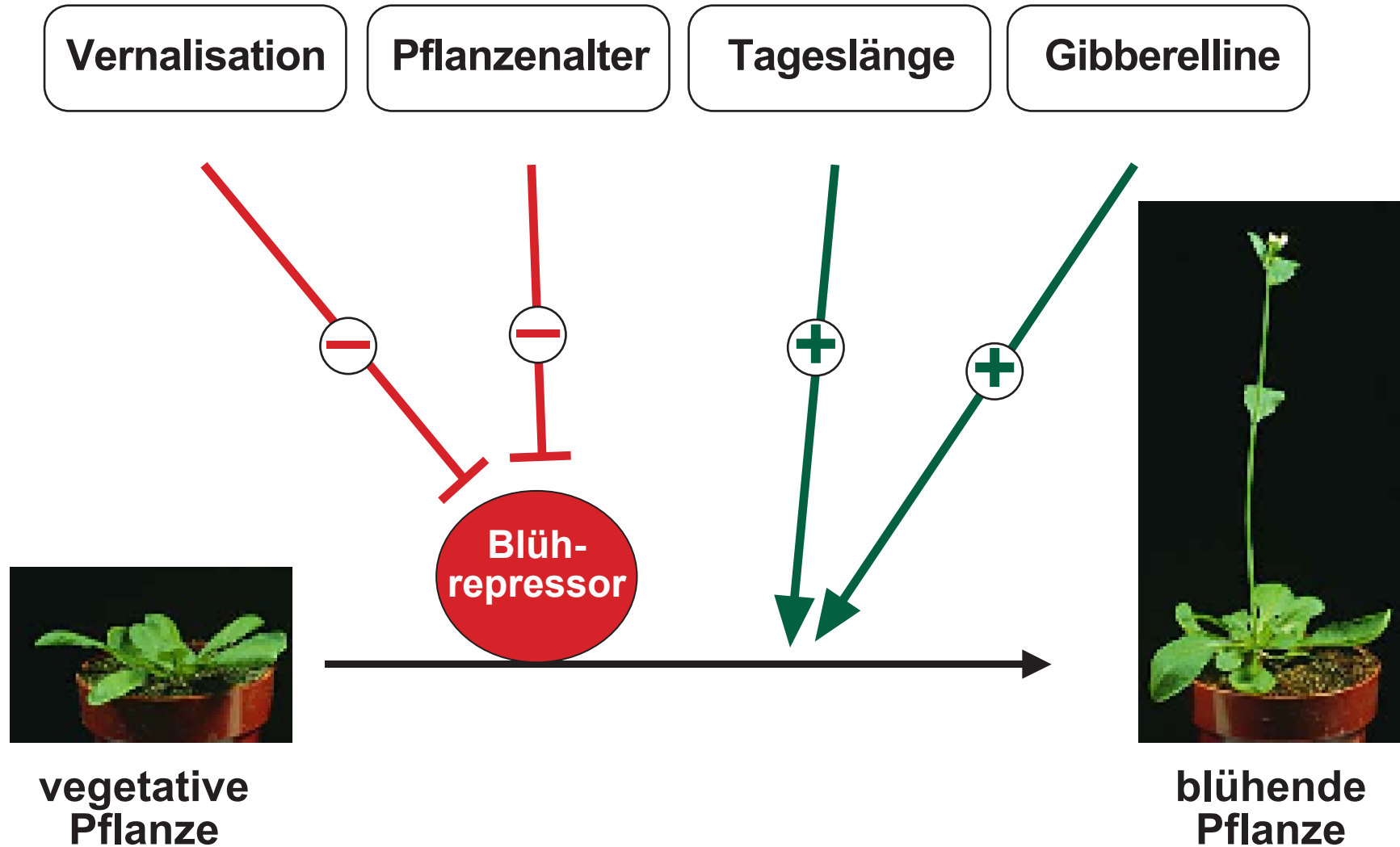
**Der Sproßapex in der reproduktiven Phase**

# Blütenstände und Blüten bei *Arabidopsis* und *Antirrhinum*

(Coen ES [1991] Annu Rev Plant Physiol Plant Mol Biol 42: 241-279)



# Regulation des Blühzeitpunktes



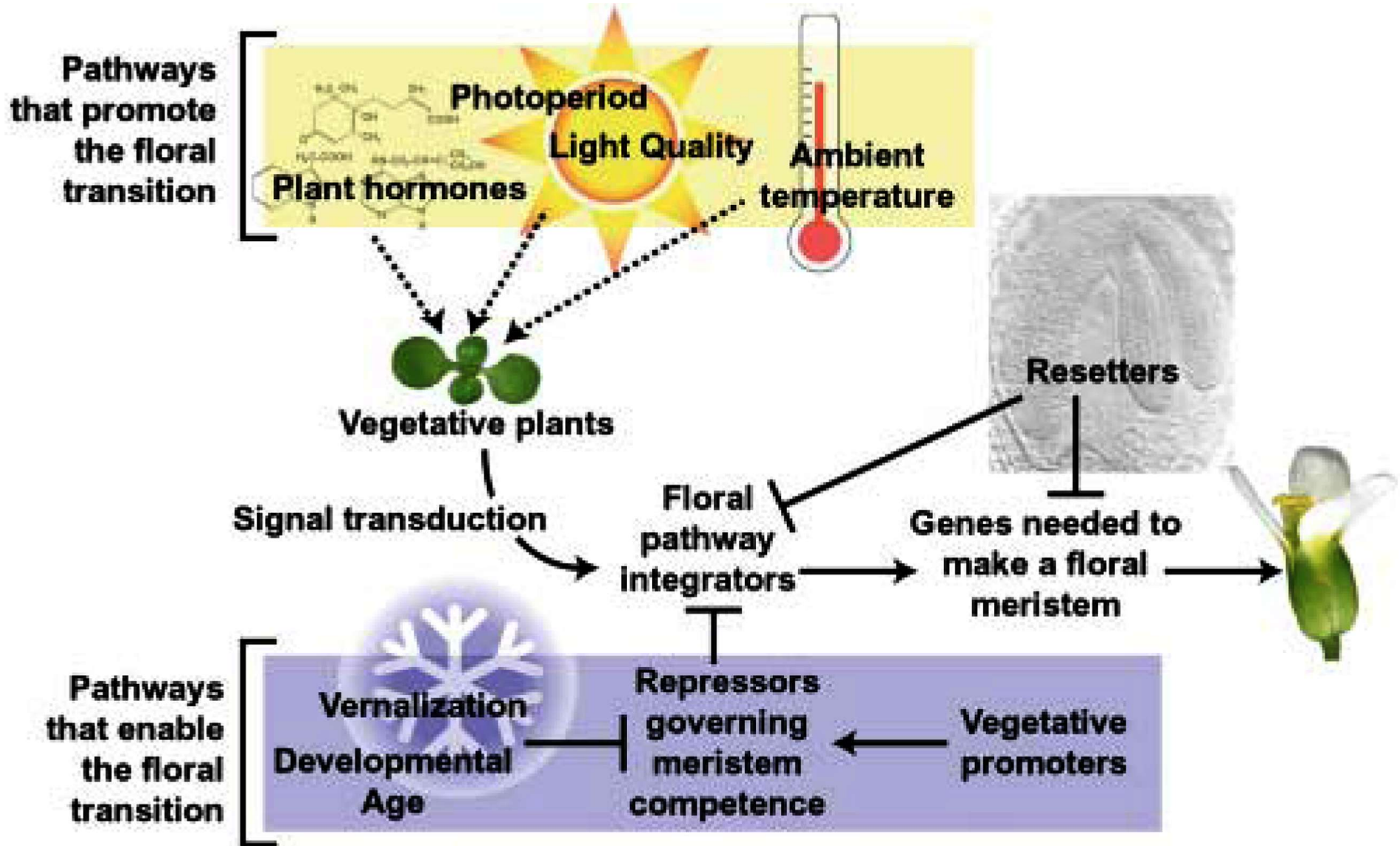
# Blühzeitpunktgene bei *Arabidopsis thaliana*

(Putterill J et al [2004] BioEssays 26: 363-373)

Abbreviation	Gene name	Predicted gene product	Pathway/Function
AGL24	AGAMOUS-LIKE 24	MADS transcription factor	Floral promoter
CCA1	CIRCADIAN CLOCK ASSOCIATED 1	MYB domain transcription factor	Circadian clock
CK2	CASEIN KINASE 2	Protein kinase	Circadian clock
CO	CONSTANS	Zinc finger transcription factor	Long day pathway
CRY1 and 2	CRYPTOCHROME 1 and 2	Blue/UV light photoreceptors	Light perception
EAT	EARLY ACTIVATION TAGGED	Transcript contains <i>Mir172</i>	Represses <i>AP2-LIKE</i> genes
ELF3	EARLY FLOWERING 3	Novel nuclear protein	Circadian clock
ELF4	EARLY FLOWERING 4	Novel protein	Circadian clock
FCA	FCA	RNA binding protein	Autonomous pathway
FKF1	FLAVIN-BINDING, KELCH REPEAT, F-BOX 1	Putative blue light photoreceptor	Long day pathway
FLC	FLOWERING LOCUS C	MADS transcription factor	Floral repressor
FLD	FLOWERING LOCUS D	Component of histone deacetylase complex	Autonomous pathway
FPA	FPA	RNA binding protein	Autonomous pathway
FRI	FRIGIDA	Novel protein	Floral repressor
FT	FLOWERING LOCUS T	Phosphatidylethanolamine binding protein	Floral promoter
FVE	FVE	WD40 repeat protein	Autonomous pathway
FY	FY	Polyadenylation factor	Autonomous pathway
GI	GIGANTEA	Novel nuclear protein	Long day pathway
HOS1	HIGH EXPRESSION OF OSMOTICALLY RESPONSIVE GENES 1	RING finger protein	Cold signalling
LD	LUMINIDEPENDENS	Nuclear-localised homeobox protein	Autonomous pathway
LHY	LATE ELONGATED HYPOCOTYL	MYB domain transcription factor	Circadian clock
MAF1-4	MADS AFFECTING FLOWERING 1-4	MADS transcription factors	Floral repressors
MAF5	MADS AFFECTING FLOWERING 5	MADS transcription factor	Putative floral promoter
PHY A-E	PHYTOCHROME A-E	Red/far-red light photoreceptors	Light perception
PIE1	PHOTOPERIOD INDEPENDENT EARLY FLOWERING 1	Chromatin remodeling protein	Floral repressor
PIF3	PHYTOCHROME INTERACTING FACTOR 3	Basic/helix-loop-helix transcription factor	Light signaling
SMZ & SNZ	SCHLAFMÜTZE and SCHNARCHZAPFEN	AP2- like transcription factor	Putative floral repressors
SOC1	SUPPRESSOR OF OVEREXPRESSION OF CONSTANS 1	MADS transcription factor	Floral promoter
TFL2	TERMINAL FLOWER 2	Heterochromatin 1 like chromatin repressor	Floral repressor
TOC1	TIMING OF CAB 1	Nuclear-localised putative transcription factor with pseudo-response regulator domain	Circadian clock
TOE1-2	TARGET OF EAT 1 and 2	AP2-like transcription factors	Putative floral repressor
VIP1-7	VERNALISATION INDEPENDENCE 1-7	VIP3 has multiple WD repeats	Floral repressors
VRN1	VERNALISATION 1	B3 DNA binding protein	Vernalisation pathway
VRN2	VERNALISATION 2	Polycomb group protein	Vernalisation pathway
ZTL	ZEITLUPE	Putative blue light photoreceptor	Circadian clock

# Steuerung des Blühzeitpunktes bei *Arabidopsis thaliana* die ermöglichenden und fördernden Wege

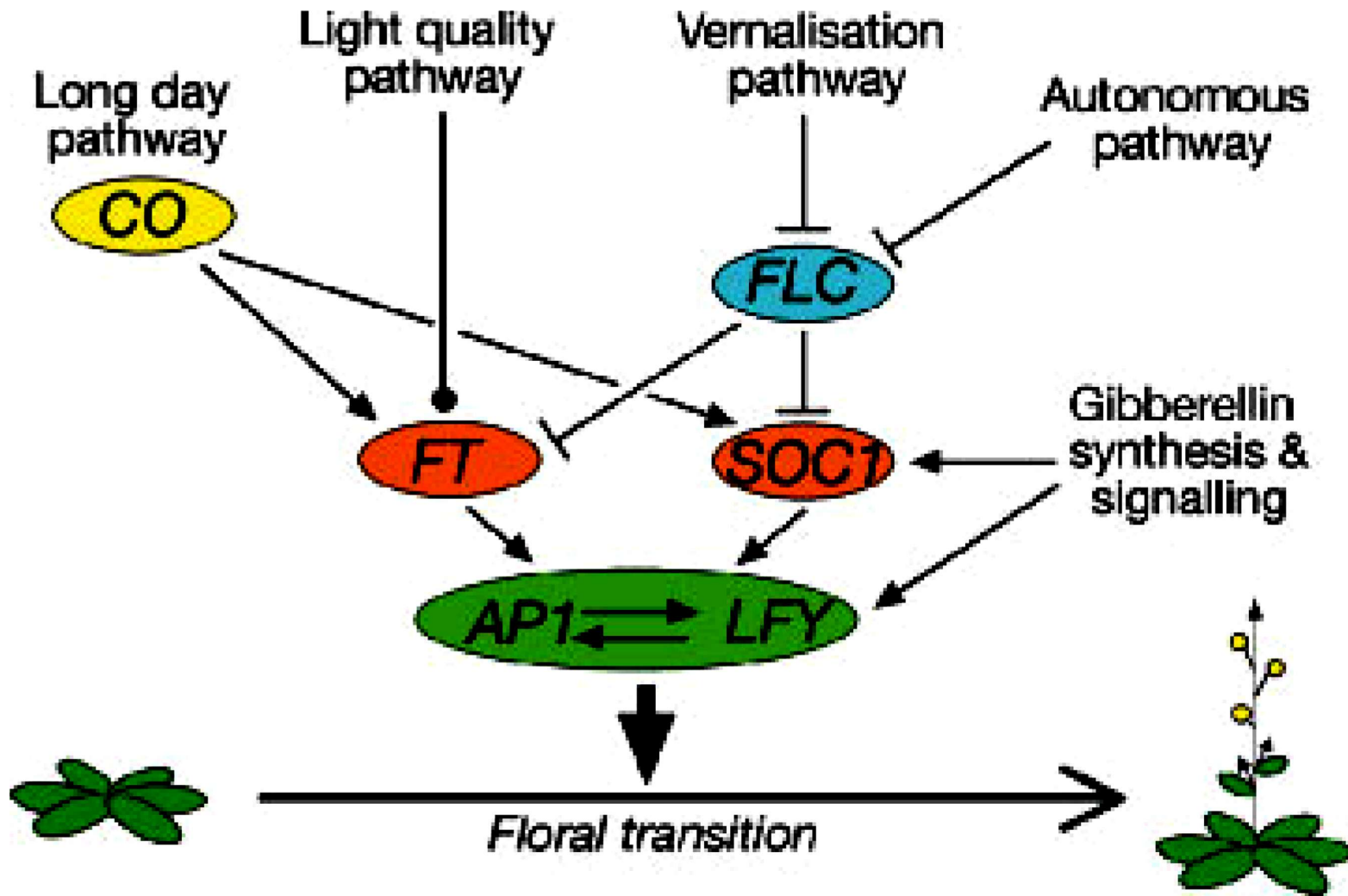
(Boss PK et al [2004] PlantCell 16: S18-S31)



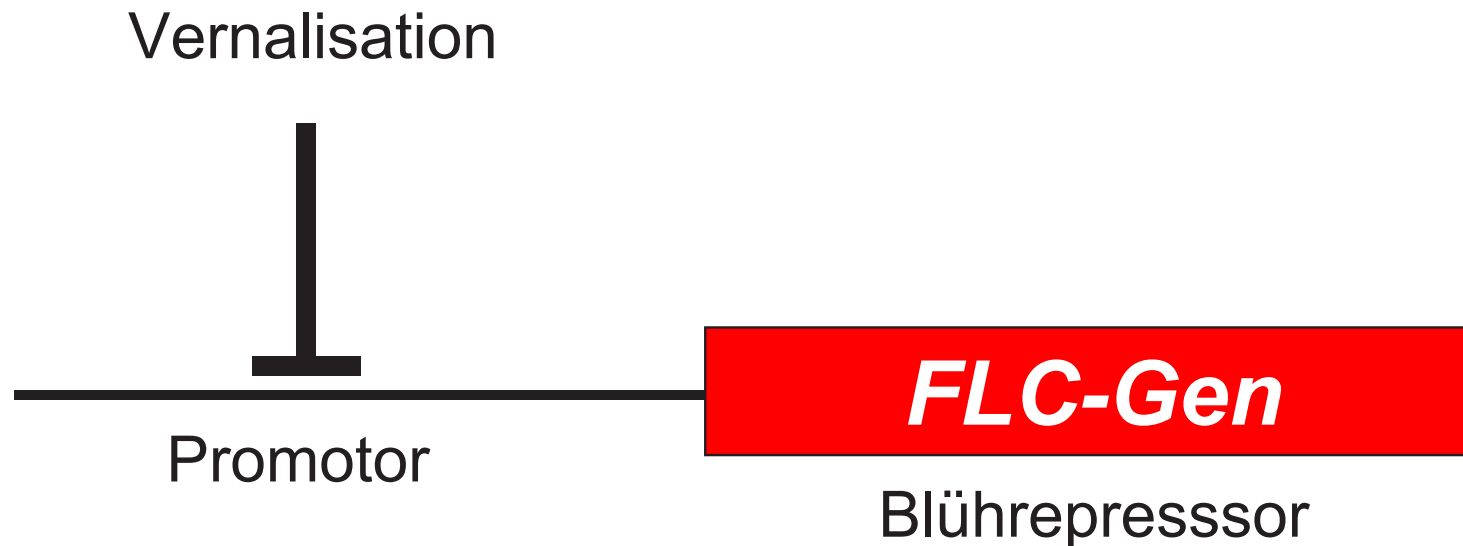
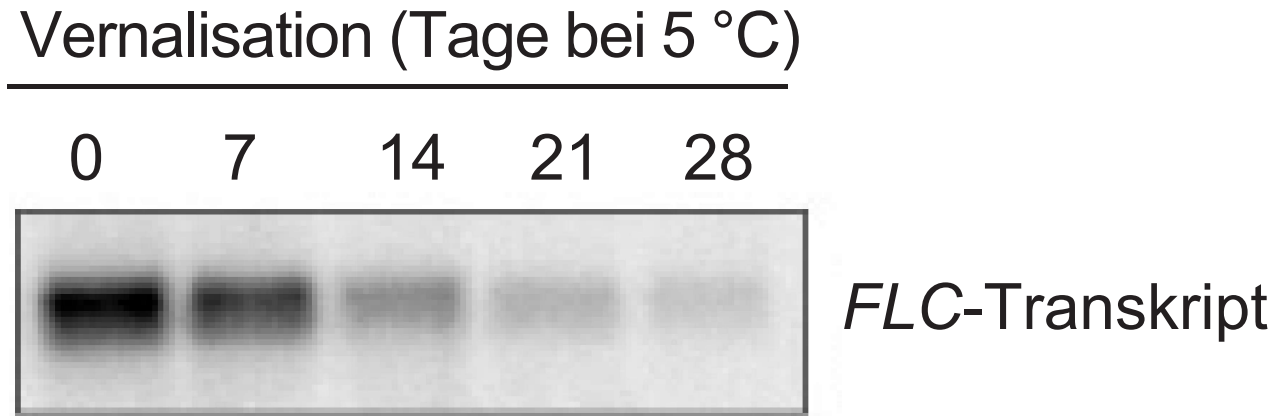


# Förderung des Blühzeitpunktes in *Arabidopsis thaliana* die Schlüsselintegratoren

(Putterill J et al [2004] BioEssays 26: 363-373)

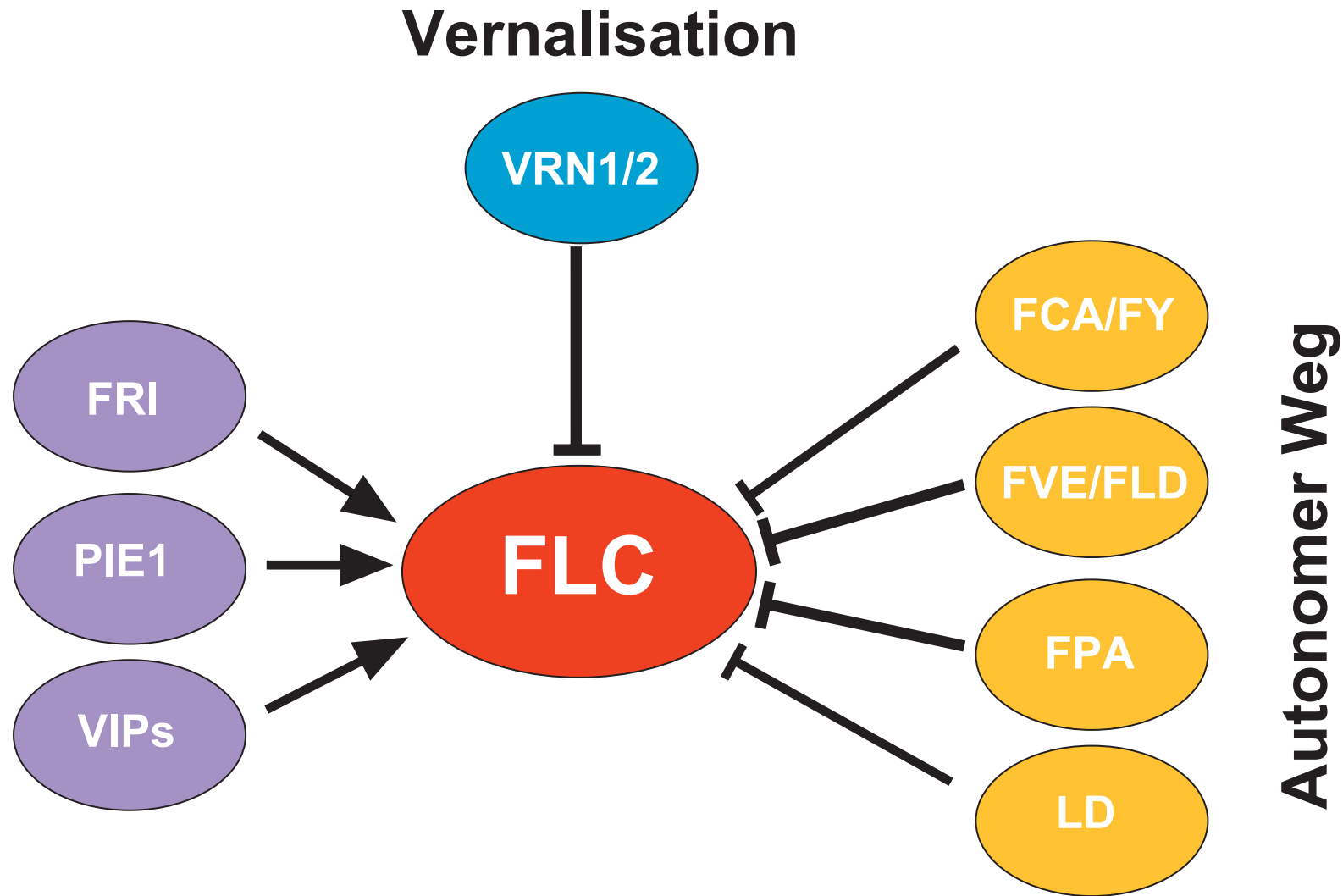


# Vernalisation reduziert die Transkription des *FLC*-Gens



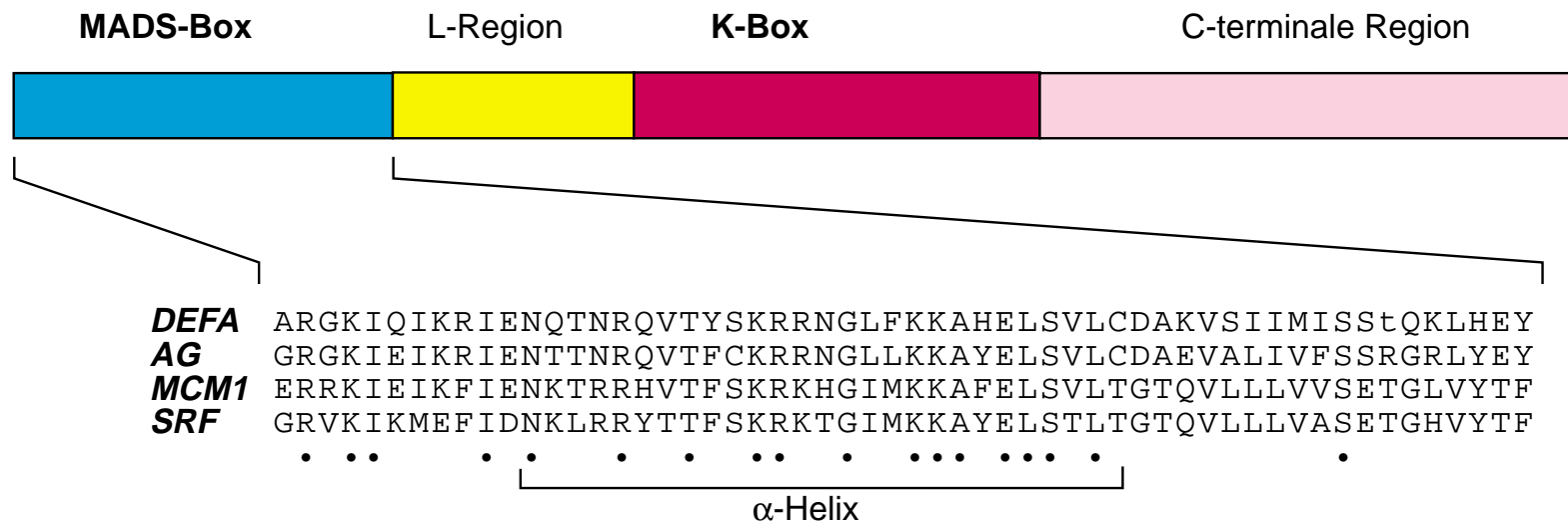


# Regulation des Blührepressors FLC in *Arabidopsis thaliana*



# Transkriptionsfaktoren vom MADS-Box-Typ

## Aufbau eines pflanzlichen MADS-Box-Proteins



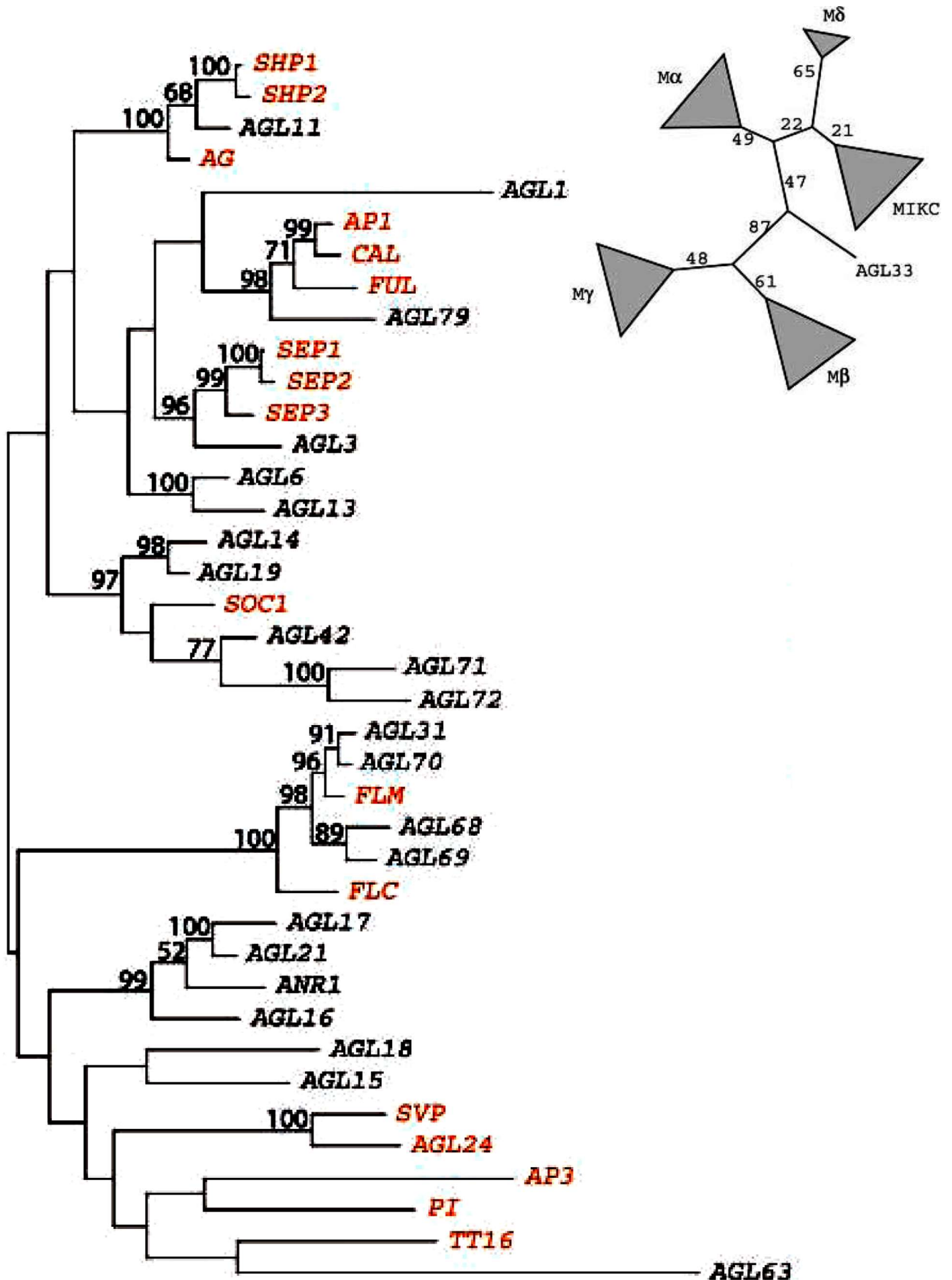
## CArg-Box im Promotor des *DEFICIENS*-Gens

-1235  
 CATCACTTTGGCAACTCTTT CCTTTT TAGG TCCCATATGGT -1195

Consensus: CC(A/T)<sub>6</sub>GG

# MADS-Box-Proteine der MIKC-Unterfamilie bei *Arabidopsis thaliana*

(Parenicová L et al [2003] PlantCell 15: 1538–1551)



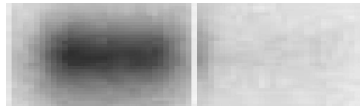
# FRIGIDA



Coiled-coil-Domänen

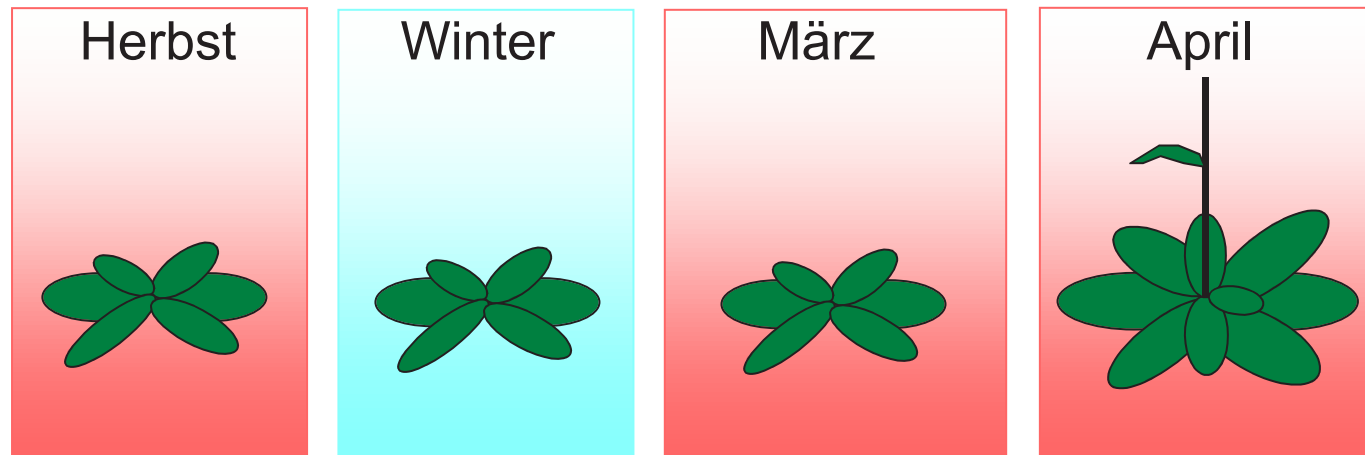
FRIGIDA

frigida



FLC-Transkript

# VRN2 kontrolliert die FLC-Transkriptpegel

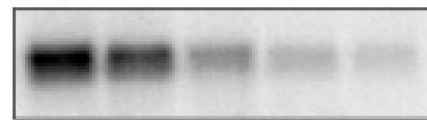


Kälte

Erwärmung

Wärme

*FLC*-Transkript

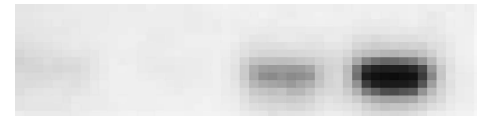


*FLC*

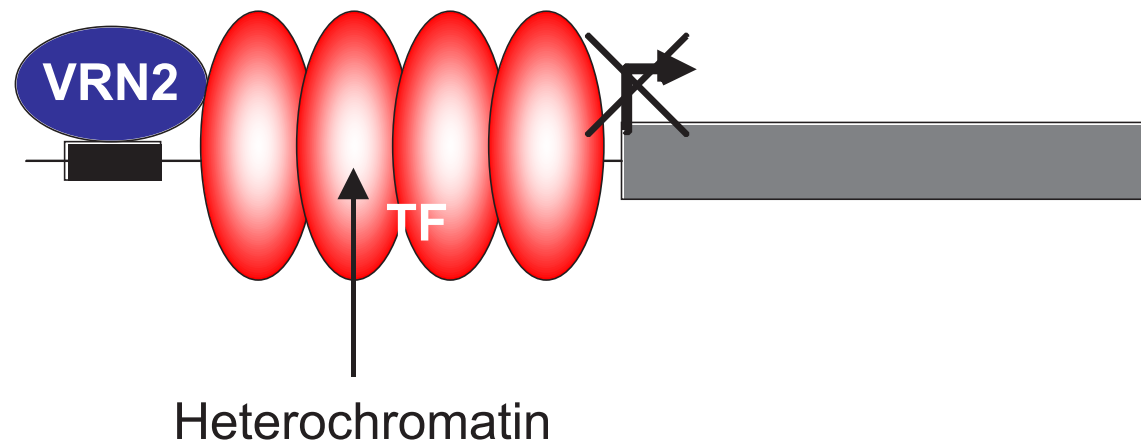
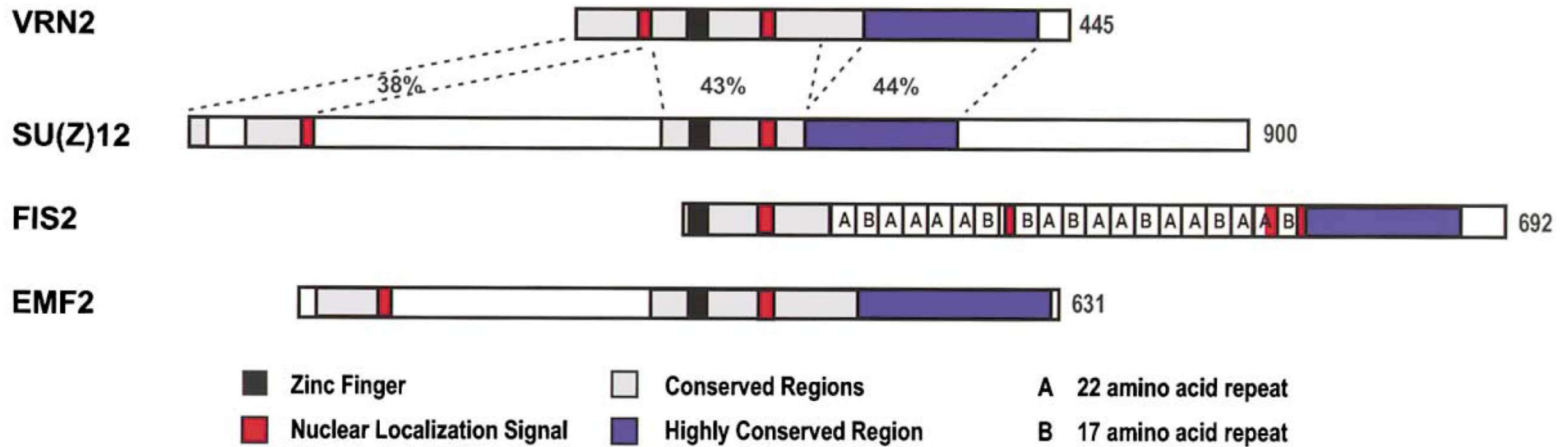


VRN2

*vrn2*-Mutante

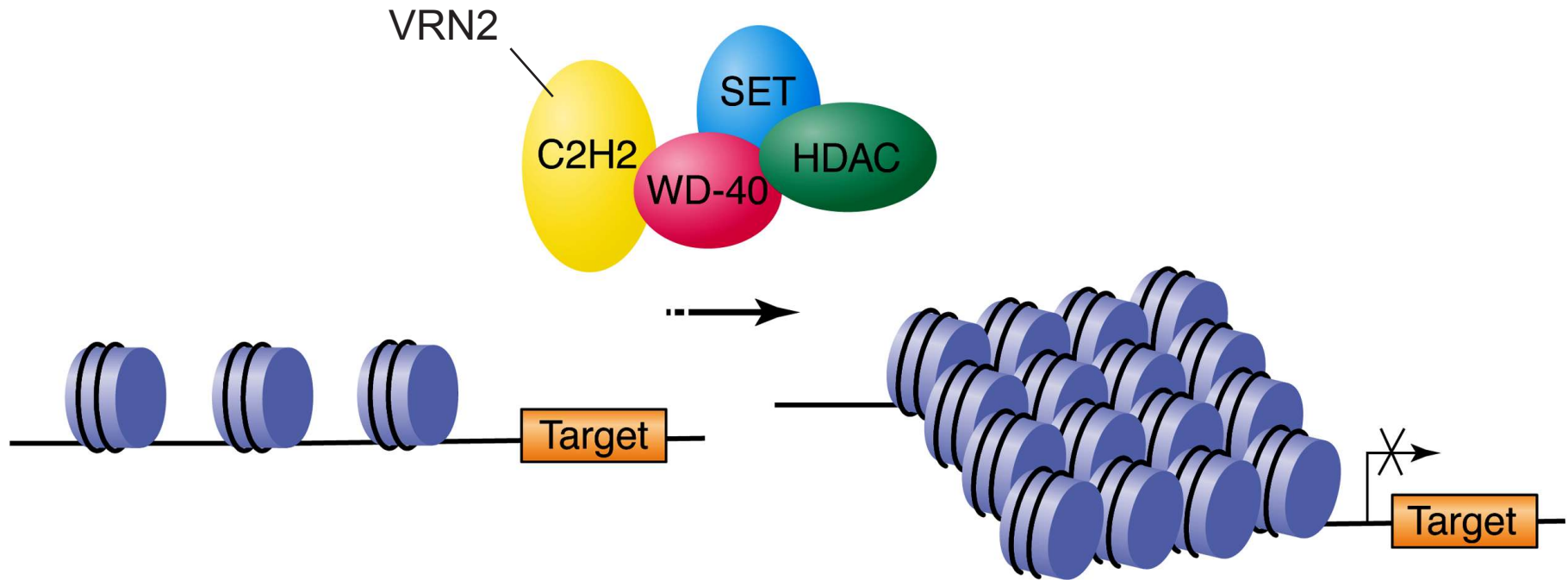


# VRN2 ist ein Polycomb-Protein



# Modell der Funktion von Polycomb-Proteinkomplexen

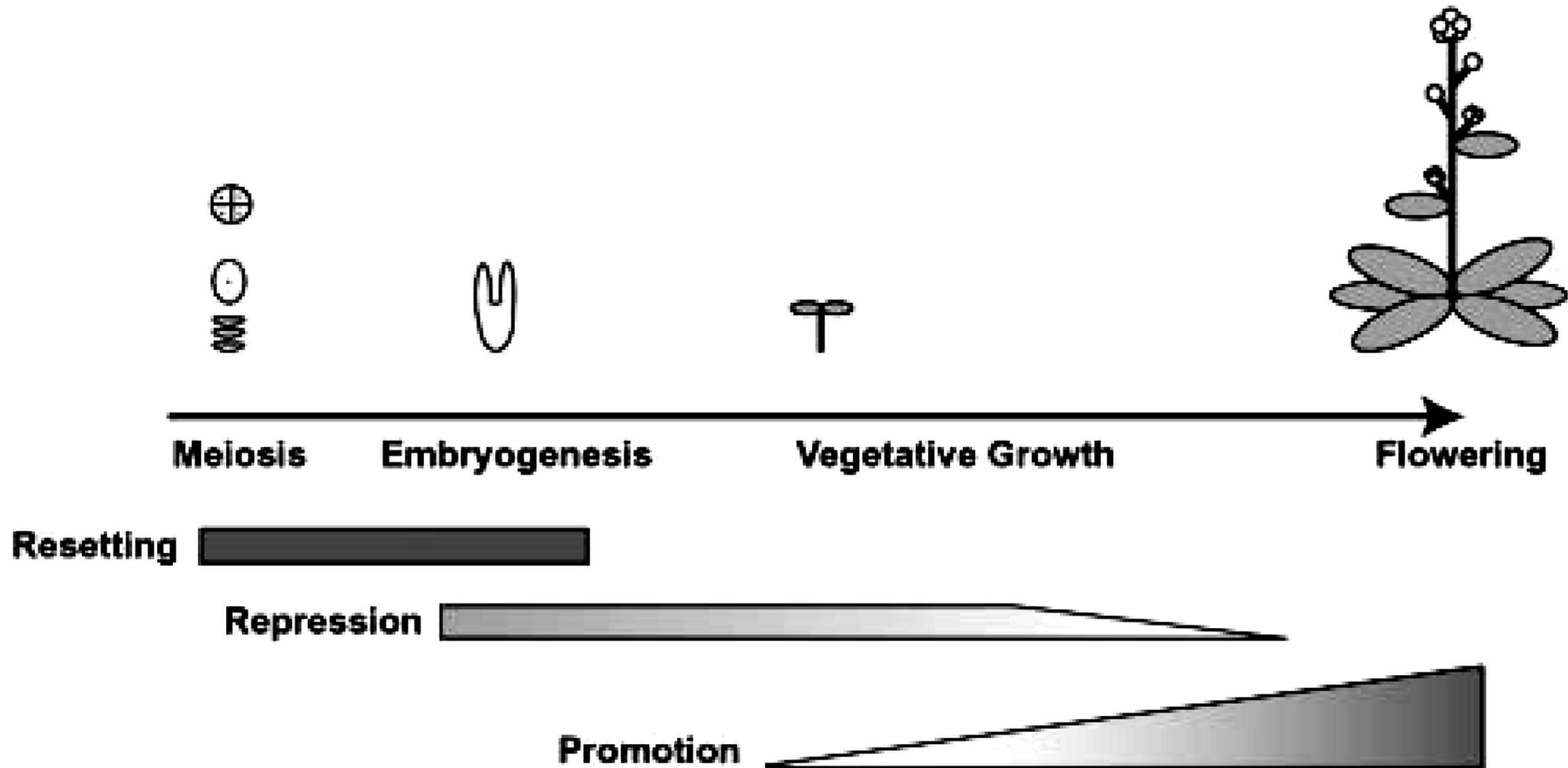
(Hsieh TF et al [2003] Trends Plant Sci 8: 439-445)





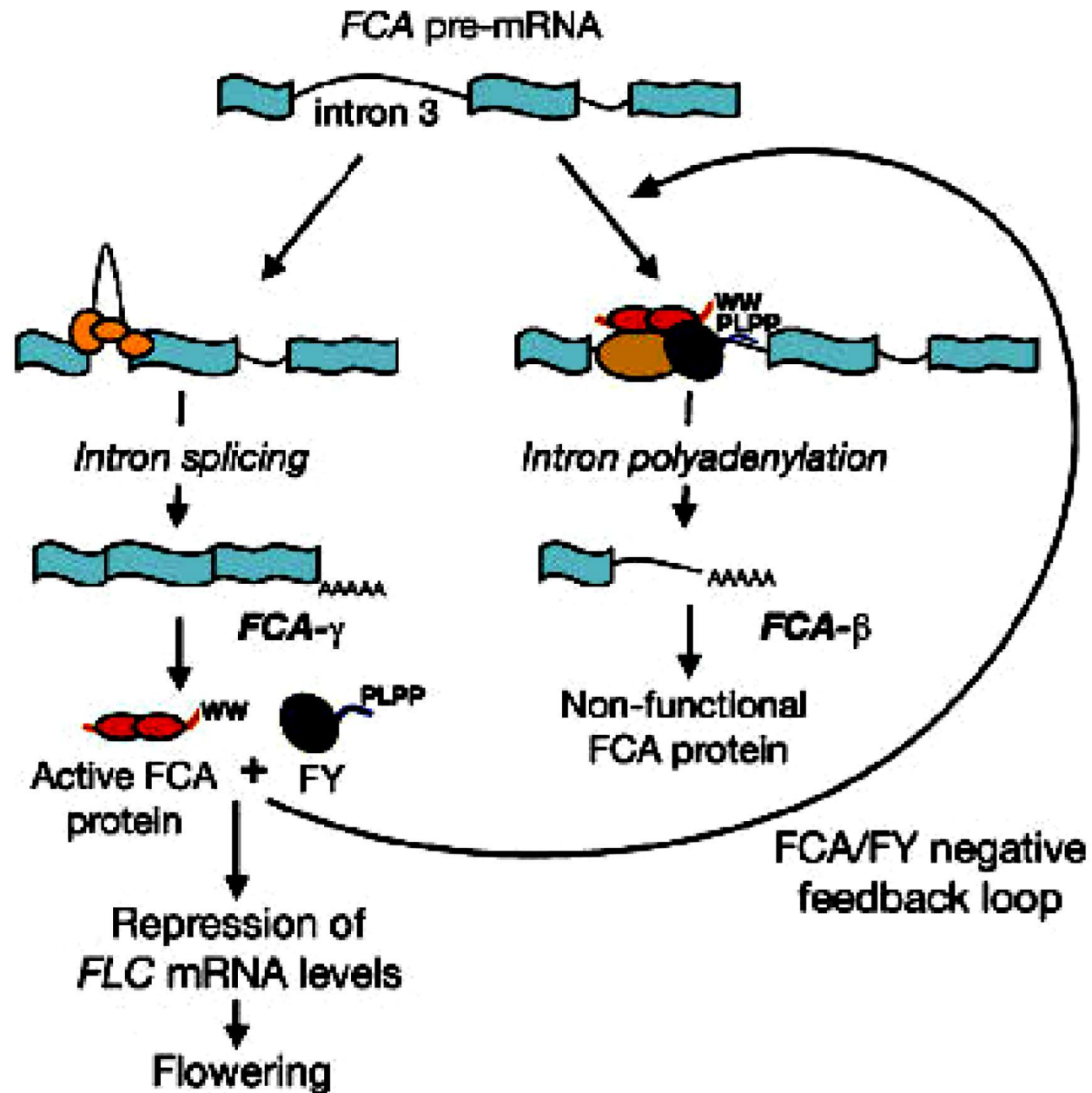
# Der Lebenszyklus von *Arabidopsis thaliana* aus dem Blickwinkel des Blühzeitpunktes

(Boss PK et al [2004] PlantCell 16: S18-S31)



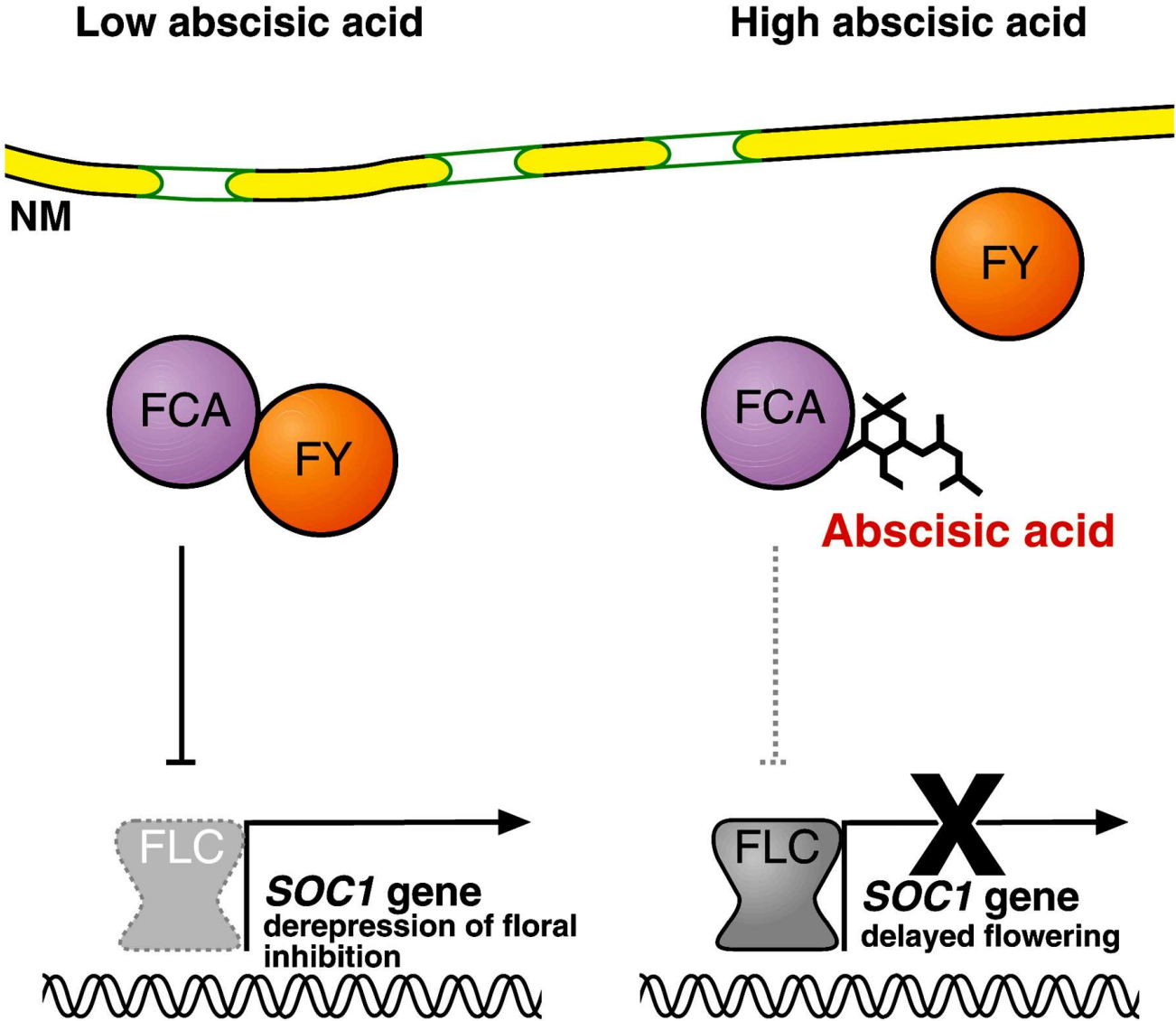
# Funktion des *FCA*-Gens im autonomen Weg der Blühinduktion bei *Arabidopsis thaliana*

(Putterill J et al [2004] BioEssays 26: 363-373)



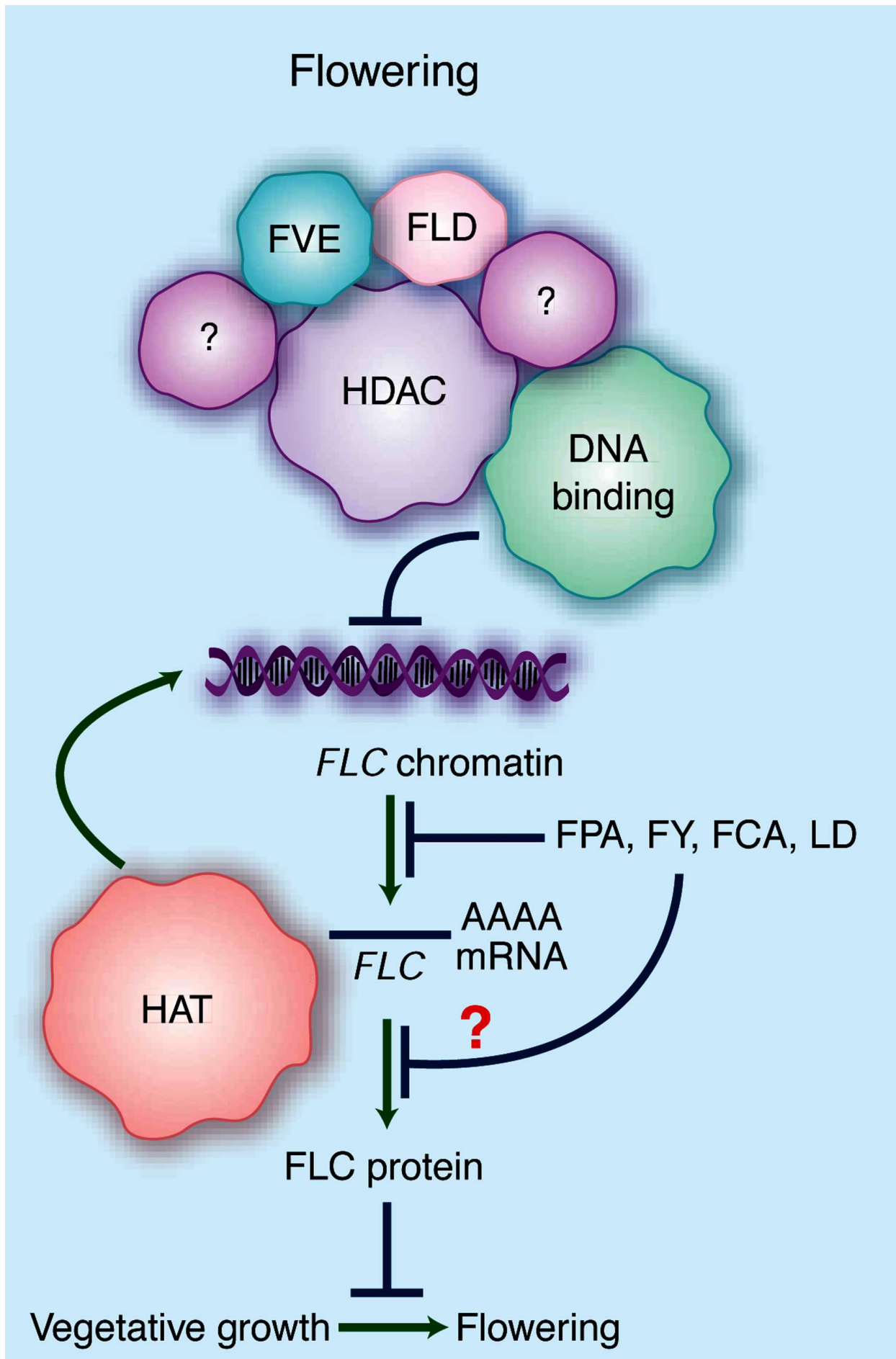
# Das FCA-Protein von Arabidopsis ist ein ABA-Rezeptor

(Bishopp et al [2006] Development 133: 1857-1869)



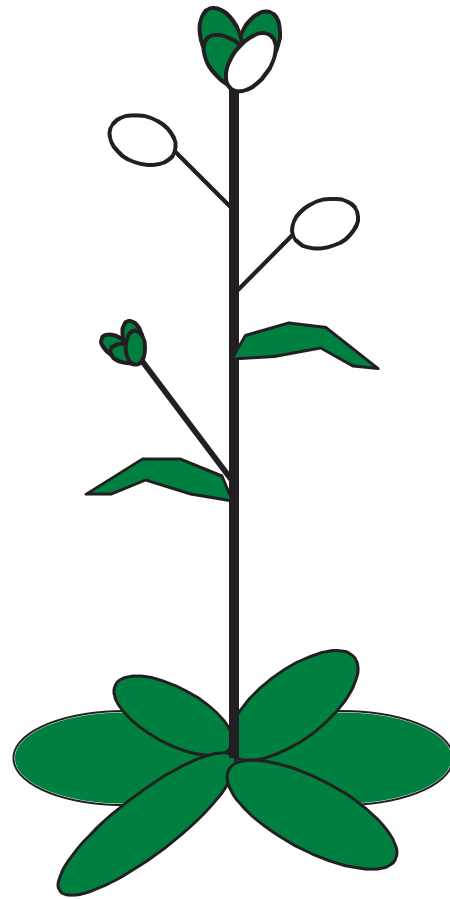
# Die Gene FVE und FLD kodieren Komponenten eines Histondeacetylase-Komplexes

(Amasino R [2004] Nat Genet 36: 111-112)



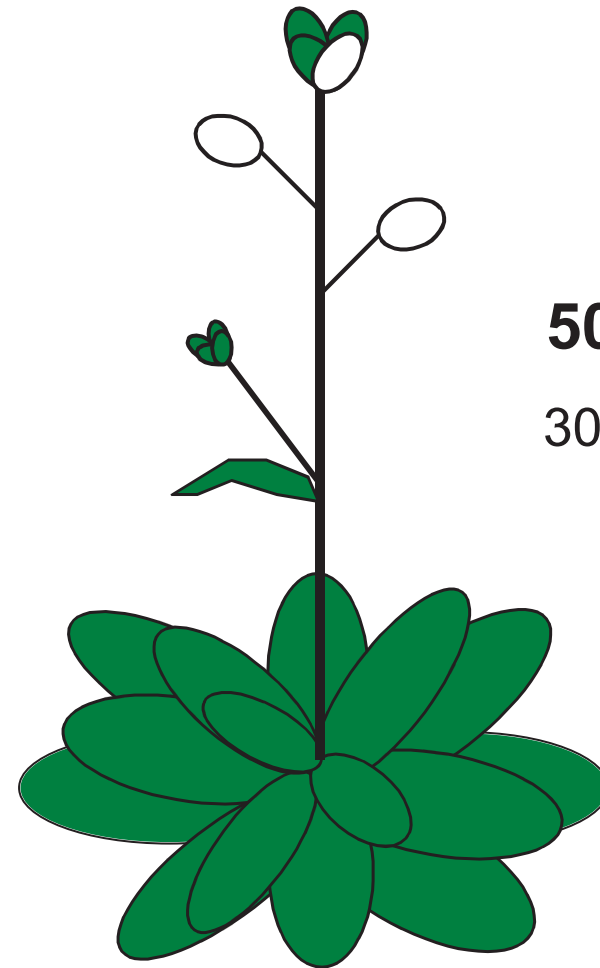
# Arabidopsis ist eine fakultative Langtag-Pflanze

**17 Tage**  
6 Blätter



Langtag

**50 Tage**  
30 Blätter



Kurztage

# Die *constans*-Mutante von *Arabidopsis*

*constans*

Wildtyp

**50 Tage**

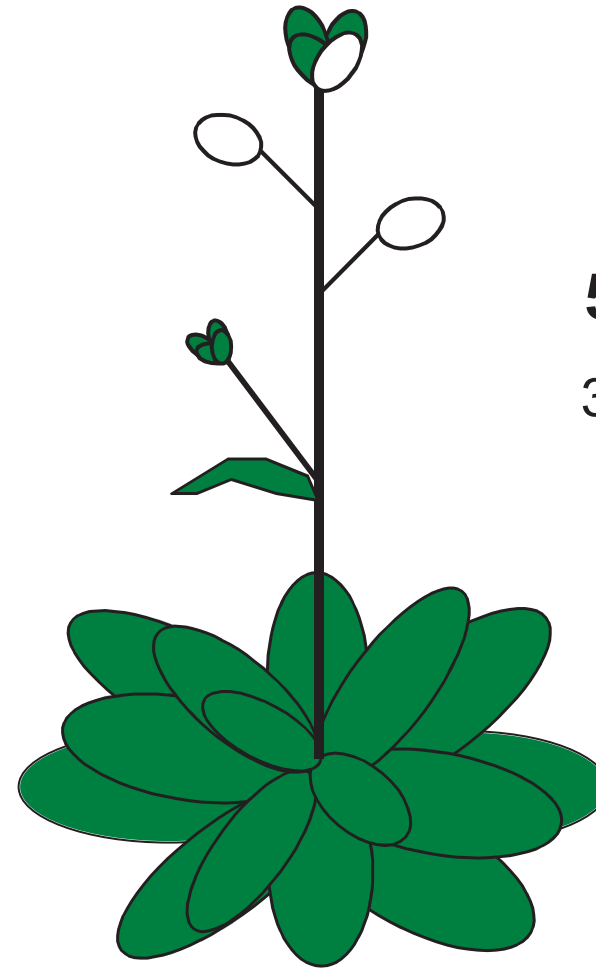
30 Blätter

**50 Tage**

30 Blätter

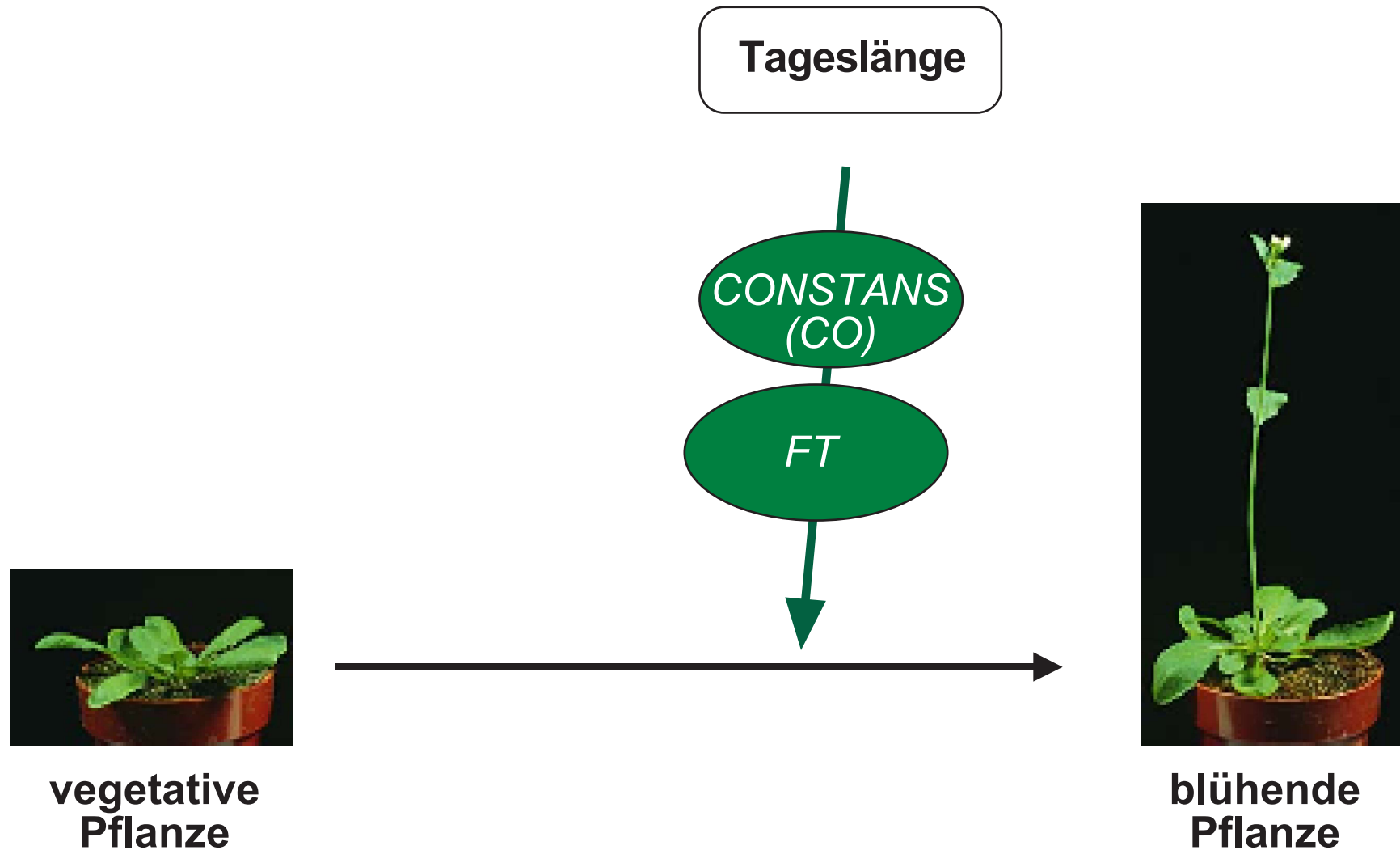


Langtag



Kurztag

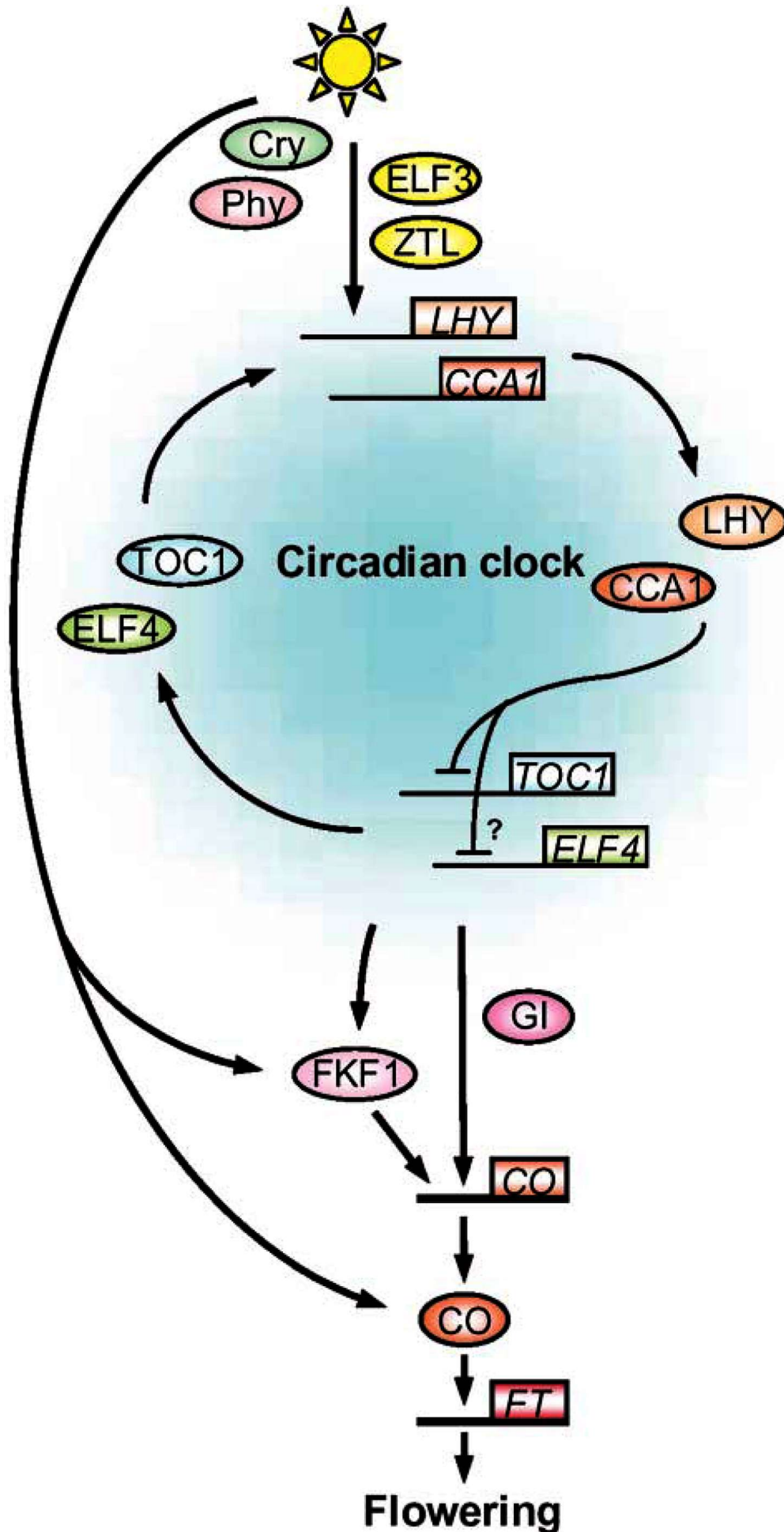
# Regulation des Blühzeitpunktes: *CONSTANS* und *FT*





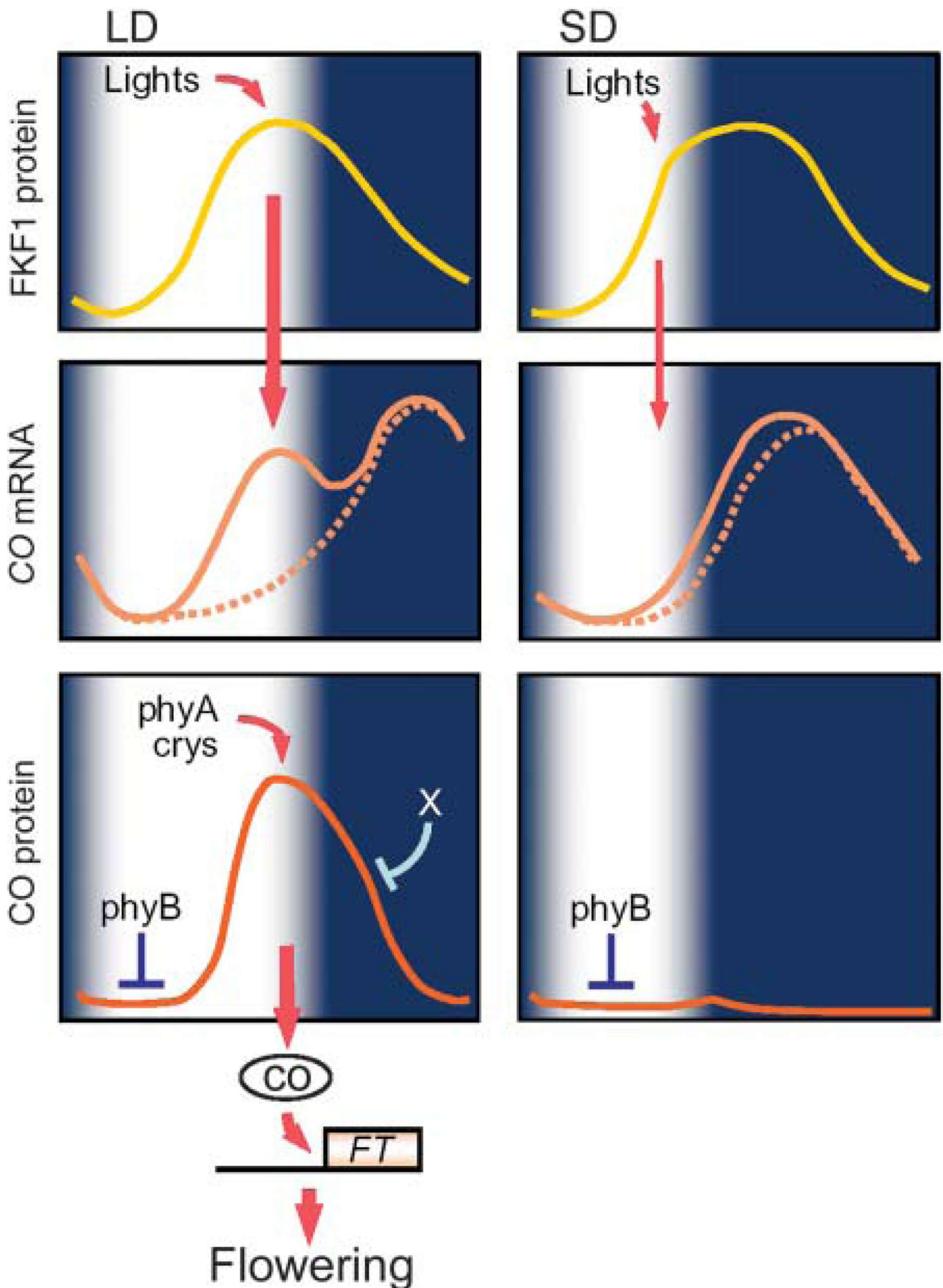
# CONSTANS und die biologische Uhr

(Hayama R & Coupland G [2004] Plant Physiol 135: 677-684)



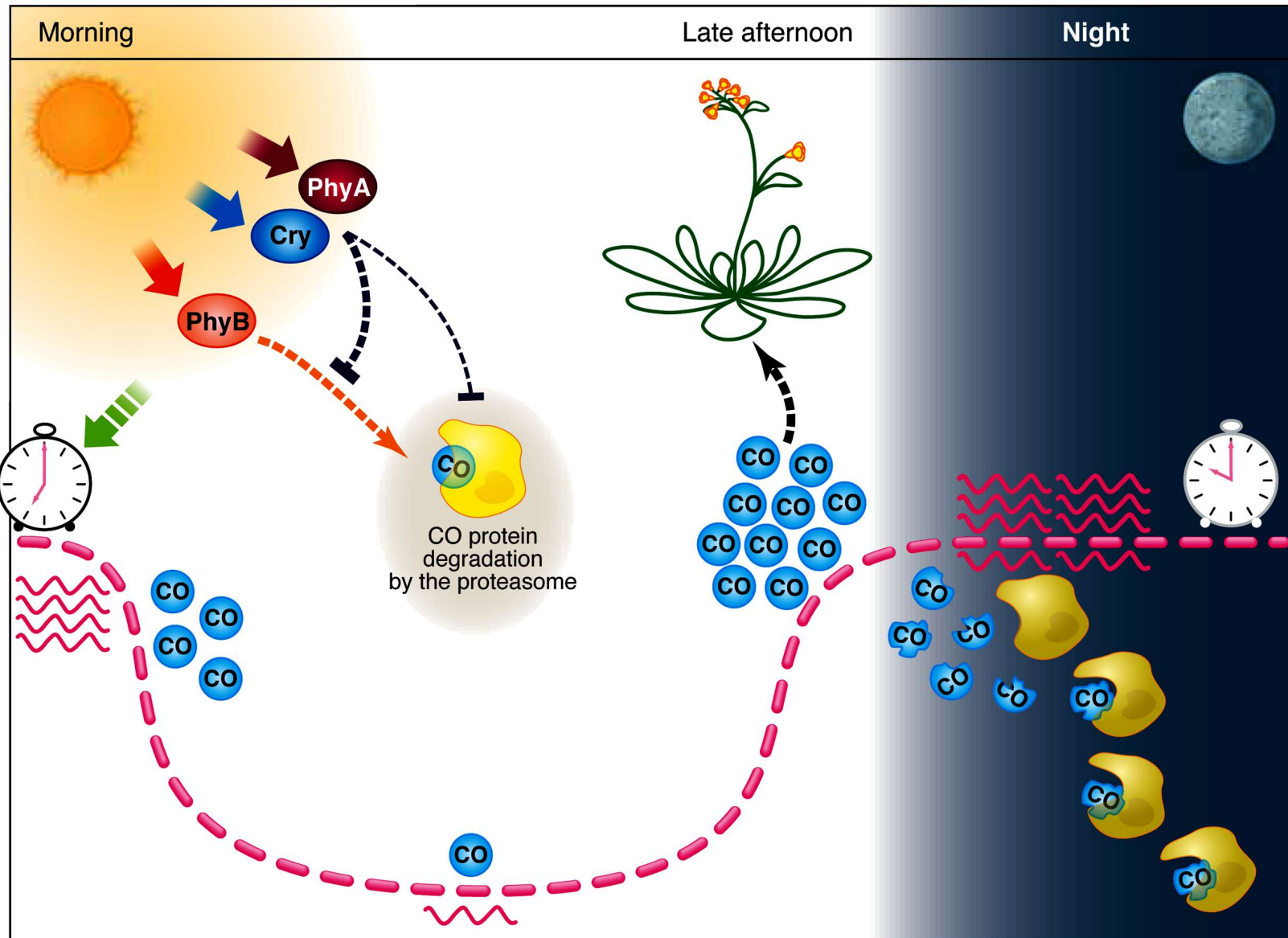
# Die Expression von **CONSTANS**

(Hayama R & Coupland G [2004] Plant Physiol 135: 677-684)



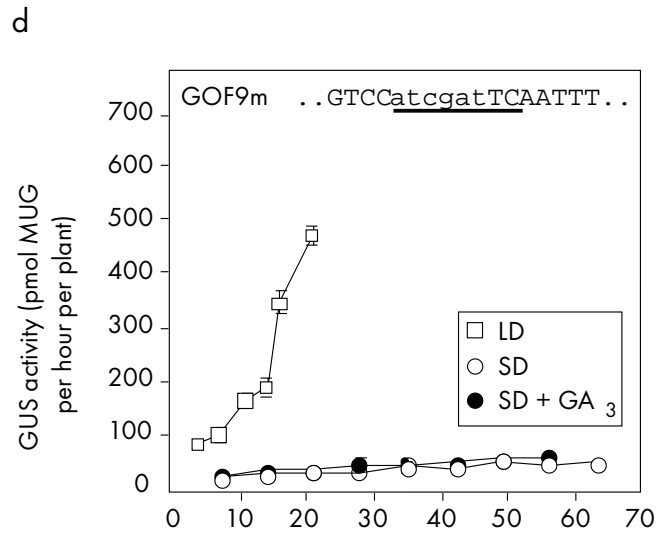
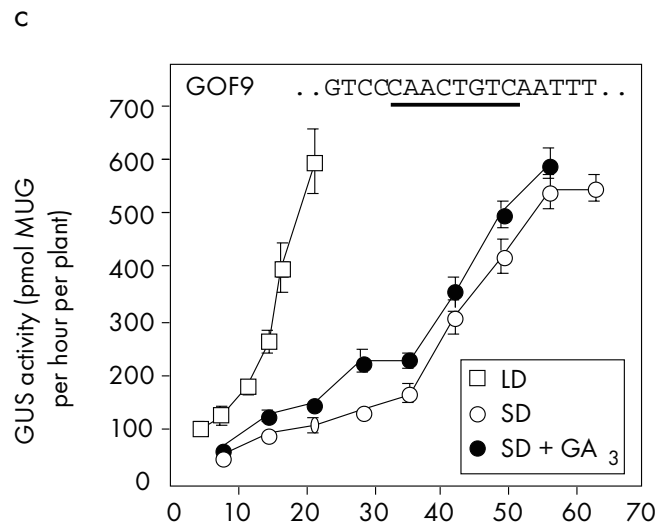
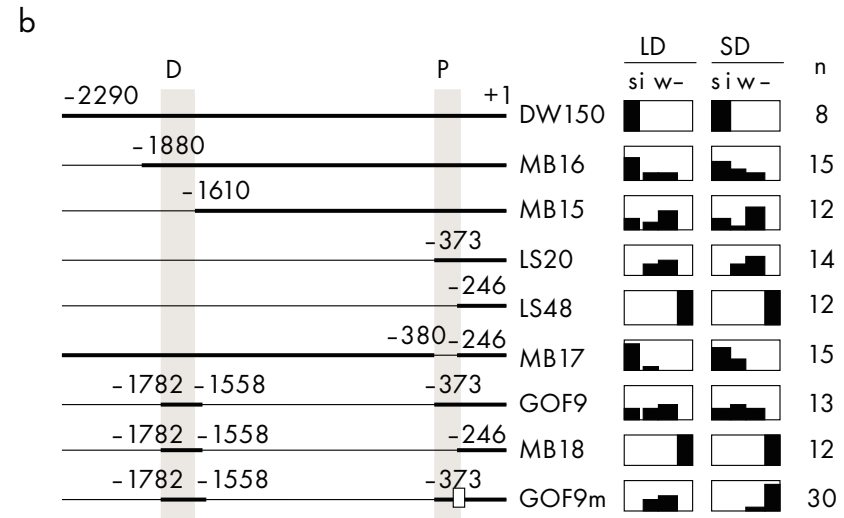
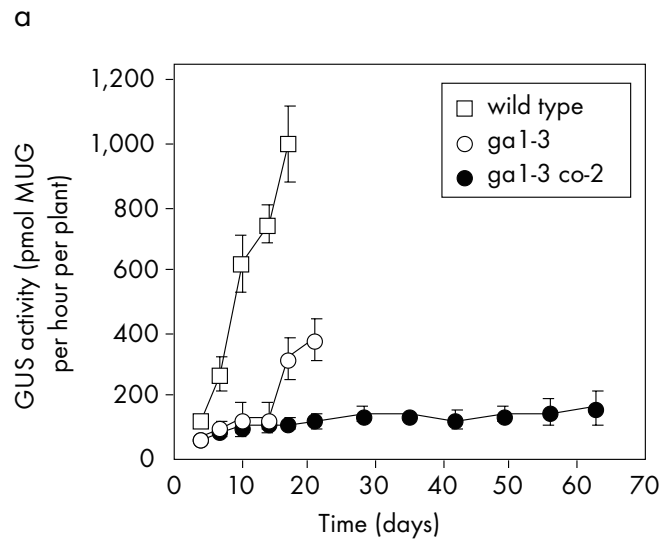
# Die Stabilität des *CONSTANS*-Proteins wird antagonistisch durch die Photorezeptoren geregelt

(Klejnot J & Lin C [2004] Science 303: 965-966)



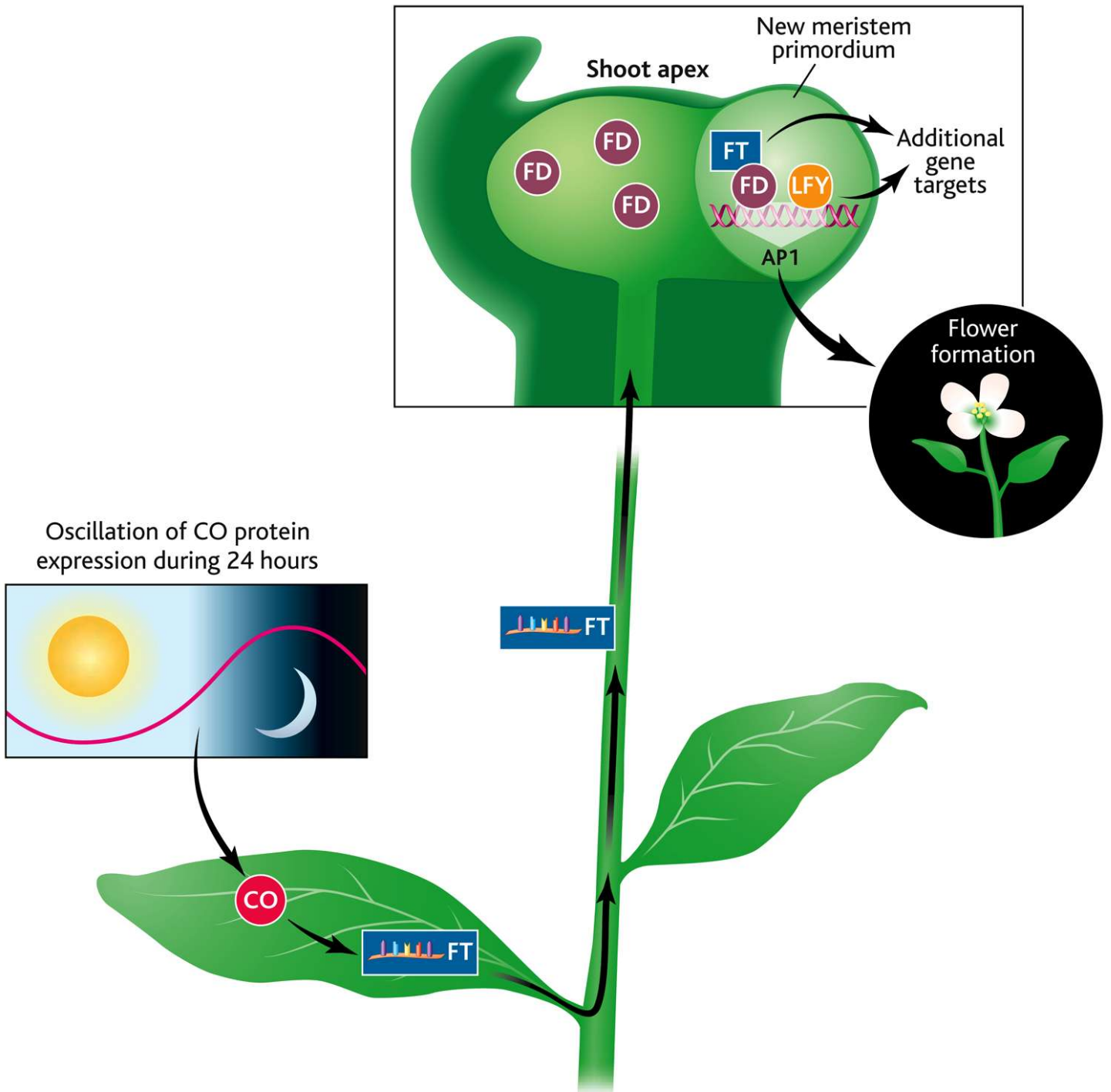
# Regulation des *LEAFY*-Promotors durch die Photoperiode und Gibberelline

(Blázquez MA & Weigel D [2000] Nature 404: 889-892)

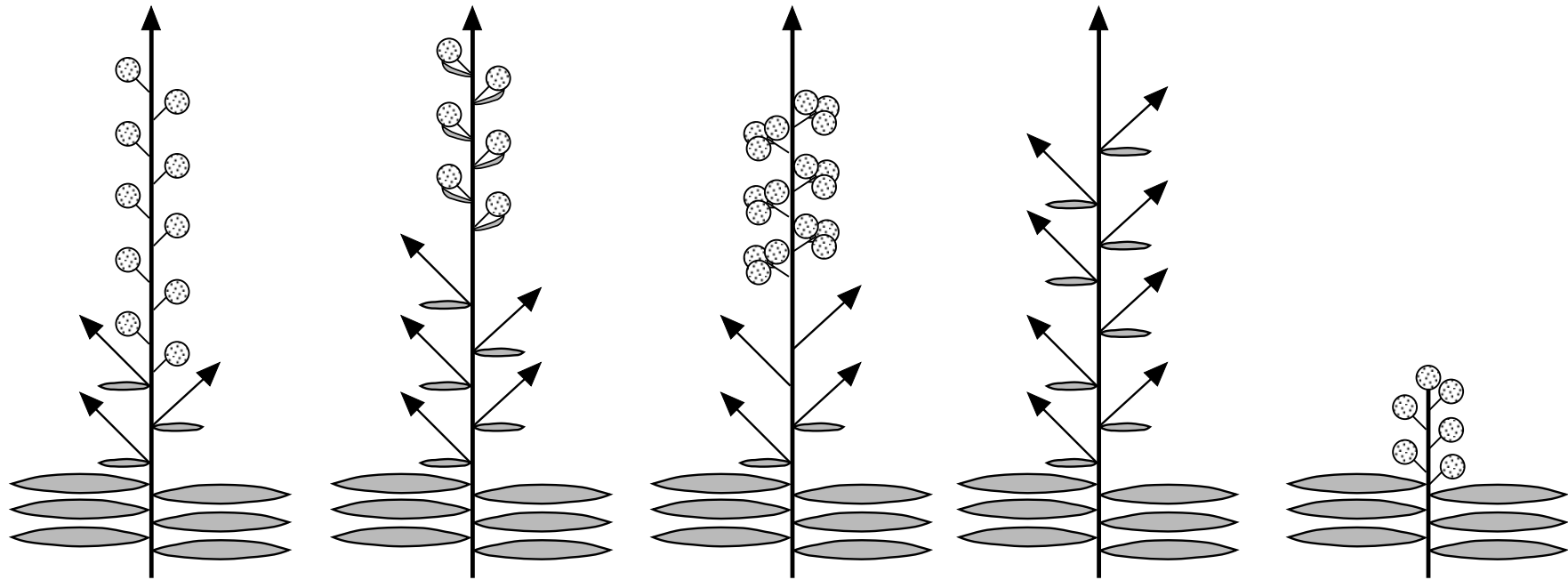


# CONSTANS & FLOWERING LOCUST und die Florigen-Hypothese

(Blázquez MA [2005] Science 309: 1024-1025)



# Die Phänotypen von Mutanten der Meristemidentitätsgene



Wildtyp

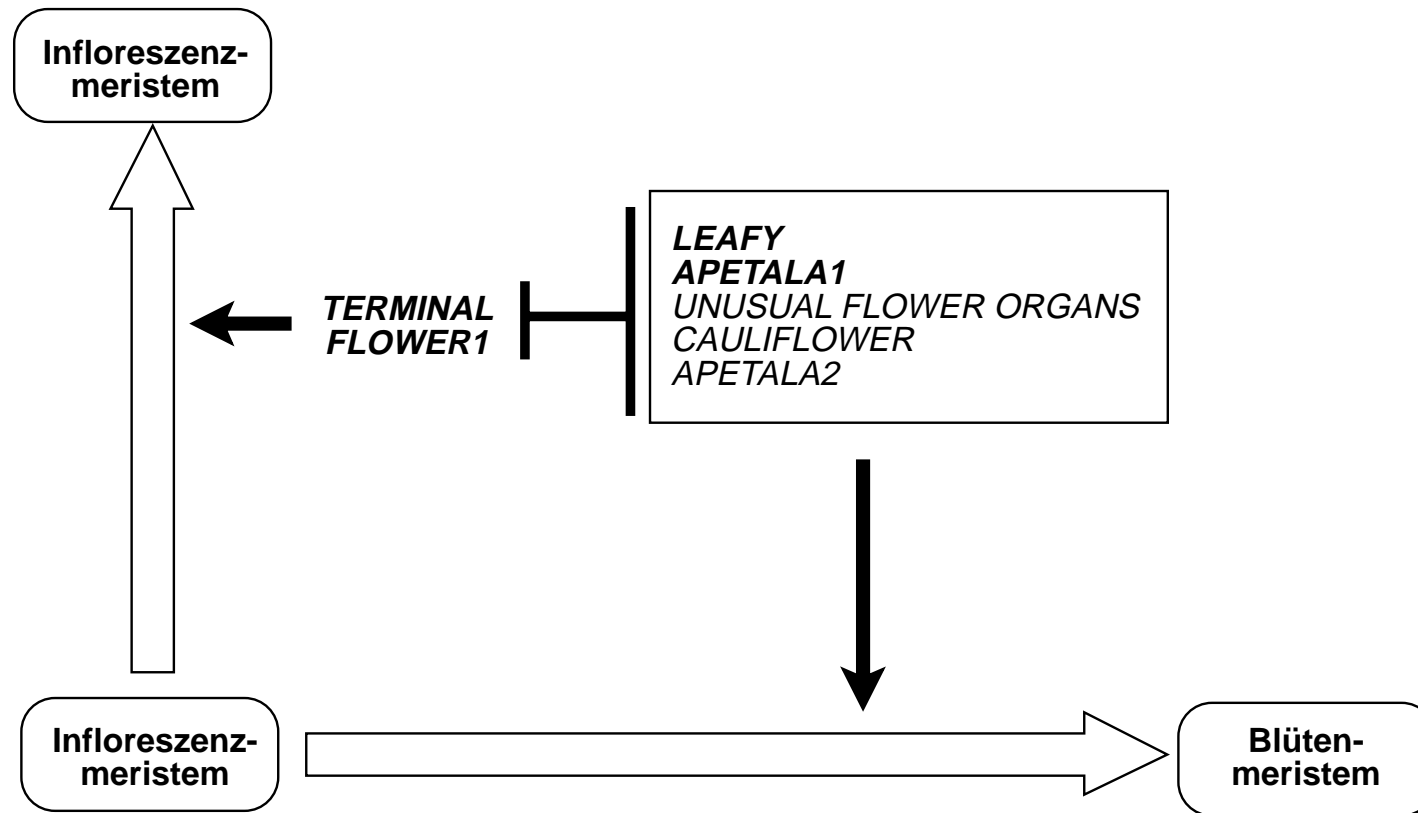
*leafy*

*apetala1*

*leafy/  
apetala1*

*35S::LEAFY*

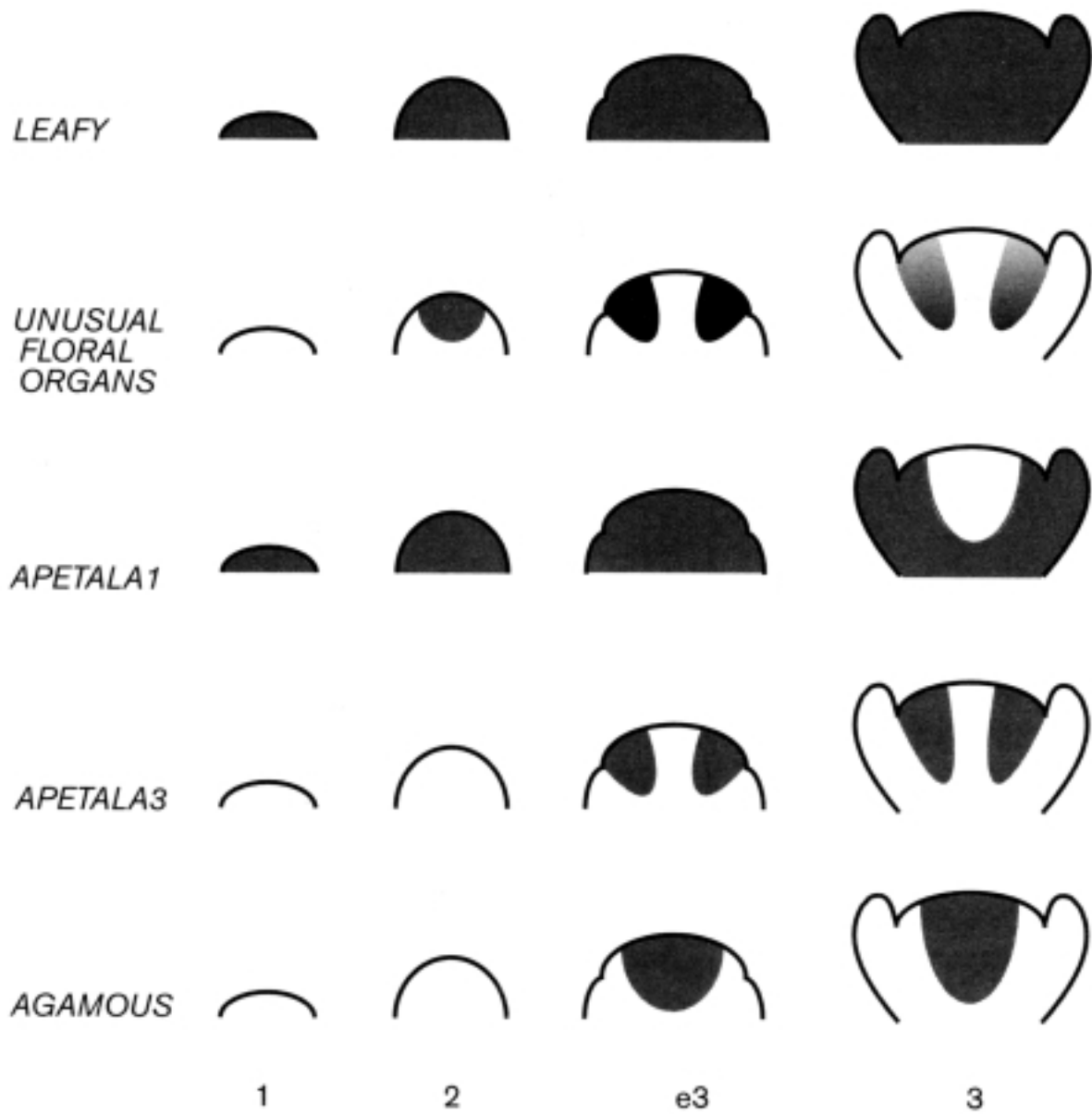
# Der Übergang vom Infloreszenz- zum Blütenmeristem



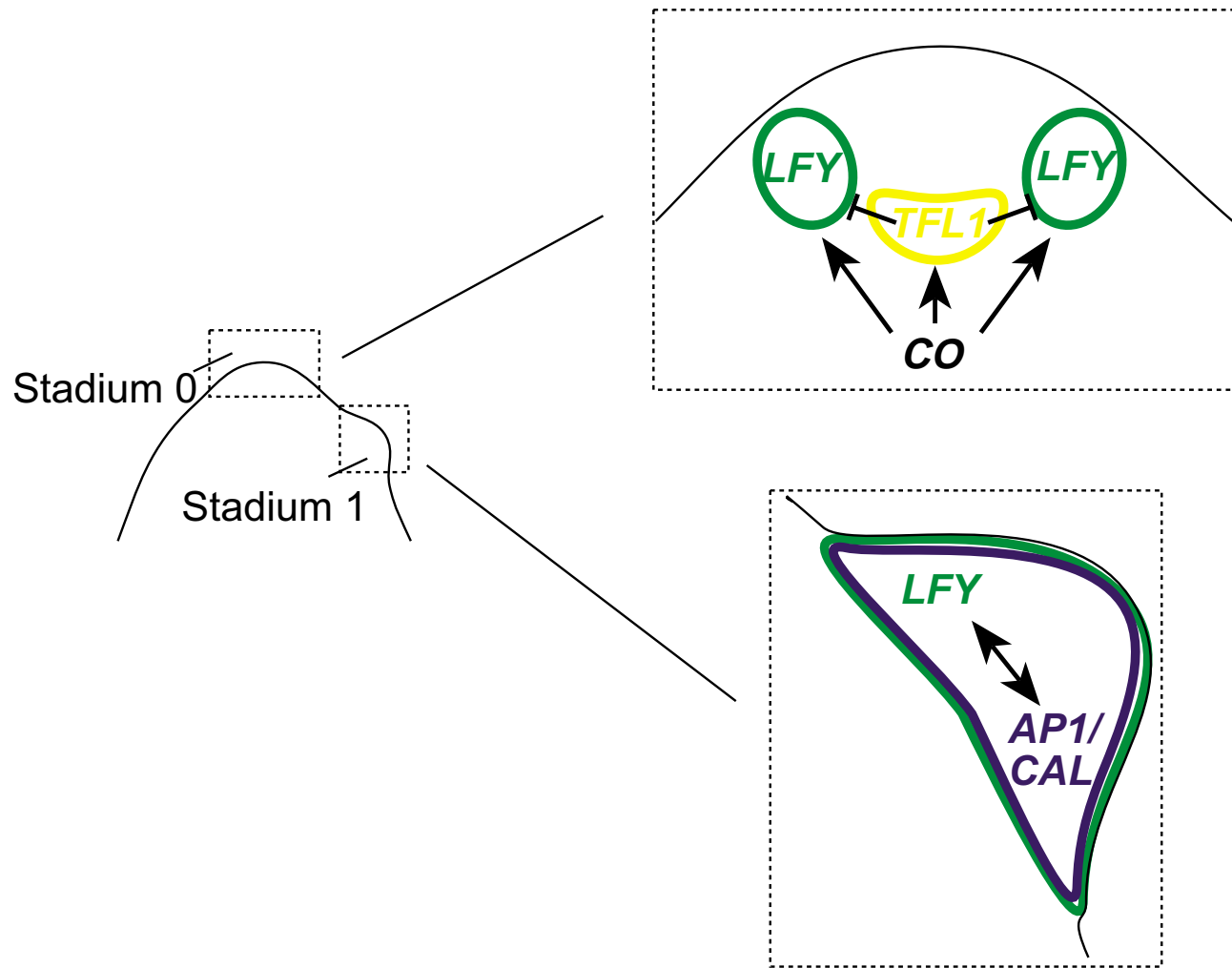


# Zeitliche Expressionsmuster von Meristem- und Organidentitätsgenen

(Ng M & Yanofsky MF [2000] Curr Opin Plant Biol 3: 47-52)



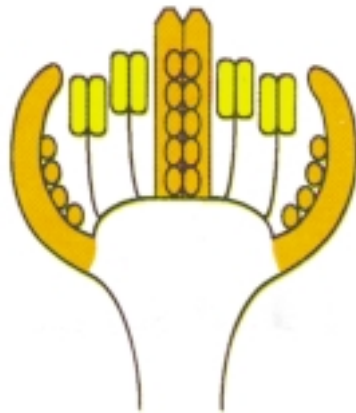
# Bildung des Blütenprimordiums: *TFL1*, *LFY* und *AP1/CAL*



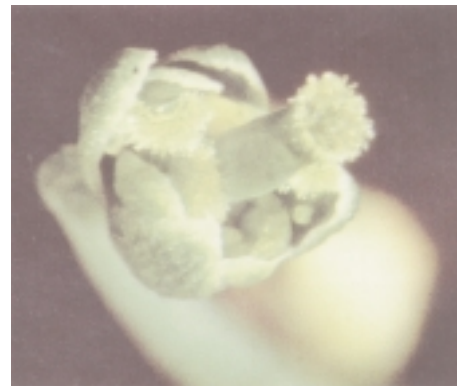
# Mutantenphänotypen homöotischer Blütengene bei *Arabidopsis thaliana*

(Meyerowitz EM , Spektrum der Wissenschaft, Januar 1995; Bowman JL et al.[1991] Development 112: 1-20)

*apetala 2*



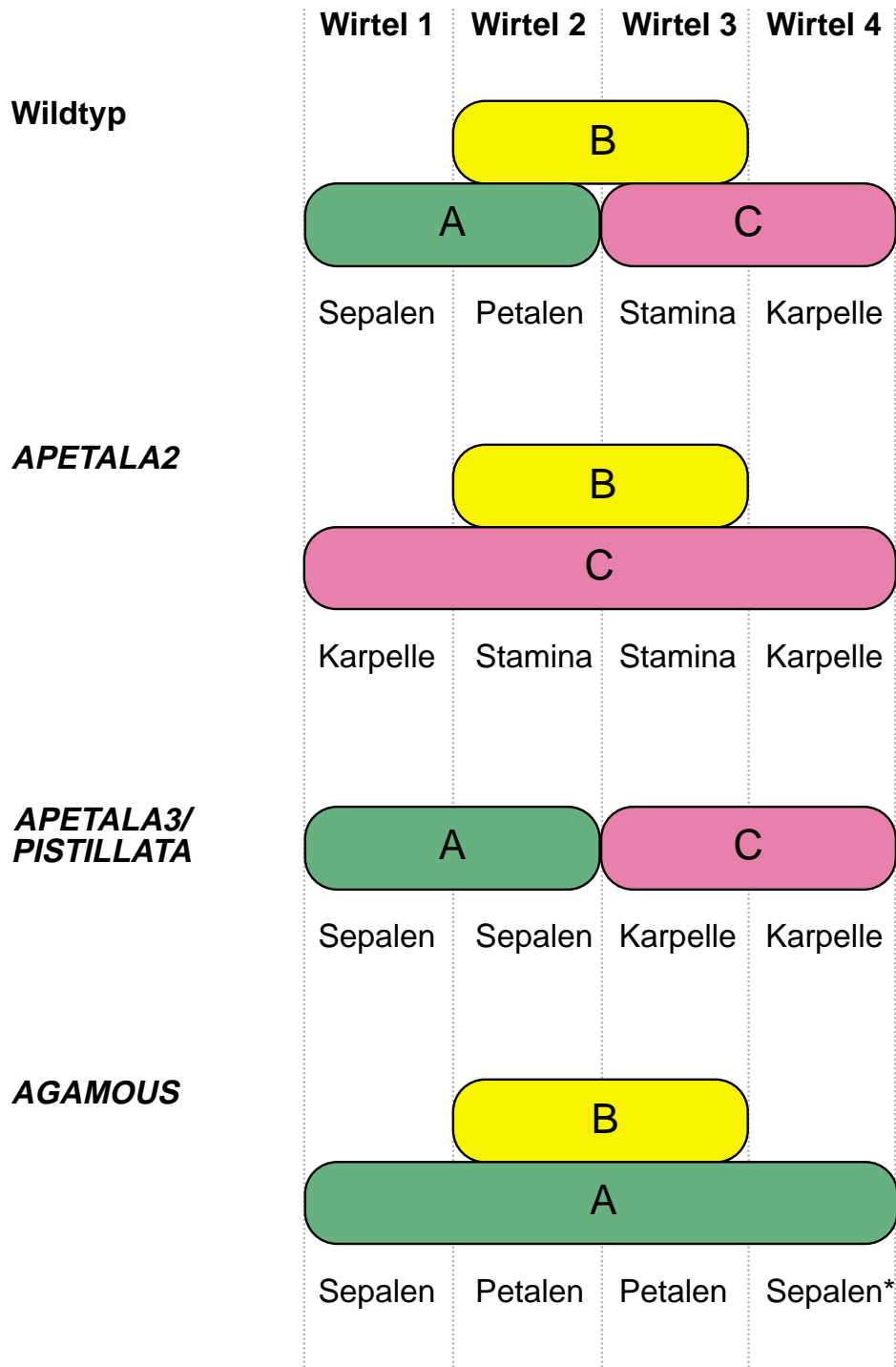
*apetala 3/pistillata*



*agamous*



# Das ursprüngliche ABC-Modell für die Aktivität der Blütenorganidentitätsgene bei *Arabidopsis thaliana*



# Mutantenphänotypen homöotischer Blütengene: Doppel- und Tripelmutanten

(Bowman JL et al.[1991] Development 112: 1-20)

*apetala 2/pistillata*  
(*apetala 2/apetala 3*)



*apetala 2/agamous*



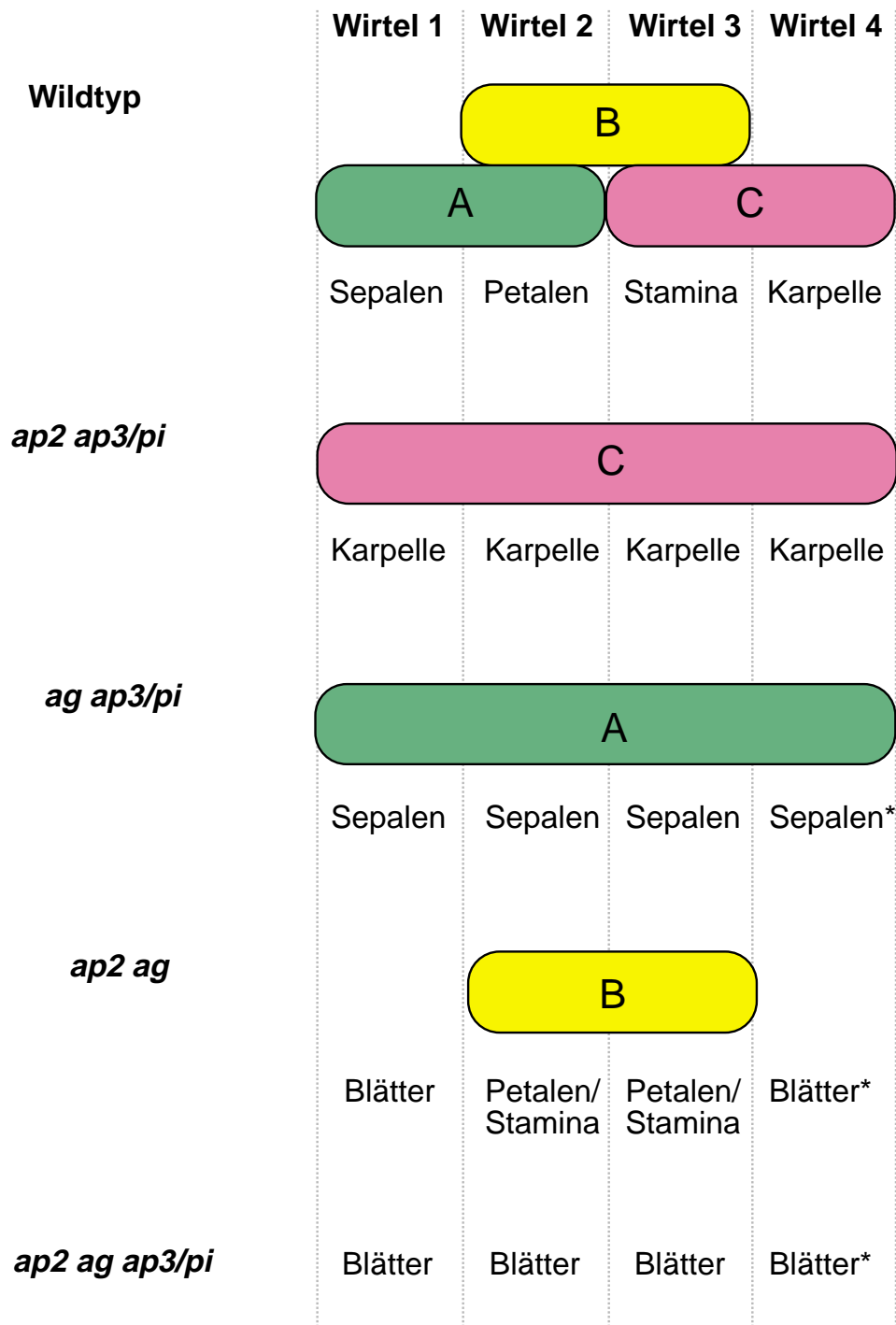
*agamous/pistillata*  
(*agamous/apetala 3*)



*apetala 2/pistillata/agamous*  
(*apetala 2/apetala 3/agamous*)



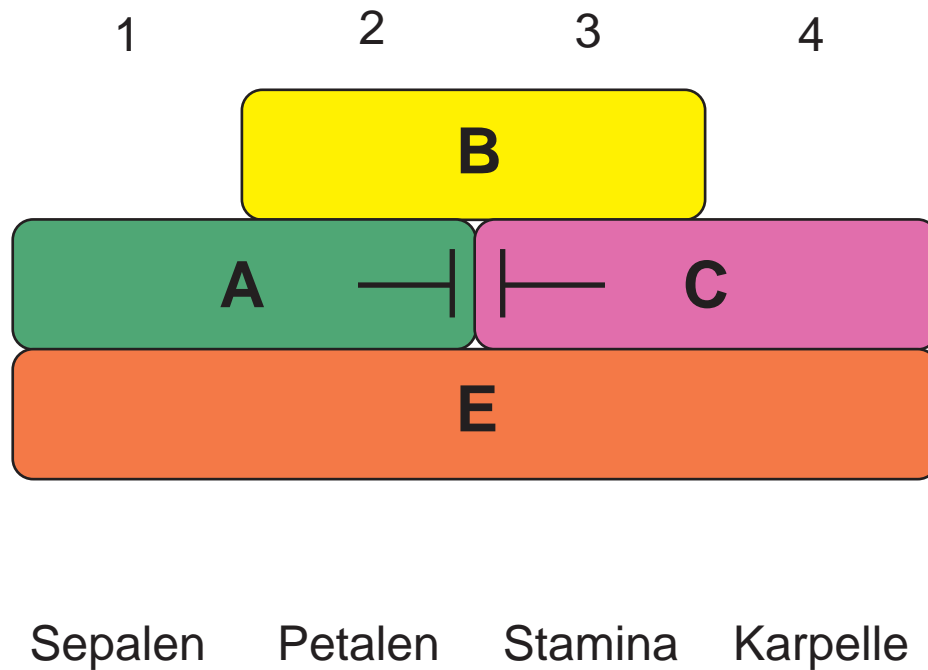
# Die Verifizierung des ABC-Modells: Doppel- und Dreifachmutanten



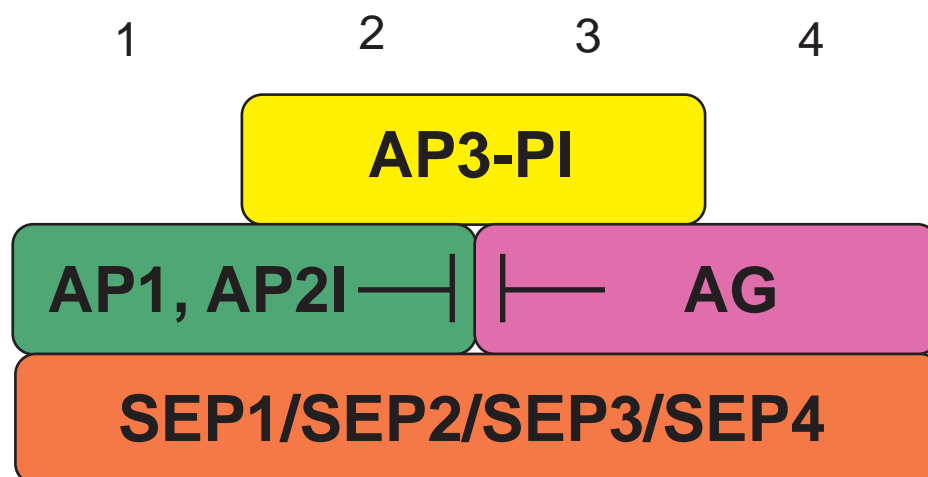
# Das ABCE-Modell für die Identität der Blütenorgane in *Arabidopsis thaliana*

(Krizek BA & Fletcher JC [2005] Nat Rev Genet 6: 688-698)

## Die Funktionen



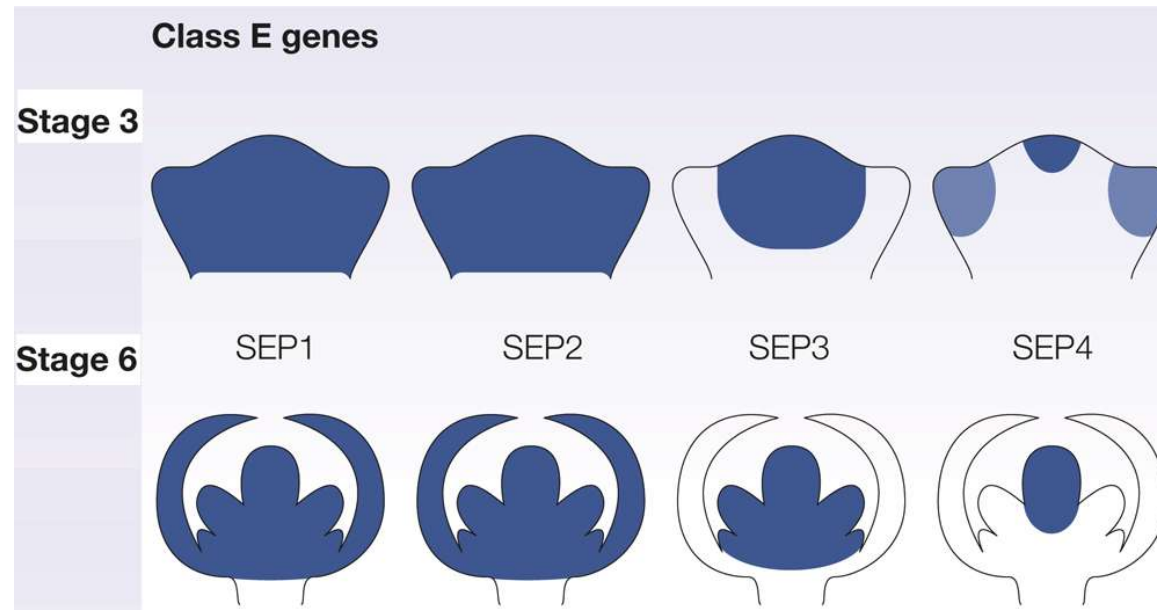
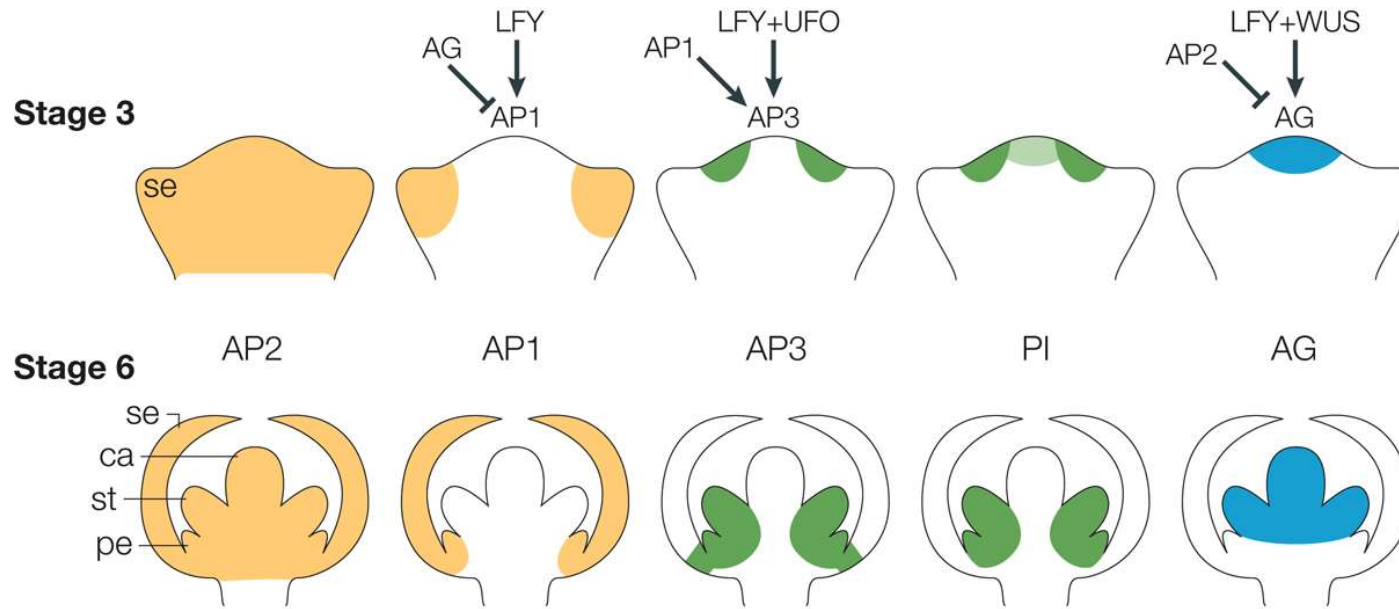
## Die Proteine





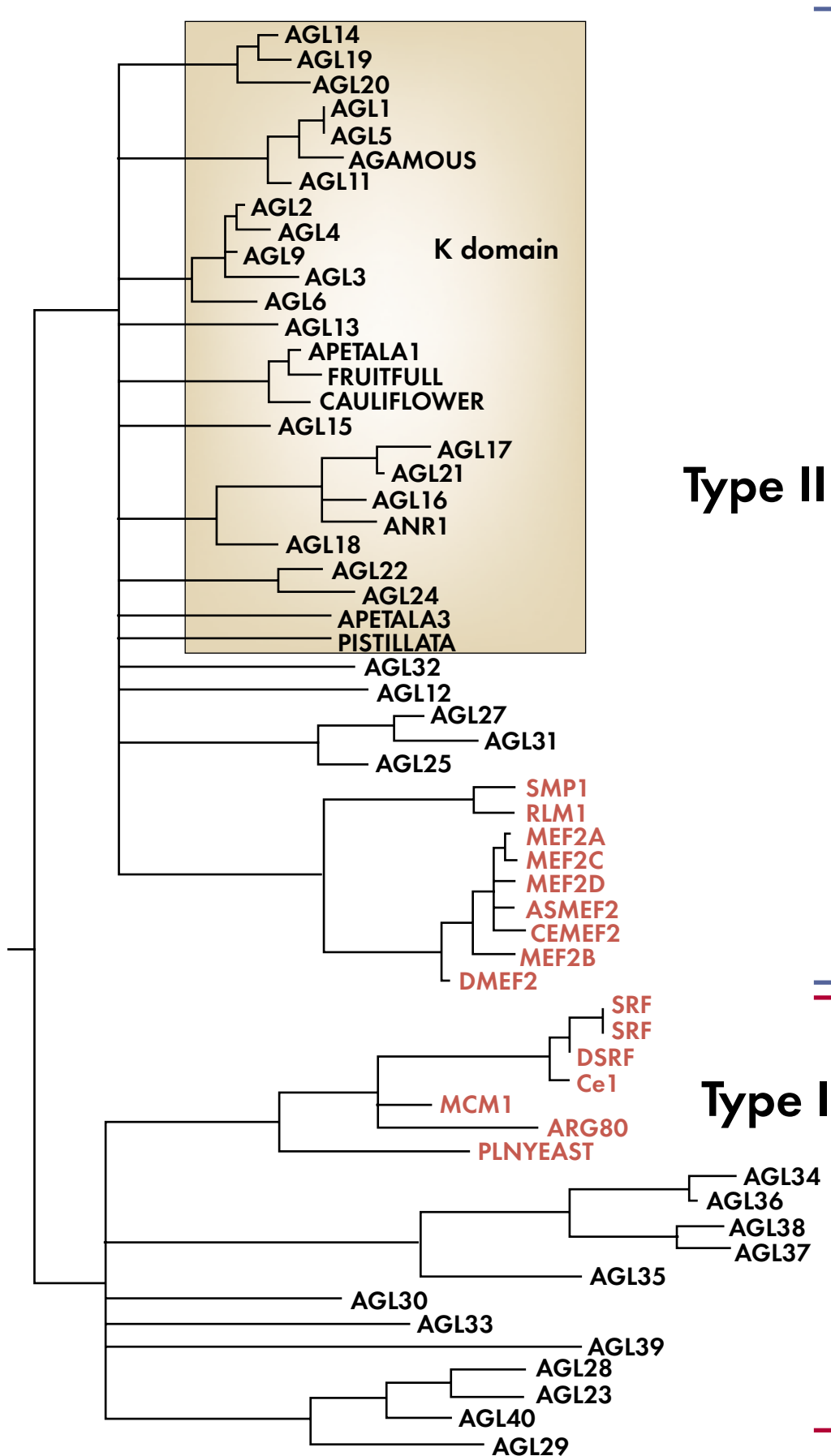
# Die Expression der ABCE-Gene

(Krizek BA & Fletcher C [2005] Nat Rev Genet 6: 688-698)



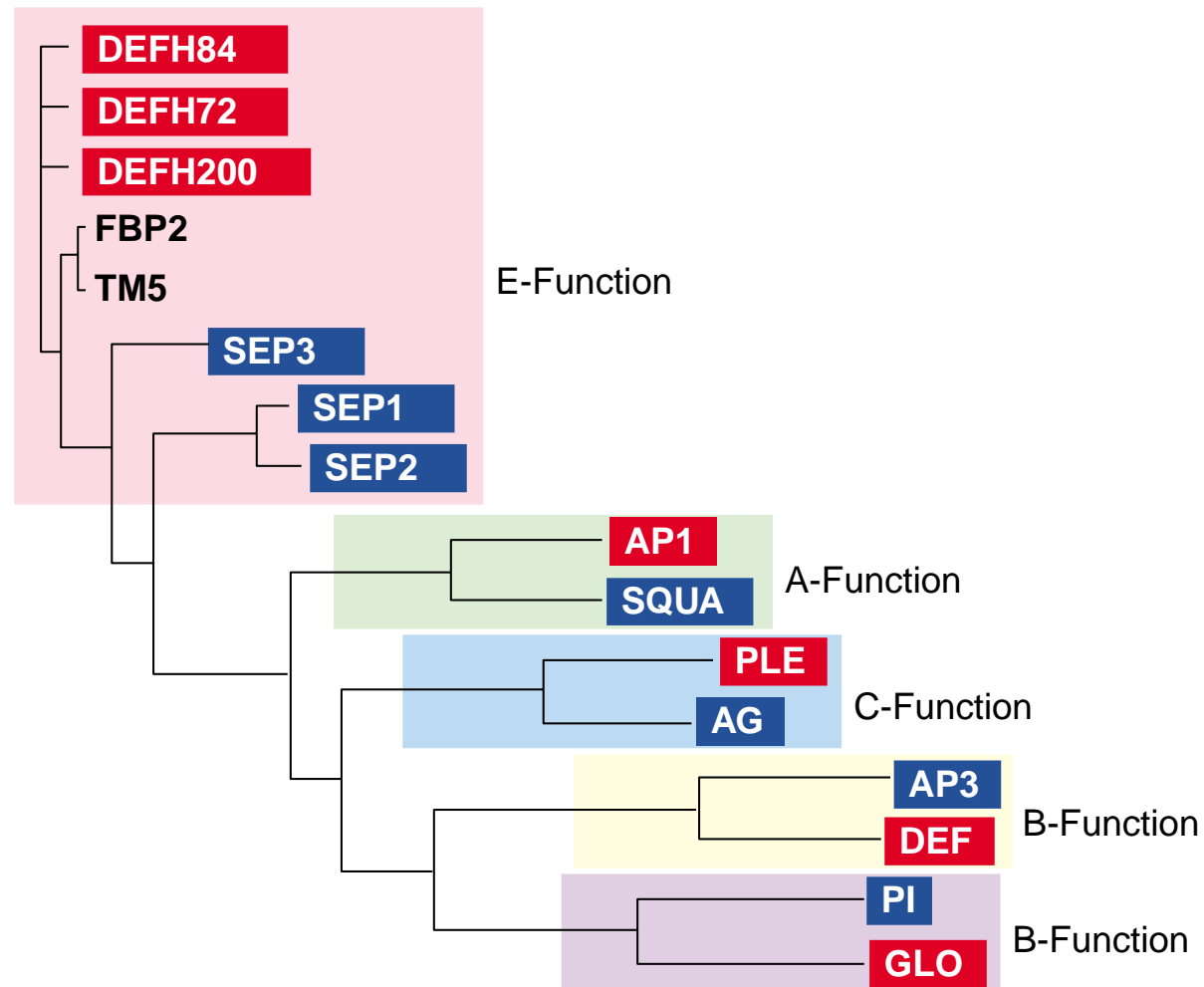
# Phylogenie der MAD5-Box-Proteinfamilie

(Ng M & Yanofsky [2001] Nat Rev Genet 2: 186-195)



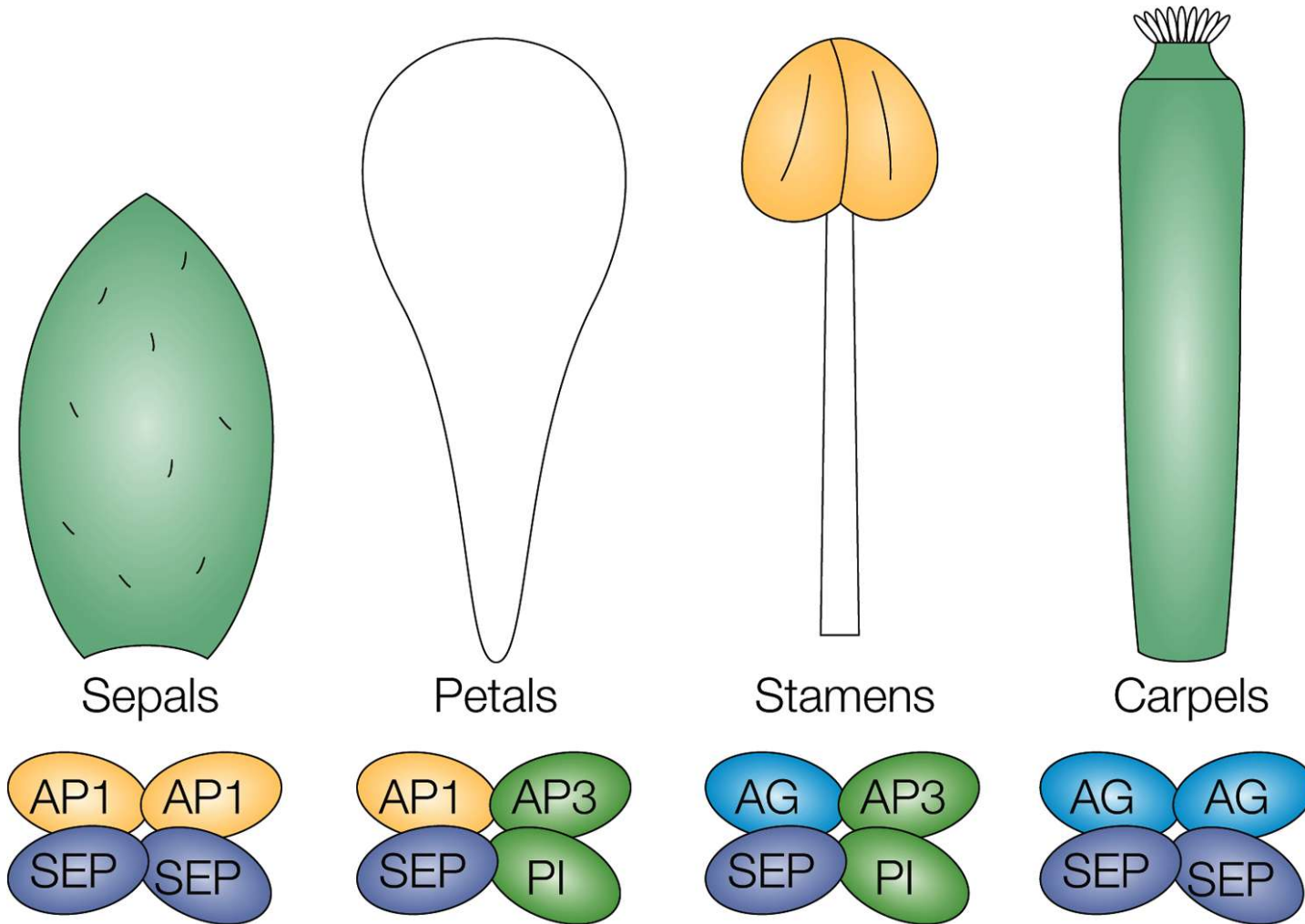
# MADS-Box-Transkriptionsfaktoren der Blütenmorphogenese

(Gutierrez-Cortines ME & Davis B [2000] Trends Plant Sci 5: 471-476)



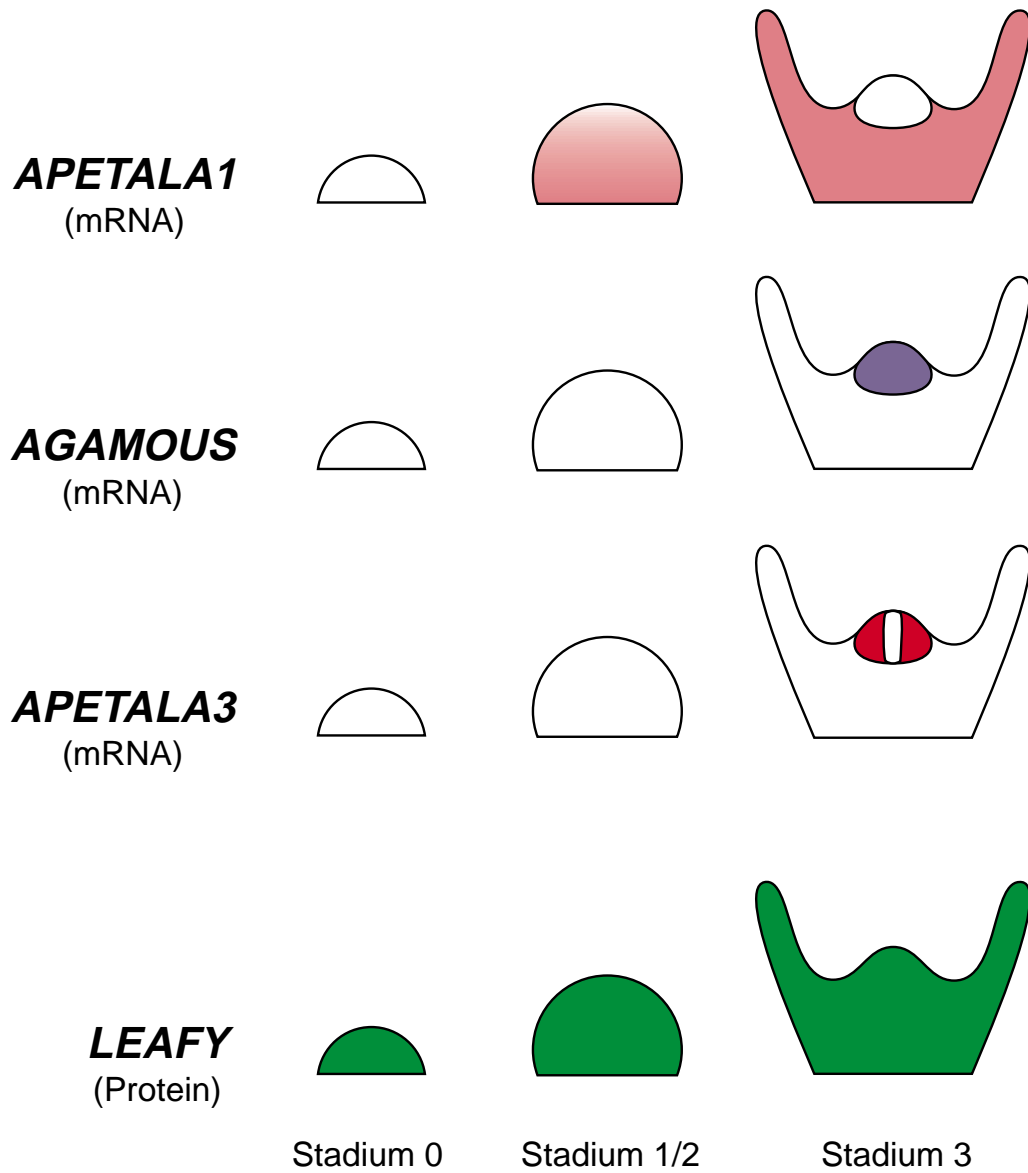
# Quartett-Model für die Bildung von MADS-Box-Protein-Komplexen

(Krizek BA & Fletcher C [2005] Nat Rev Genet 6: 688-698)



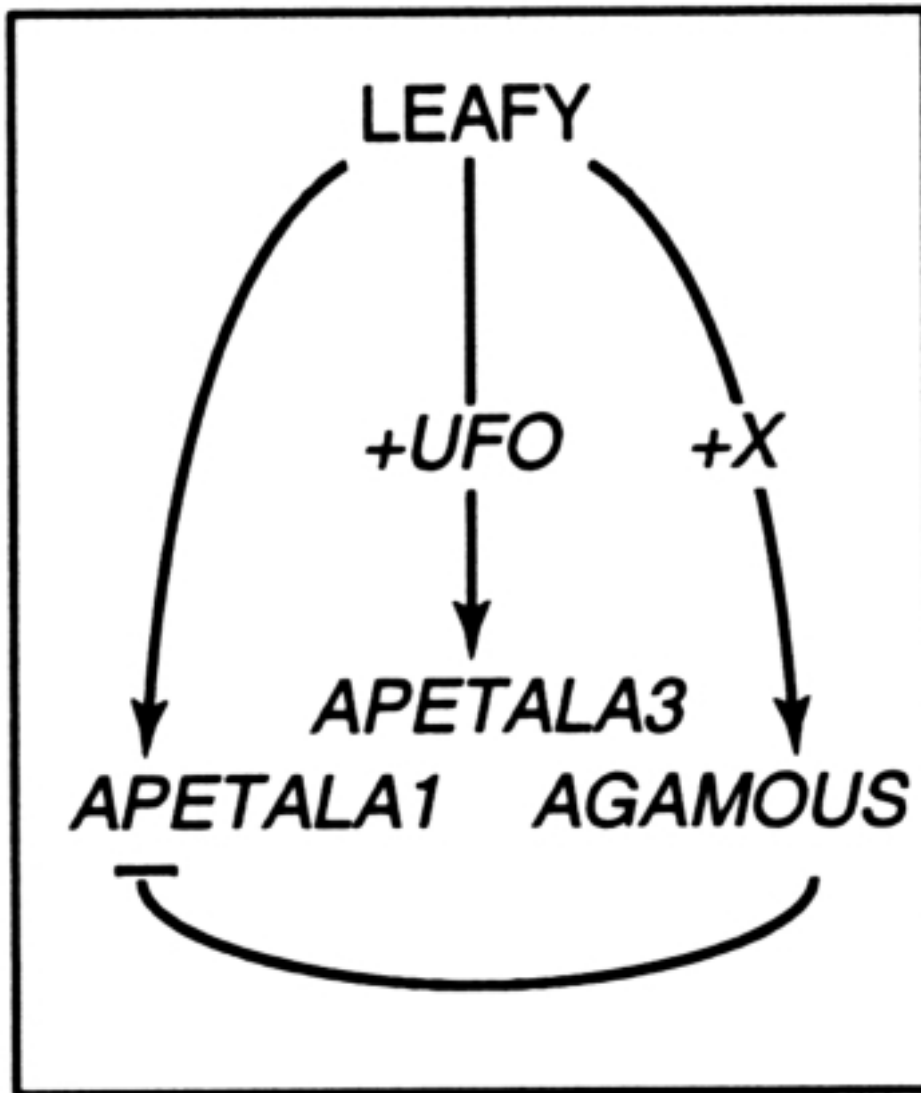
# Aktivierung der ABC-Gene durch *LEAFY*

(Parcy et al. [1998] Nature 395: 561-566)



# Aktivierung der ABC-Gene durch *LEAFY*

(Parcy et al. [1998] Nature 395: 561-566)



# Organidentitätsgene bei dem Gras *Zea mays*

(McSteen et al [2000] Trends Plant Sci 5: 61-66 und Ambrose et al [2000] Molec Cell 5: 569-579)

