THE BIOLOGICAL CLOCK OF PLANTS

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CLASSIFICATION

Biological rhythms are classified under three main titles depending on their duration;

- Ultradian rhythm: A biological rhythm that occurs with a frequency of less than 24 hours.
- Infradian rhythm: A biological rhythm that lasts more than 24 hours.
- Circadian rhythm: The circadian rhythm is a rhythm that repeats every 24 hours.

CIRCADIAN RITHYM

Circadian is a Latin word which literally means **about a day**.

The circadian clock, in other words, the daily clock, is an **endogenous mechanism** that allows for the temporal regulation of the biological processes of an organism and to coordinate at certain times of the day or night.

The circadian clock mechanism **is found in many organisms**, as most organisms adapt their physiology and behavior to periodic oscillations in external signals that occur during each intraday cycle.

TAMARINDUS INDICUS

The earliest circadian rhythm known in written sources is based on the observation made by Androsthenes on the chicory tree in the 4th century.

MIMOSA PUDICA

Scientifically, French astronomer Jean-Jacques stated that organisms may have an internal clock according to his observations on mimosa plant in 1729.*

It was determined by Mairan that the leaves show these rhythmic movements when the mimosa is completely put into darkness, and that this rhythmic movement is controlled by an internal mechanism.

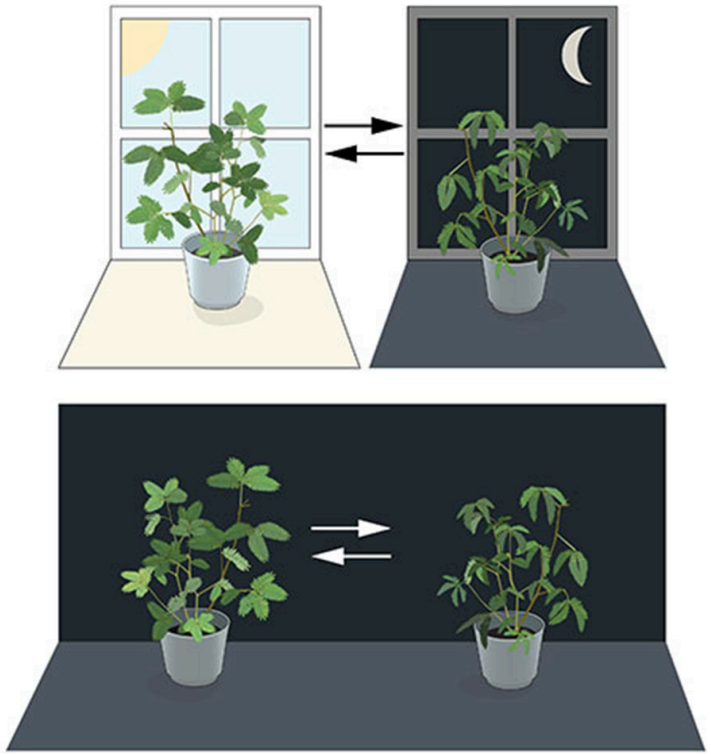
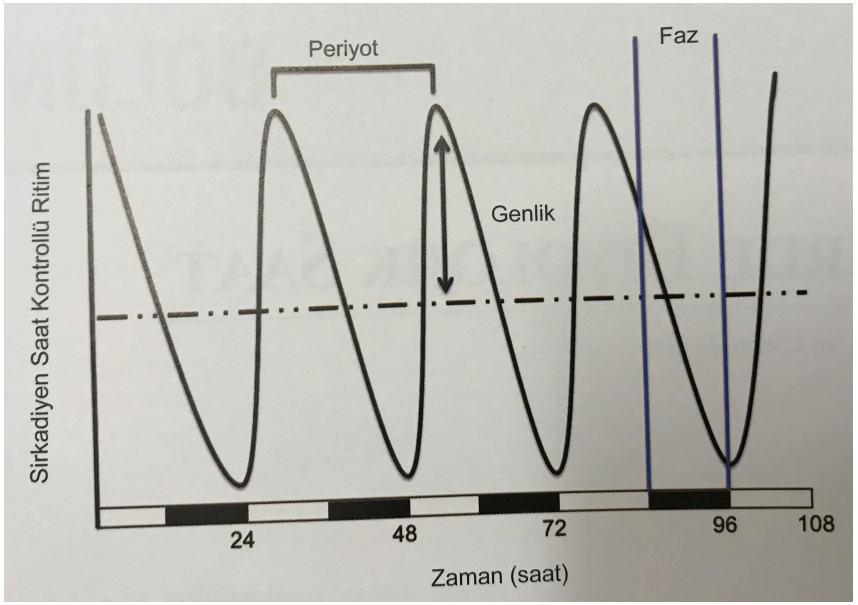


Figure 1. An internal biological clock. The leaves of the mimosa plant open towards the sun during day but close at dusk (upper part). Jean Jacques d'Ortous de Mairan placed the plant in constant darkness (lower part) and found that the leaves continue to follow their normal daily rhythm, even without any fluctuations in daily light.

FEATURES OF THE CIRCADIAN RHYTHM

The circadian rhythm is a subunit of biological rhythms and
is defined by certain parameters with the completion of a cycle in 24 hours.



The **period** refers to the time required to complete a single cycle.

The **period length** defines the elapsed time between two repeated times

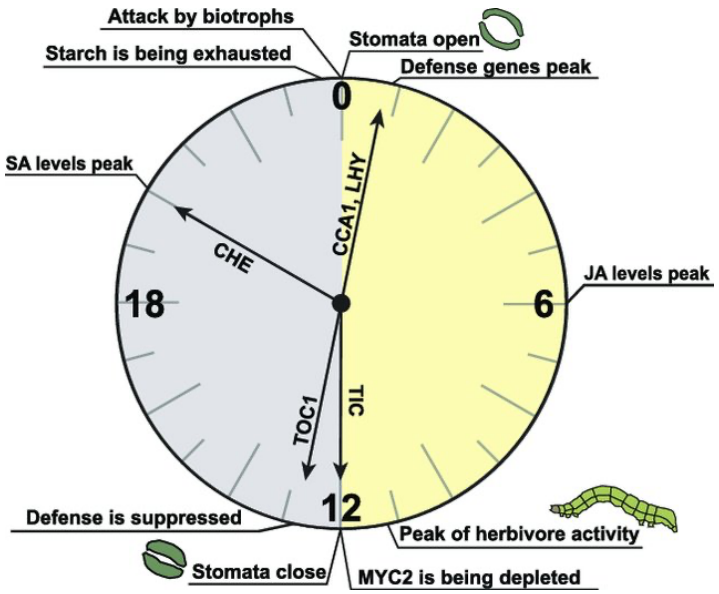
Amplitude is defined as half of the range where the rhythm is the least and the most.

The **phase** of a circadian rhythm reflects where the peak and the trough occur, for example, the peak and trough of performance within the 24 h.

FEATURES OF THE CIRCADIAN RHYTHM

Studies in single-cell *Cyanobacteria* have shown that non-clocked *Cyanobacteria* cannot compete with the wild type and over time their extinction is extinct.

Studies on the necessity of the circadian clock have revealed that the clock is a necessary mechanism for survival.



FEATURES OF THE CIRCADIAN RHYTHM

- Studies have shown that the circadian clock has three main features in all plants and living organisms.

a. Continuation of the circadian rhythm in cells in the absence of environmental stimulants,

b. Circadian rhythm being adjusted by factors such as dark-light cycle or heat,

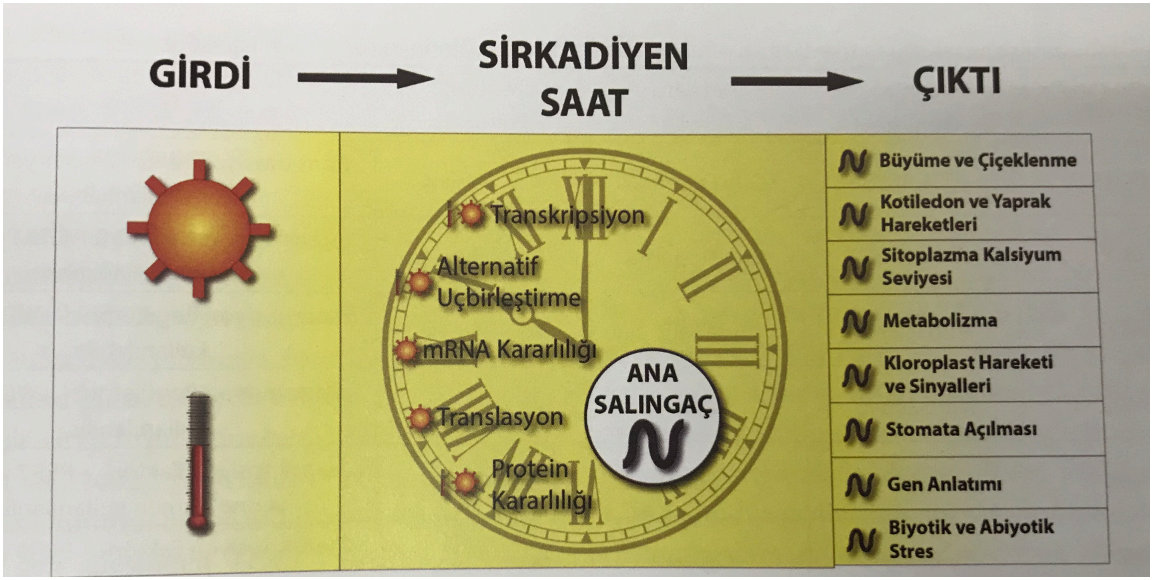
c. Circadian period is not affected by temperature change

FEATURES OF THE CIRCADIAN RHYTHM

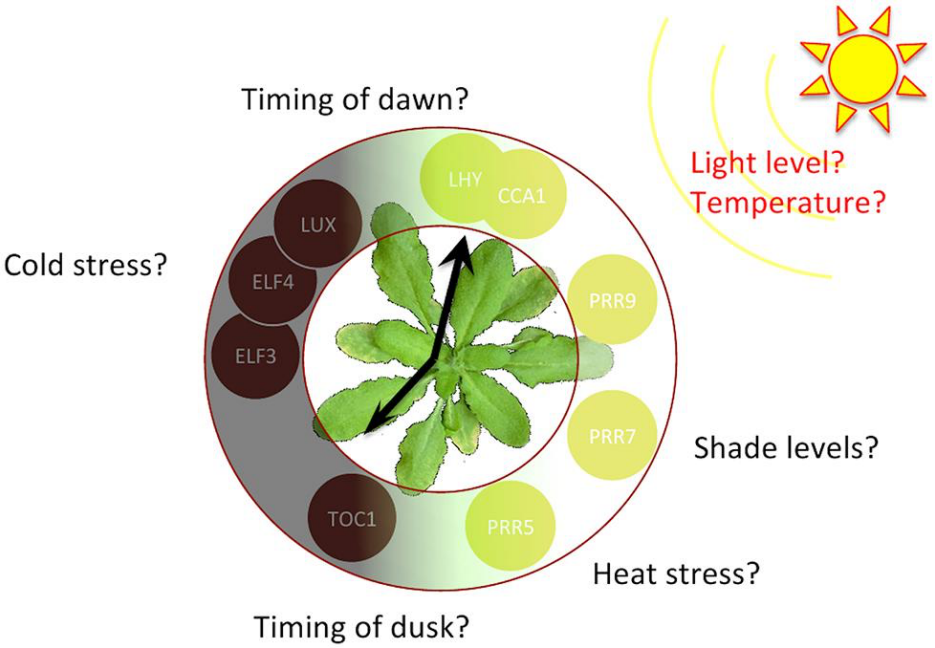
It is determined that the circadian rhythm consists of three main elements in plants. These are;

- a. Oscillation element
- b. Input element
- c. Output element

*Entrainment



FEATURES OF THE CIRCADIAN RHYTHM



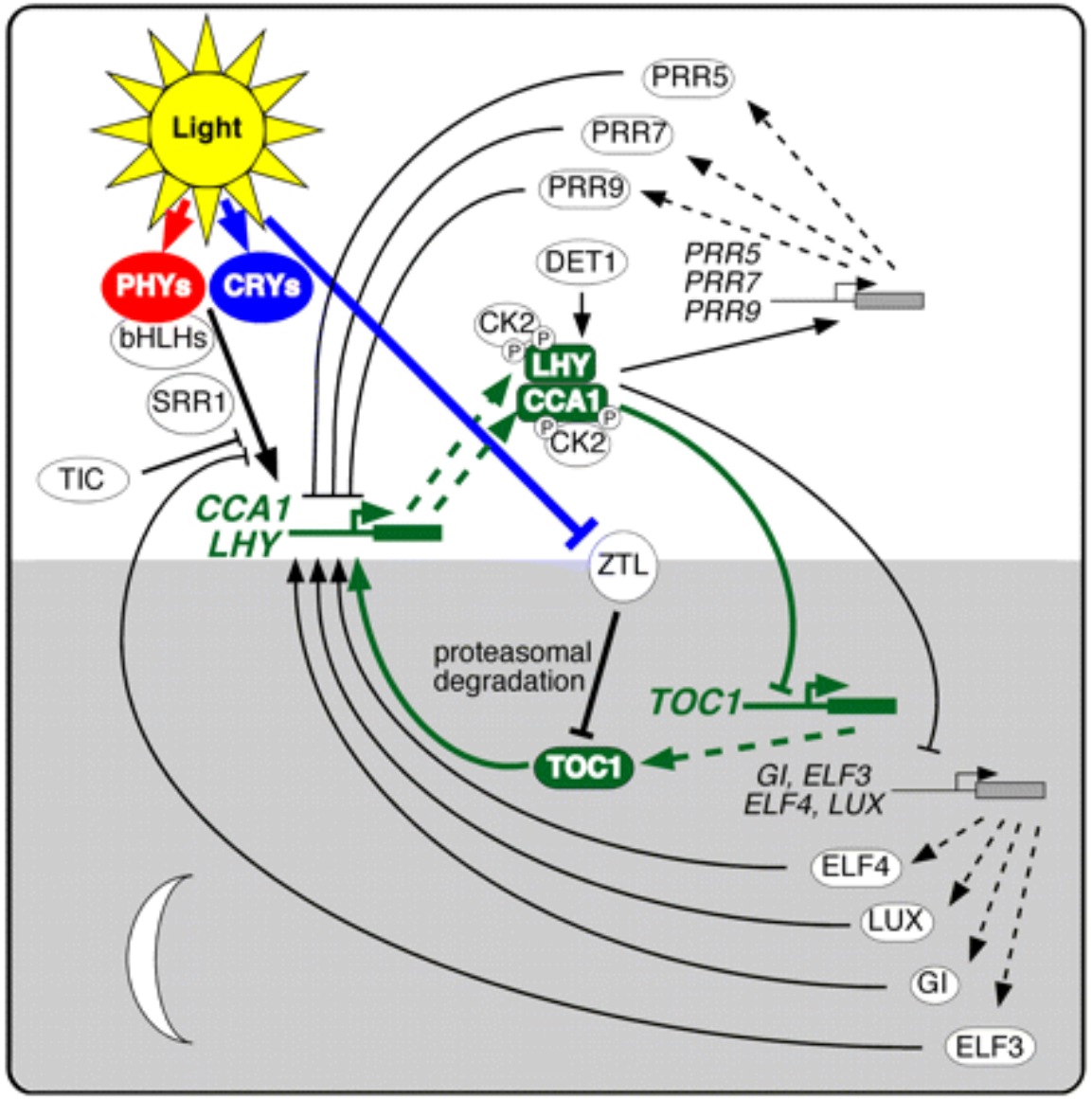
- Although the circadian rhythm operates independently of environmental conditions, a number of environmental elements such as light and temperature are required for the transfer of time information to the organism and synchronization of the internal clock according to the environmental conditions.

- The type and intensity of light causes the circadian clock to be arranged differently at the molecular level and the gene expression associated to it regulates at different levels.

IMPORTANCE OF LIGHT ON CIRCADIAN CLOCK

- Vital activities such as expression of clock genes, mRNA stability, protein production and protein structural stability are all affected by light.

- But how light information is processed and transmitted by the main clock mechanism has not been fully illuminated.



IMPORTANCE OF LIGHT ON CIRCADIAN CLOCK

In the light of all this information, understanding the environmental signals of physiological activities starting from the cell level through the circadian clock to the organism level, how they affect homeostasis and how environmental changes are predicted is very important in terms of understanding how plants maintain their lives in harmony with their environment.

MOLECULAR MECHANISMS OF BIOLOGICAL CLOCK IN PLANTS

Current information about the circadian rhythm in plants is generally based on genetic and biochemical studies conducted in the late 1990s that first defined the main clock cycle at the level of gene expression.

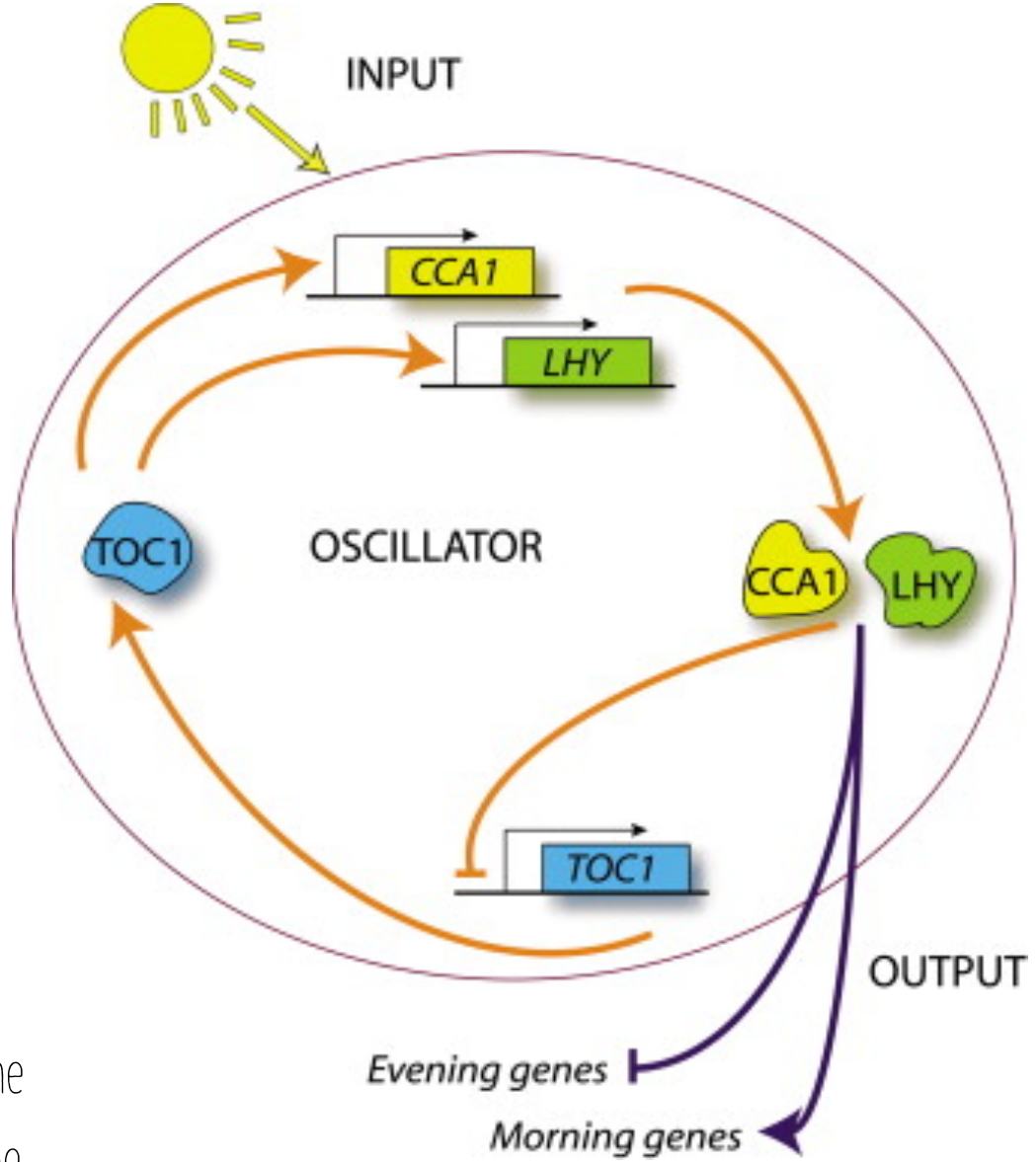
The clock components discovered for the first time using Arabidopsis thaliana are transcription factors CCA1 and LHY*.

Gen Adı	AGI Numarası	Aktivite Zamanı	Mutant Fenotipi	Görevi
CCA1	AT2G46830	Gün Doğumu	Kısa Periyot	Transkripsiyon Faktörü – LHY yerine kısmen kullanılabilir.
LHY	AT1G01060	Gün Doğumu	Kısa Periyot	Transkripsiyon Faktörü – CCA1 yerine kısmen kullanılabilir.
LWD1	AT1G12910	Sabah	Kısa Periyot	Transkripsiyon Regülatörü – LWD2 yerine kullanılabilir.
LWD2	AT3G26640	Sabah	Kısa Periyot	Transkripsiyon Regülatörü – LWD1 yerine kullanılabilir.
PRR9	AT2G46790	Sabah	Uzun Periyot	Transkripsiyon Faktörü – PRR7 ve PRR5 yerine kısmen kullanılabilir.
PRR7	AT5G02810	Öğlen	Uzun Periyot	Transkripsiyon Faktörü – PRR9 ve PRR5 yerine kısmen kullanılabilir.
RVE8	AT3G09600	Öğleden Sonra	Uzun Periyot	Transkripsiyon Faktörü – RVE6 ve RVE4 yerine kısmen kullanılabilir.
RVE6	AT5G52660	Öğleden Sonra (Varsayılan)	Belli Değil	Transkripsiyon Faktörü – RVE8 ve RVE4 yerine kısmen kullanılabilir.
RVE4	AT5G02840	Öğleden Sonra (Varsayılan)	Belli Değil	Transkripsiyon Faktörü – RVE8 ve RVE6 yerine kısmen kullanılabilir.
LNK1	AT5G64170	Öğleden Sonra	Uzun Periyot	Transkripsiyon Regülatörü – LNK2 yerine kullanılabilir.
LNK2	AT3G54500	Öğleden Sonra	Uzun Periyot	Transkripsiyon Regülatörü – LNK1 yerine kullanılabilir.
PRR5	AT5G24470	İkindi	Kısa Periyot	Transkripsiyon Faktörü – PRR9 ve PRR7 yerine kısmen kullanılabilir.
PRR3	AT5G60100	Akşam	Kısa Periyot	Transkripsiyon Regülatörü (Varsayılan)
TOC1 (PRR1)	AT5G61380	Akşam	Kısa Periyot	Transkripsiyon Regülatörü
CHE	AT5G08330	Akşam	Belli Değil	Transkripsiyon Faktörü
GI	AT1G22770	Akşam	Kısa Periyot	Transkripsiyon Regülatörü (Varsayılan)
NOX (BOA)	AT5G59570	Gece	Kısa Periyot	Transkripsiyon Faktörü
LUX (PCL1)	AT3G46640	Gece	Aritmik	Transkripsiyon Faktörü
ELF4	AT2G40080	Gece	Aritmik	Transkripsiyon Regülatörü
ELF3	AT2G25930	Gece		

CCA1 AND LHY TRANSCRIPTION FACTORS

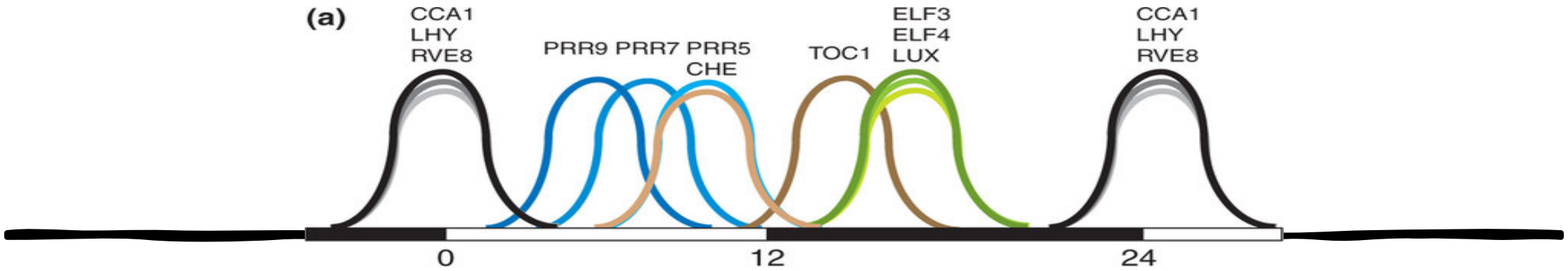
When any of the CCA1 or LHY genes were deleted with knockout technology, it was observed with a partial circadian period, and when both were deleted, the plant was completely arrhythmic, in other words, the circadian rhythm was completely lost.

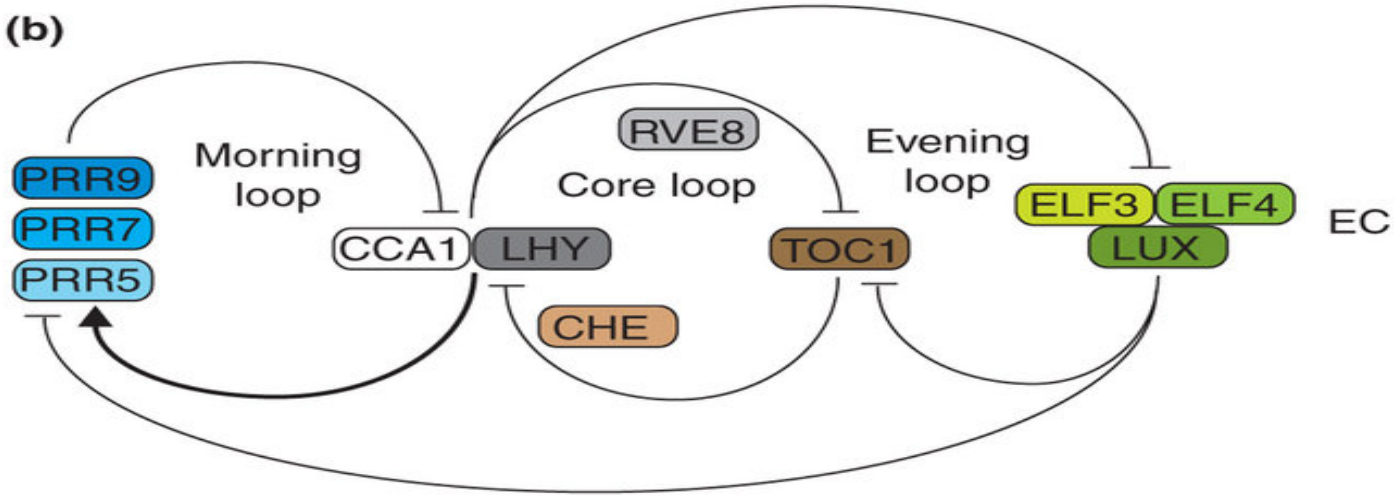
The gene in which day expression is suppressed by CCA1 / LHY is the TOC1 (Timing of CAB expression 1, also known as PRR1) gene from the PRR gene family.

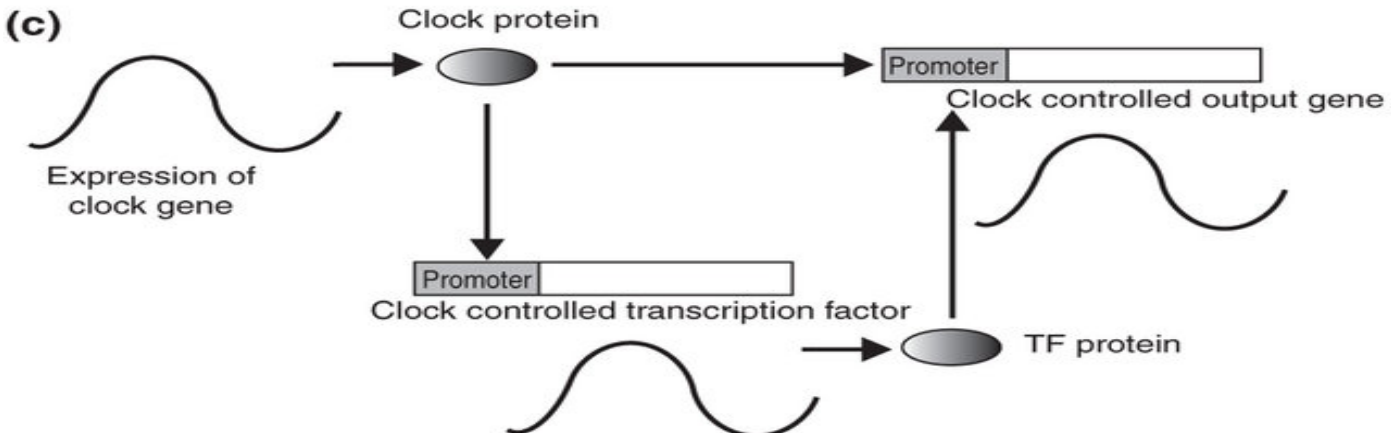


PRR PROTEINS

- CCA1 and LHY suppress gene expression of daytime TOC1 and other PRR family proteins at the level of transcription.
- On the other hand, PRR proteins are expressed sequentially throughout the day and both CC1 and LHY transcription are suppressed by these proteins.
- This time-set suppression starts at noon with PRR9, continues in the afternoon with PRR7 and PRR5, and evening time ends with TOC1.
- PRR proteins terminate the circadian daily rhythm by suppressing their expression in addition to their suppressive effects on CCA1 and LHY.


(a)
CCA1
LHY
RVE8
PRR9 PRR7 PRR5
CHE
TOC1
ELF3
ELF4
LUX
CCA1
LHY
RVE8
0
12
24

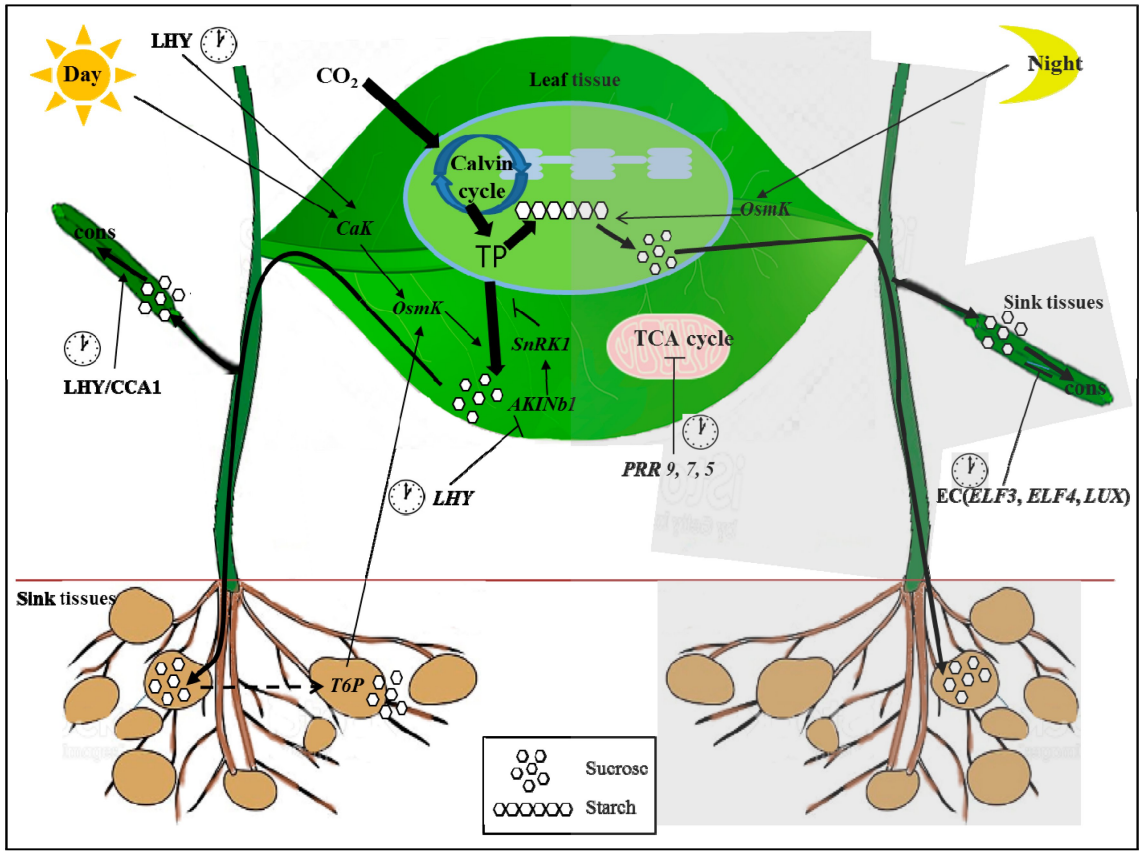

(b)
PRR9
PRR7
PRR5
Morning
loop
RVE8
Core loop
Evening
loop
ELF3
ELF4
LUX
EC
CCA1
LHY
TOC1
CHE


(c)
Clock protein
Promoter
Clock controlled output gene
Expression of
clock gene
Promoter
Clock controlled transcription factor
TF protein

THE RELATIONSHIP BETWEEN CARBOHYDRATE METABOLISM AND CIRCADIAN CLOCK IN PLANTS

Carbohydrates regulate the biological clock !!!

- As a result of the light input perceived by photoreceptors at sunrise, the circadian clock is adjusted.
- As the light intensity increases during the day, depending on the carbohydrate metabolism, a secondary adjustment is made at the molecular level at the circadian clock.



RESULTS

Advances in this area have accelerated with the knowledge of Circadian biology and the identification of genes that play an important role in the mechanism.

Especially, how the plants perceive light and transmit it to other tissues, how the circadian main clock genes contribute to the mechanism by determining the main clock genes, how the output elements are arranged after the circadian clock is created are studied extensively.

It will be possible to improve the yield of the plant by improving the clock in the long term and to develop various stress resistant species.