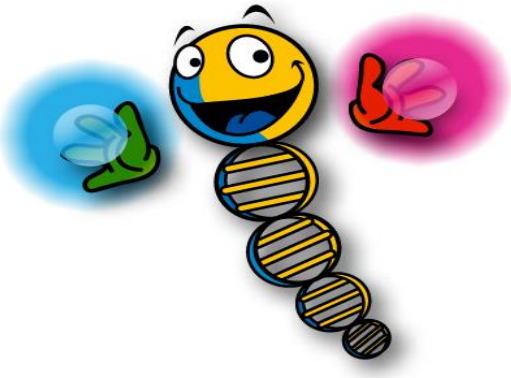
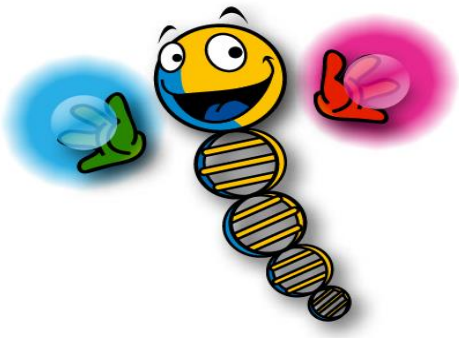
Changes in gene expression as response to abiotic stress

Dr Mohammed Hamdan Al-Issawi



Outlines

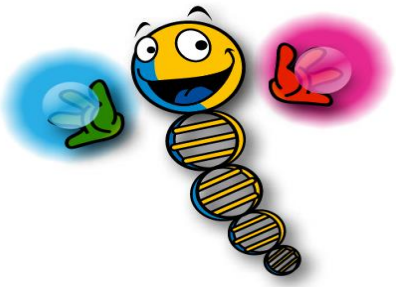


- Abiotic stress
- Gene expression and regulation
- Plant responses to abiotic stress
- Researches findings regarding plant responses to environmental stresses

Questions to Ponder

- How do plant cells “know” what kind of cell they are?
- How do plant cells “know” when to make a particular protein? When to stop making it?
- How does the environment affect plant cells?

ANSWER: Gene Expression



What is the stress

- Stress is the external condition that adversely affect growth, development and/or productivity.
- Stress triggers wide range of plant responses:
  - altered gene expression
  - cellular metabolism
  - changes in growth rates and crop yield

Type of stress

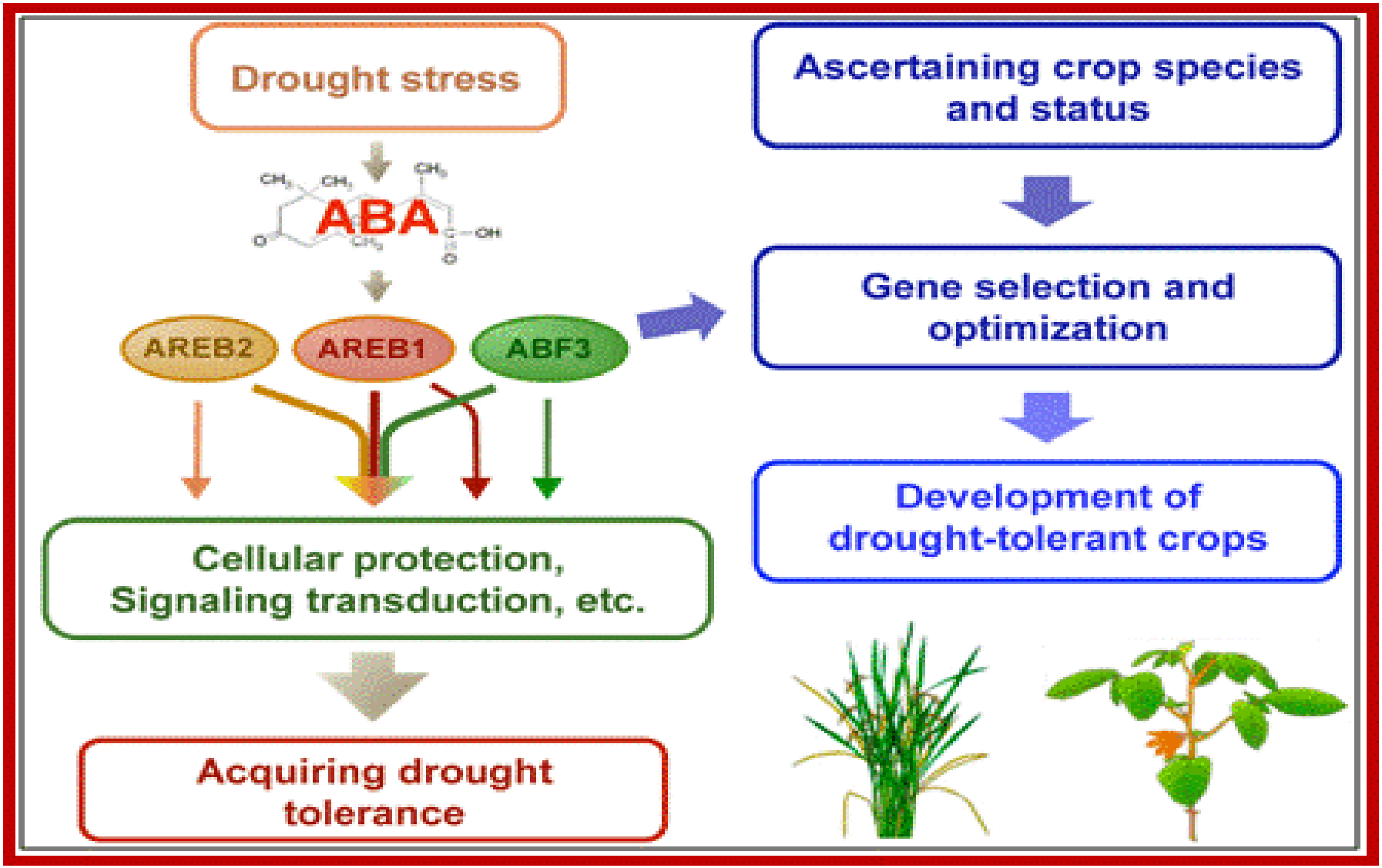
- Biotic: imposed by organisms
- Abiotic: arising from an excess or deficit in the physical or chemical environmental

Biotic and Abiotic stresses can reduce average of plant productivity by 65% to 87% (in major plant)

Drought

- Basically, water is essential for all metabolic process in plant (from germination to physiological maturity)-(80-90% from fresh tissue)
- Drought term is differ according to the scientific concept (Climate, Soil, Plant)
- It is better to use water stress
  - High temperature
  - Cold stress
  - High salinity….

ABA role in drought tolerance



Salinity

- The use of bad quality irrigation water
- Bad drainage systems
- Mixing with sea water
- Accumulation of salt next to root of plant due to Evaporation

Salinity Effects

- Lack in P, K and Ca absorption
- Ion poisoning because of Na^{+}, Cl^{-} and $SO4^{-}$
- Increasing in osmotic pressure leading to hindering water absorption

Mechanisms of salt tolerance

- Homeostasis (Osmoses adjustment)
- Tolerate salinity and repairing the damage
- Ability of DETOXIFICATION
- Ability of regulating growth under salt stress

Temperature

- High temperature
- Low temperature
  - Chilling
  - Freezing

High temperature

- Inhibition of germination
- Reduction of plant growth
- Alteration in photosynthesis
- Alteration in phenology
- Alteration in dry matter partitioning
- Water loss
- Yield reduction
- Reduction of yield quality
- Oxidative stress

Chilling effects

- Poor germination
- Poor seedling establishment
- Stunted growth
- Wilting, chlorosis, necrosis
- pollen sterility
- Poor seed set/ seed formation
- Locked open stomata
- ABA accumulation
- Reduces membrane stability
- Poor chlorophyll synthesis
- Reduced photosynthesis
- Toxicity due to H_2O_2 formation

Freezing

- Ice formation
  - Intercellular ice formation
  - Intracellular: it is most lethal may be due to physical disruption of subcellular structure by ice crystals
  - Membrane disruption

  - Freezing causes disruption and alter semi preamble properties of plasma membrane
  - Loss of solutes from the cell
  - Cell remains plasmolysed even after thawing

Heavy metals

- Metals that are generally with relatively high densities, atomic weights or atomic numbers.
- Cadmium
- Copper
- Nickle
- Lead
- Zinc
- Mercury
- Chromium

Stress resistance mechanisms

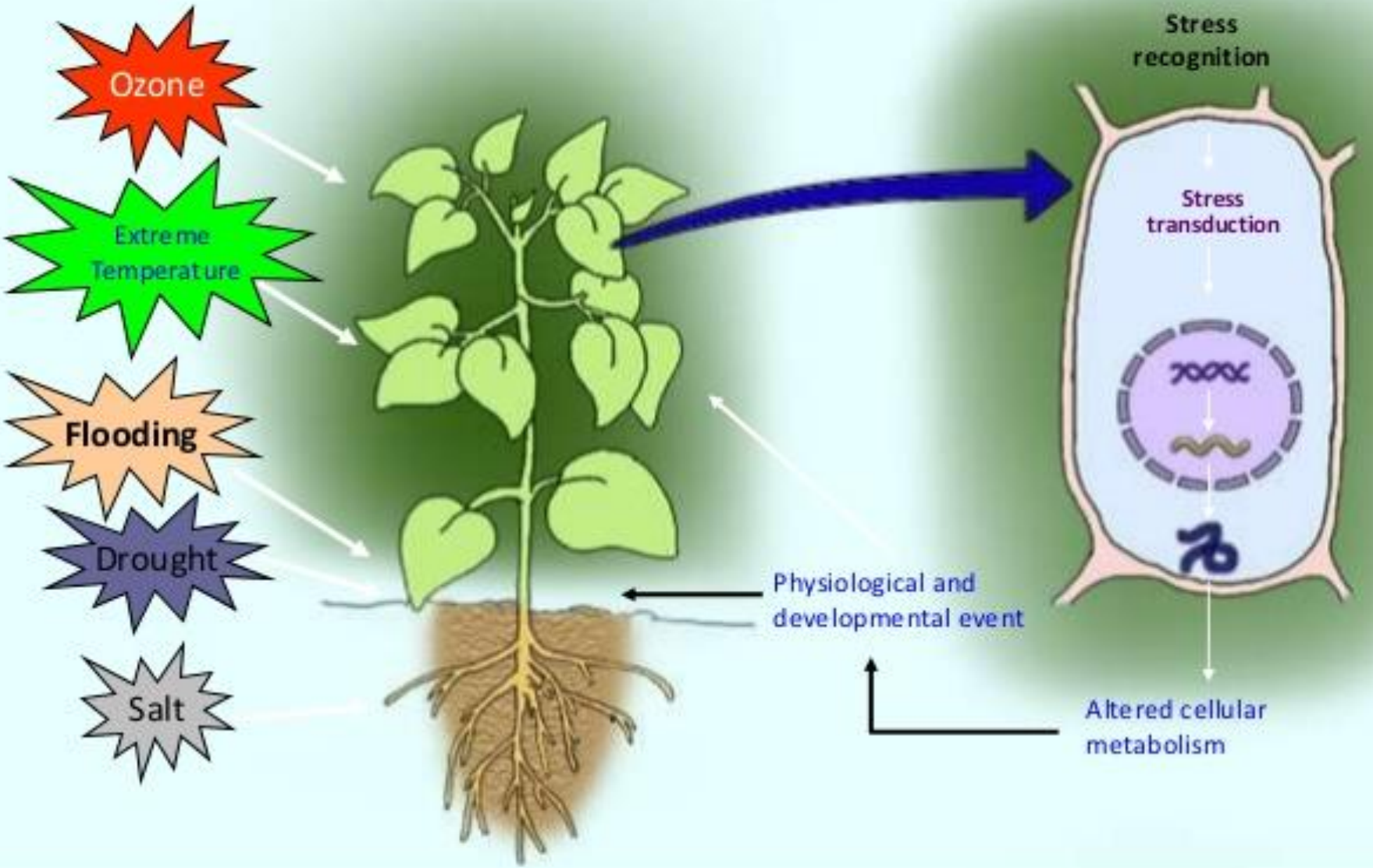
- Avoidance: prevent exposure to stress

- Tolerance: Permit the plant to withstand stress

- Acclimation:
- Alter their physiology in response to stress

1- alter their physiology in response to stress
2- INCREASE GENE EXPRESSION

Response of Plants to Various Stresses



Signal transduction in plants: Cross-talk with the environment.

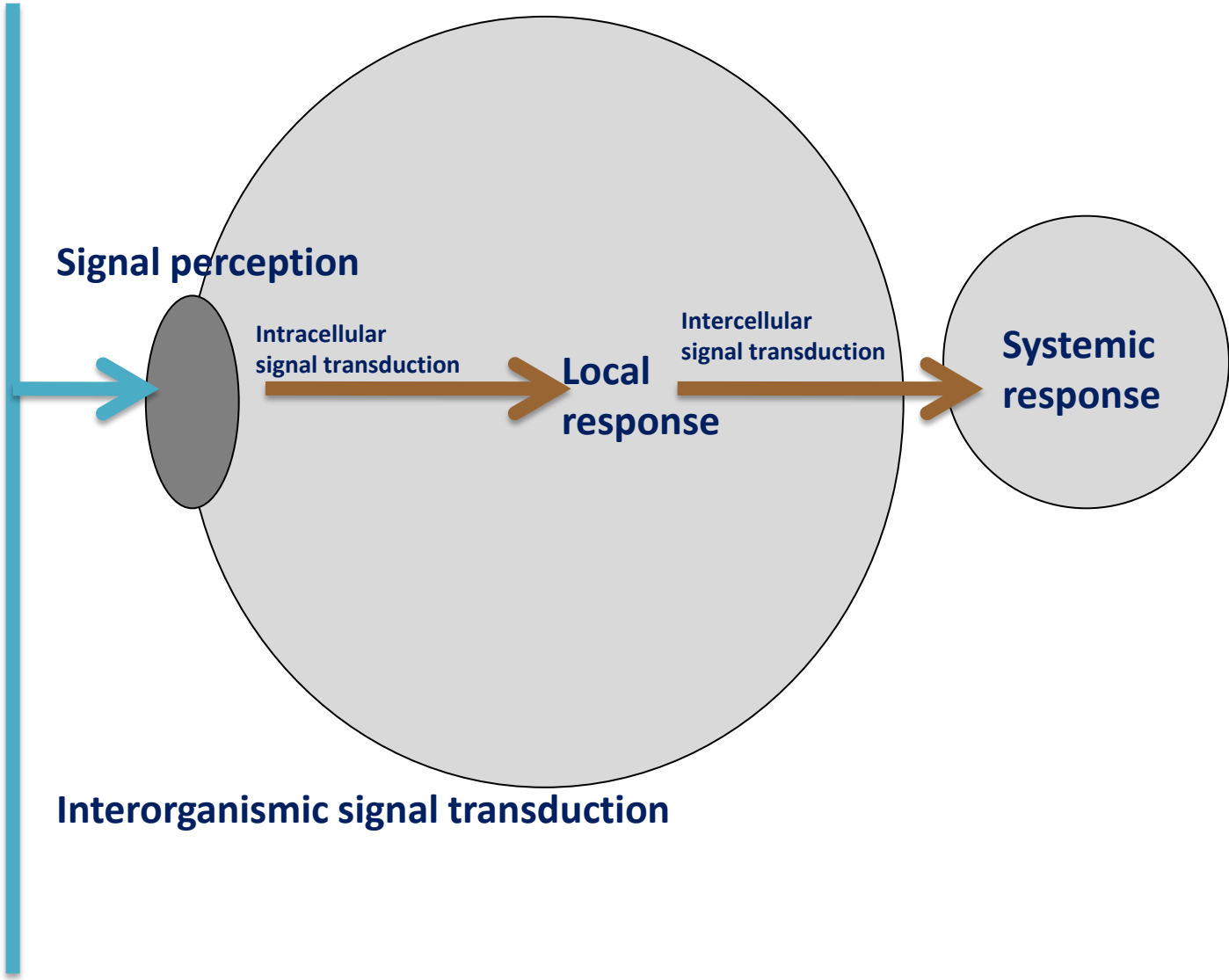
Environmental signals

Abiotic:

- Light
- Heat
- Salt
- Drought
- Low temperature
- Heavy metals
- Ozone
- Wind/Touch

Biotic:

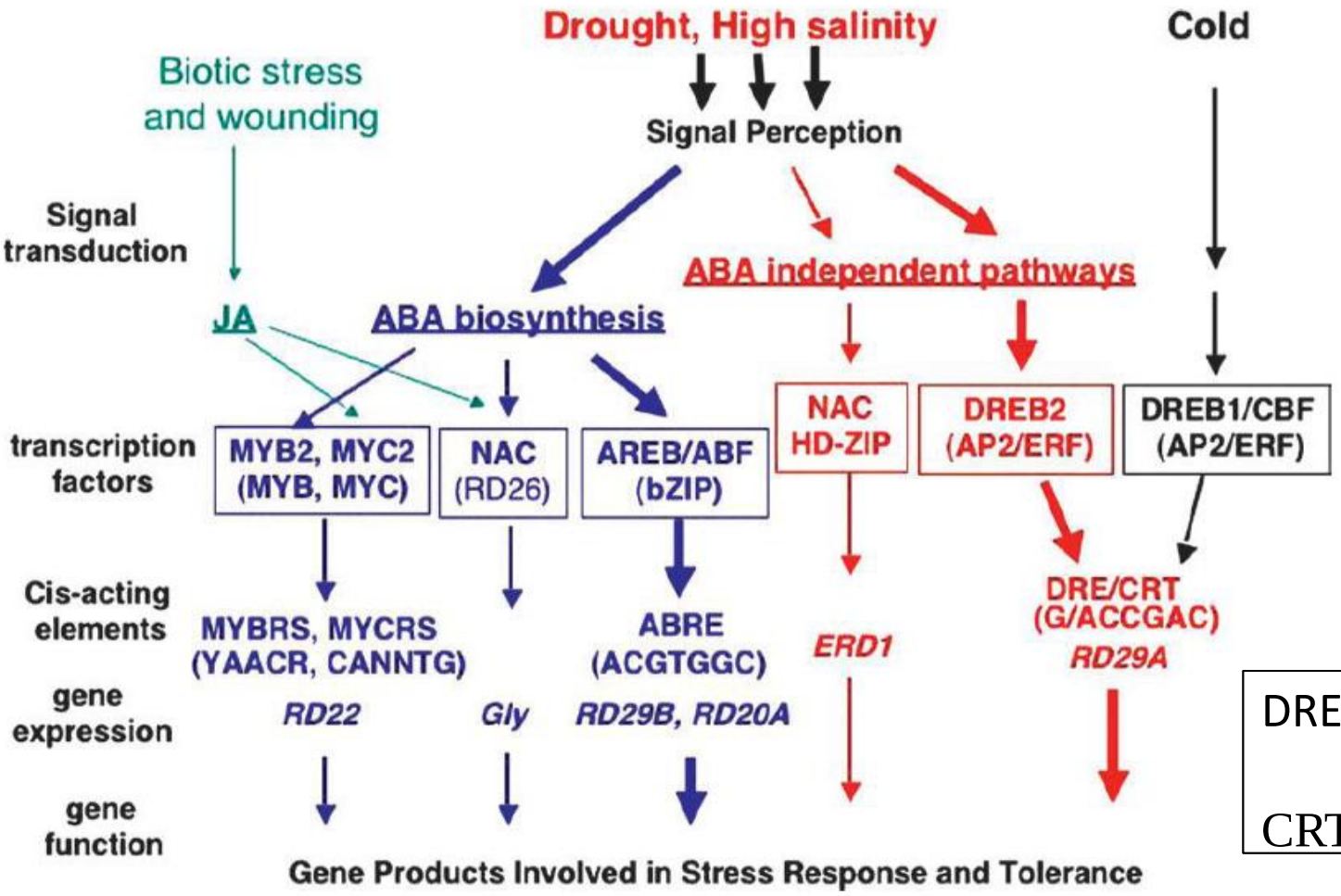
- Pathogen
- Symbionts
- insects



Plants molecular mechanisms in response to stress involve:

- Activation of signaling pathways
- Production of ROS
- Activation of transcription factors
- Alter gene expression
- Breakdown of macro molecules
- Decrease in protein synthesis
- Synthesis of osmolytes

The Abiotic Stress Transcription Factors



DRE: TA**CCGAC**AT

CRT:TGG**CCGAC**

Changes in gene expression to stress

- A stress response is initiated when plants recognizes stress at the cellular level
- Stress recognition activates signal transduction pathways that transmit information within the individual cell and throughout the plant
- Changes in gene expression may modify growth and development and even influence reproductive capabilities

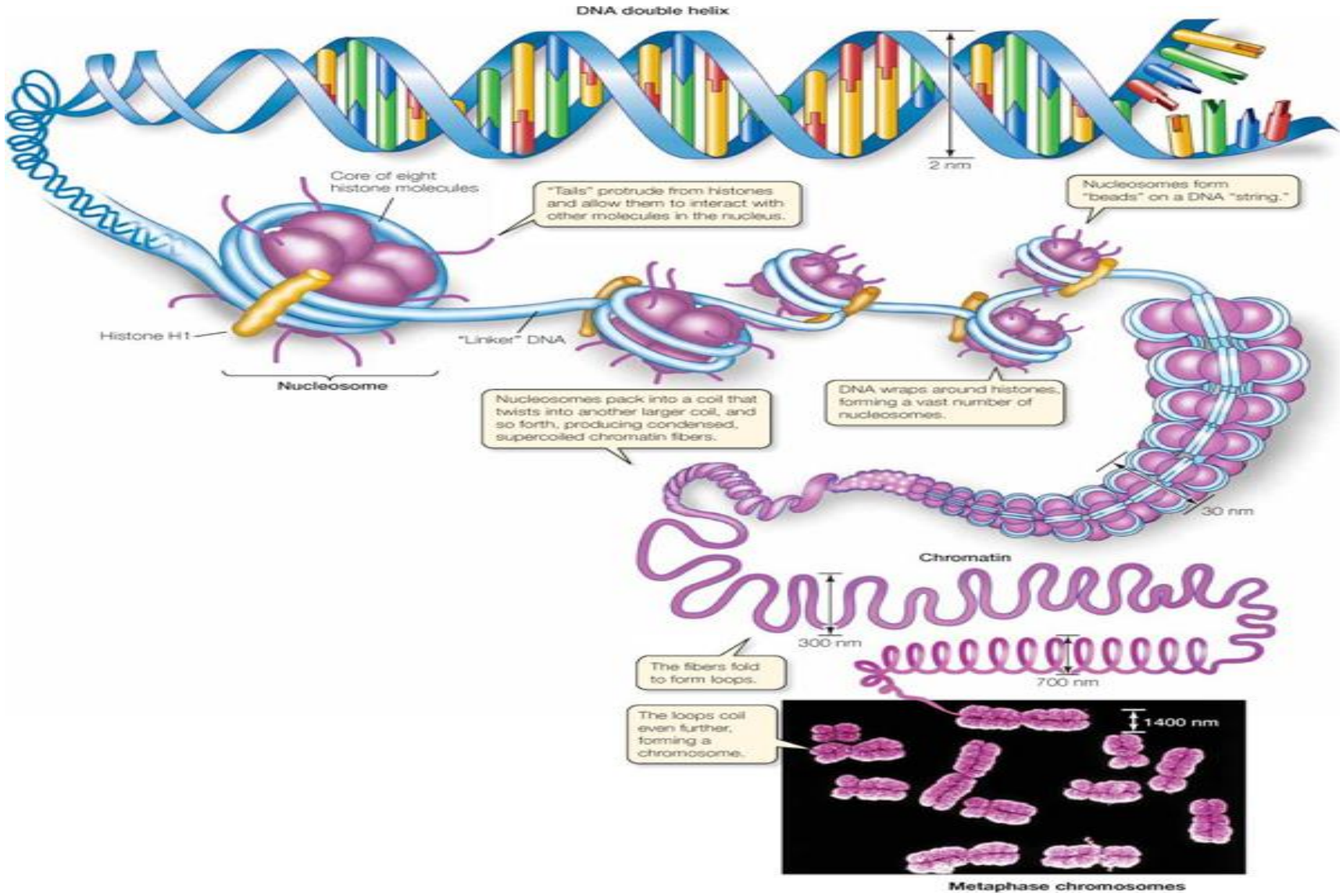
Gene expression results in:

- Increase amounts of specific mRNA
- Enhance translation
- Stabilize proteins
- Altered protein activity
- A combination of the above

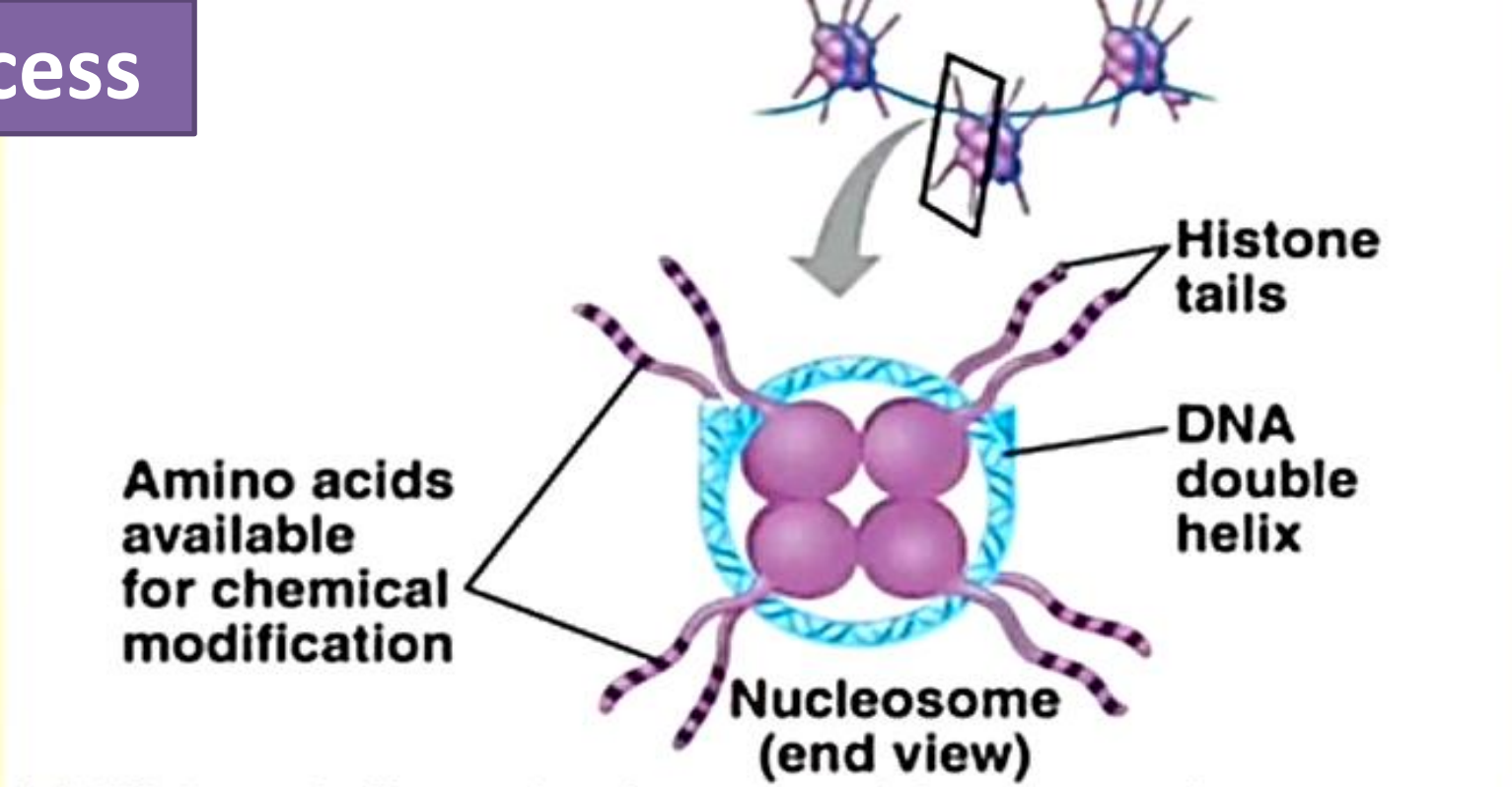
Gene Expression and regulation

- Gene can be expressed and regulated at five steps:
- 1- DNA access
- 2- Pre-Transcription
- 3- Post- Transcription
- 4- Pre-Translation
- 5- Post-Translation

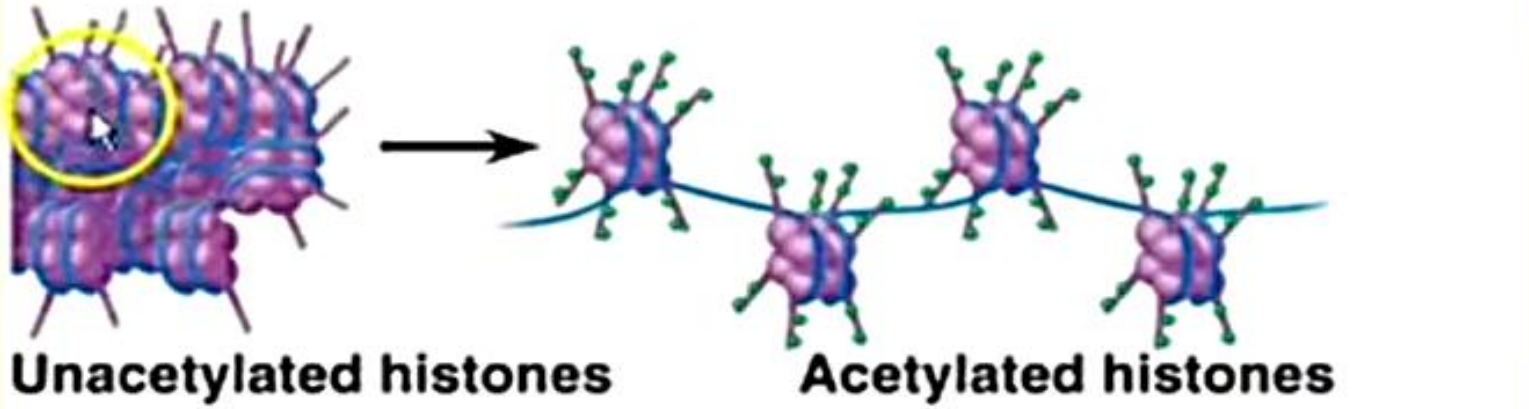
What is Gene


DNA double helix
2 nm
Core of eight histone molecules
"Tails" protrude from histones and allow them to interact with other molecules in the nucleus.
Nucleosomes form "beads" on a DNA "string."
Histone H1
"Linker" DNA
Nucleosome
Nucleosomes pack into a coil that twists into another larger coil, and so forth, producing condensed, supercoiled chromatin fibers.
DNA wraps around histones, forming a vast number of nucleosomes.
30 nm
Chromatin
300 nm
700 nm
The fibers fold to form loops.
The loops coil even further, forming a chromosome.
1400 nm
Metaphase chromosomes

DNA access

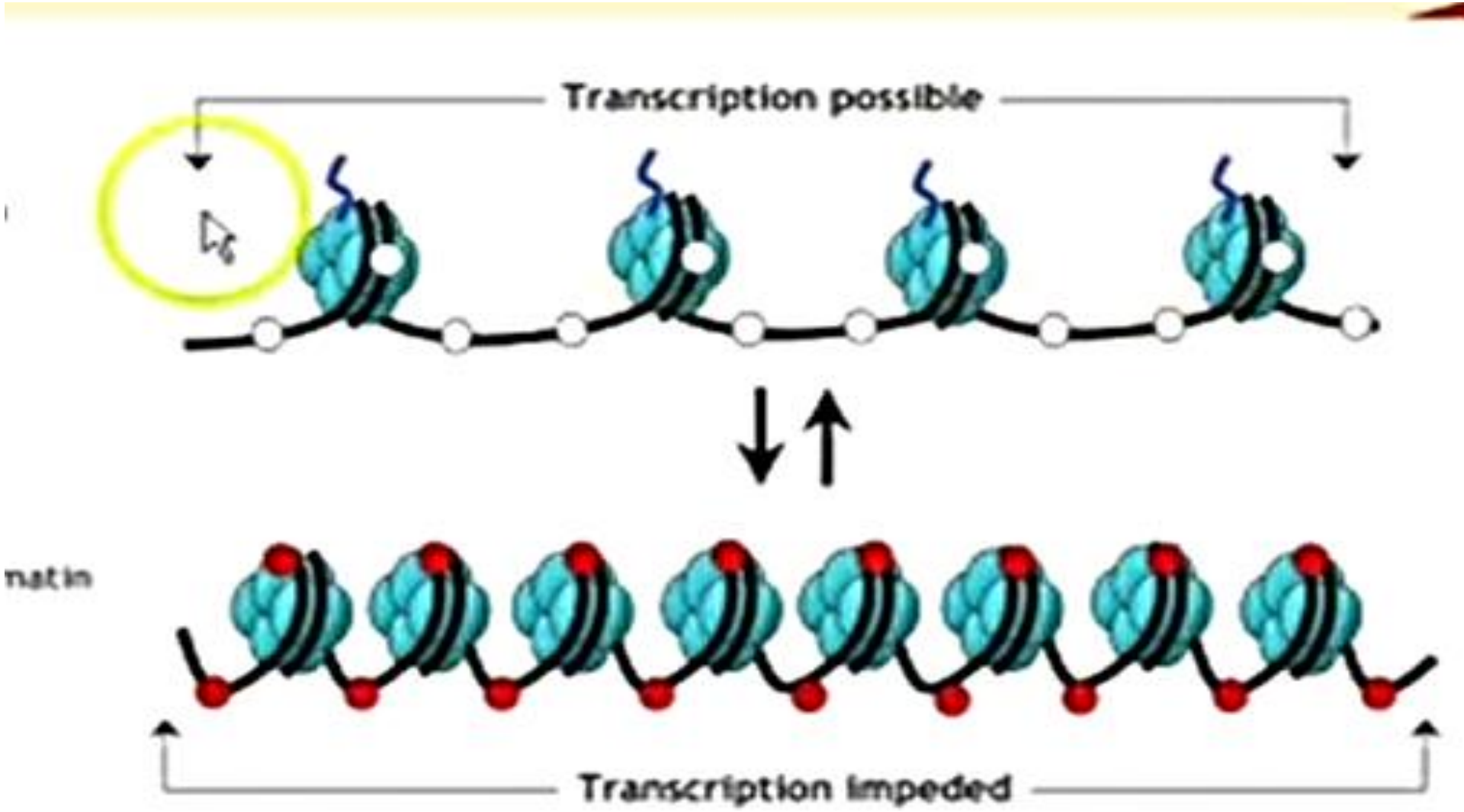


(a) Histone tails protrude outward from a nucleosome

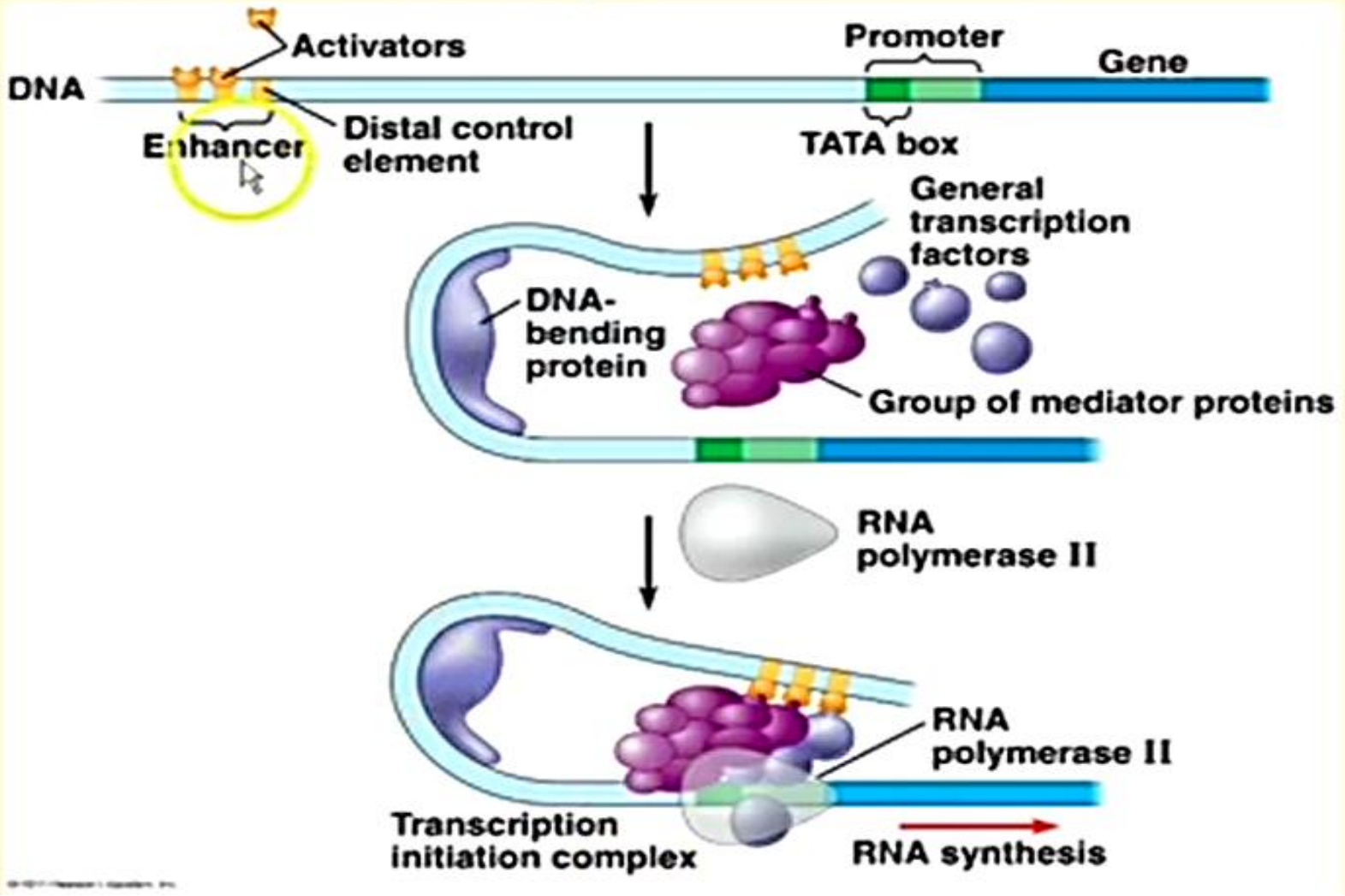


(b) Acetylation of histone tails promotes loose chromatin structure that permits transcription

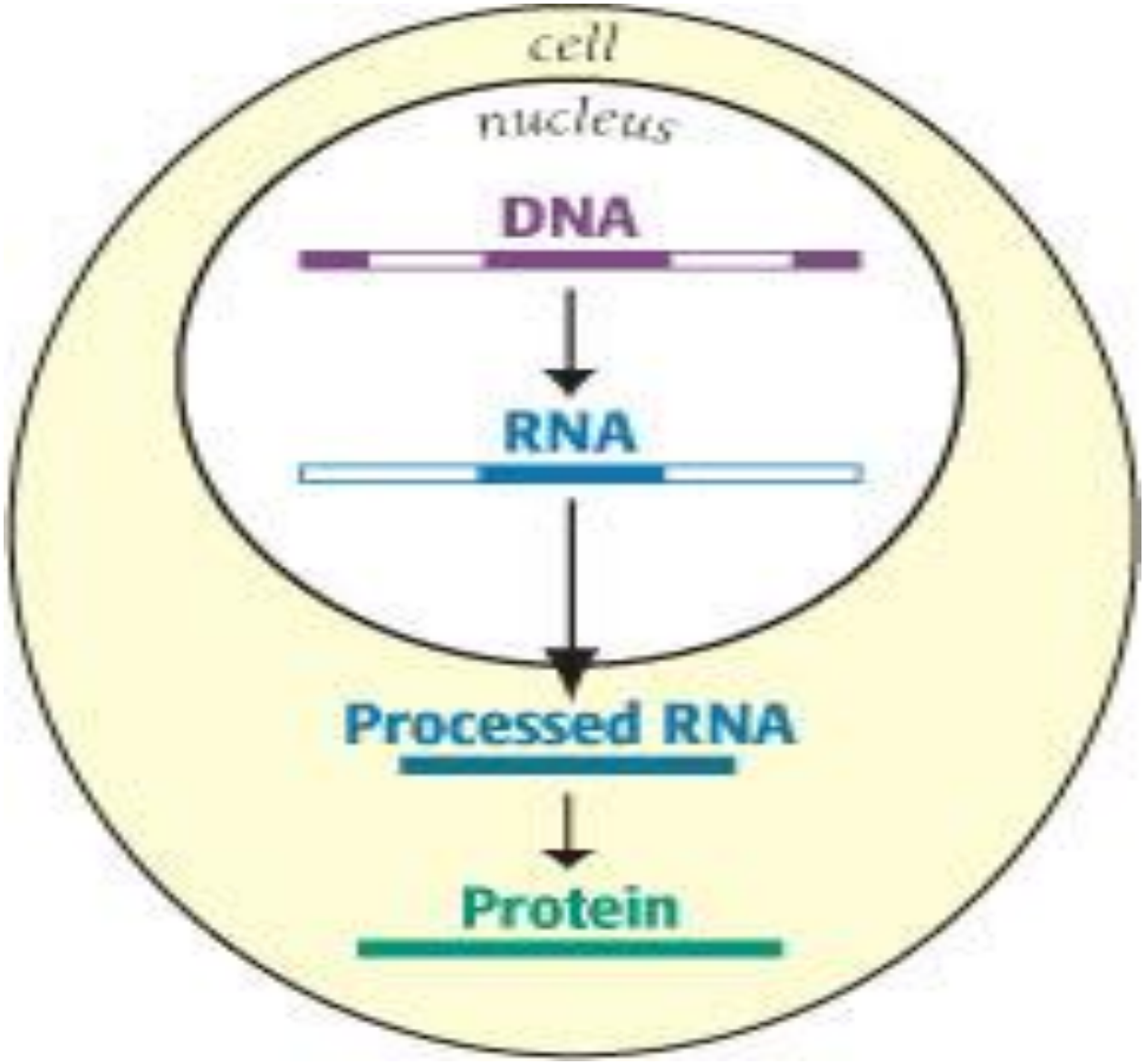
DNA methylation: Methyl groups added to DNA, inactivates DNA



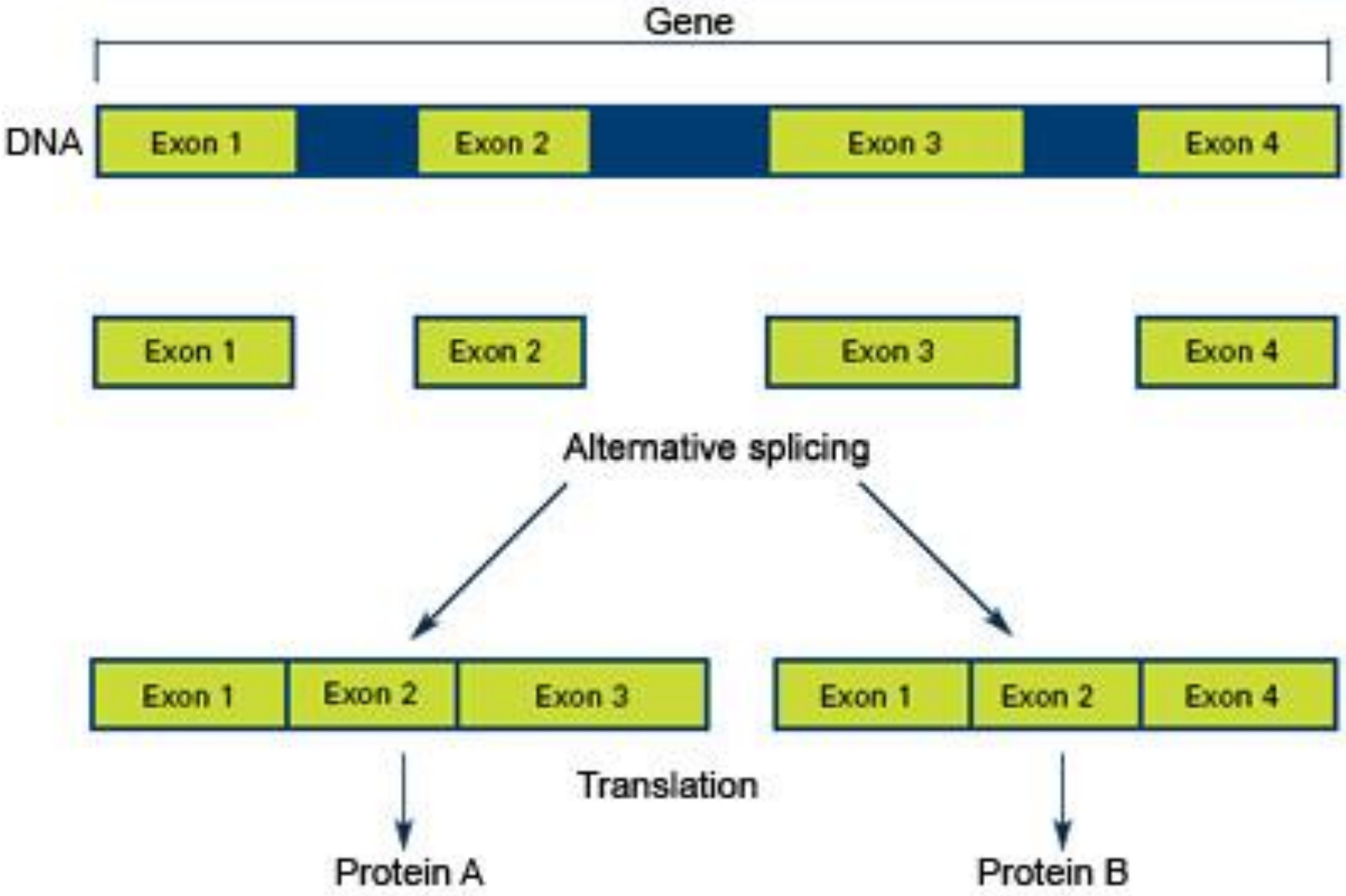
The proteins that mediate RNA polymerase are known as “Transcription Factors”



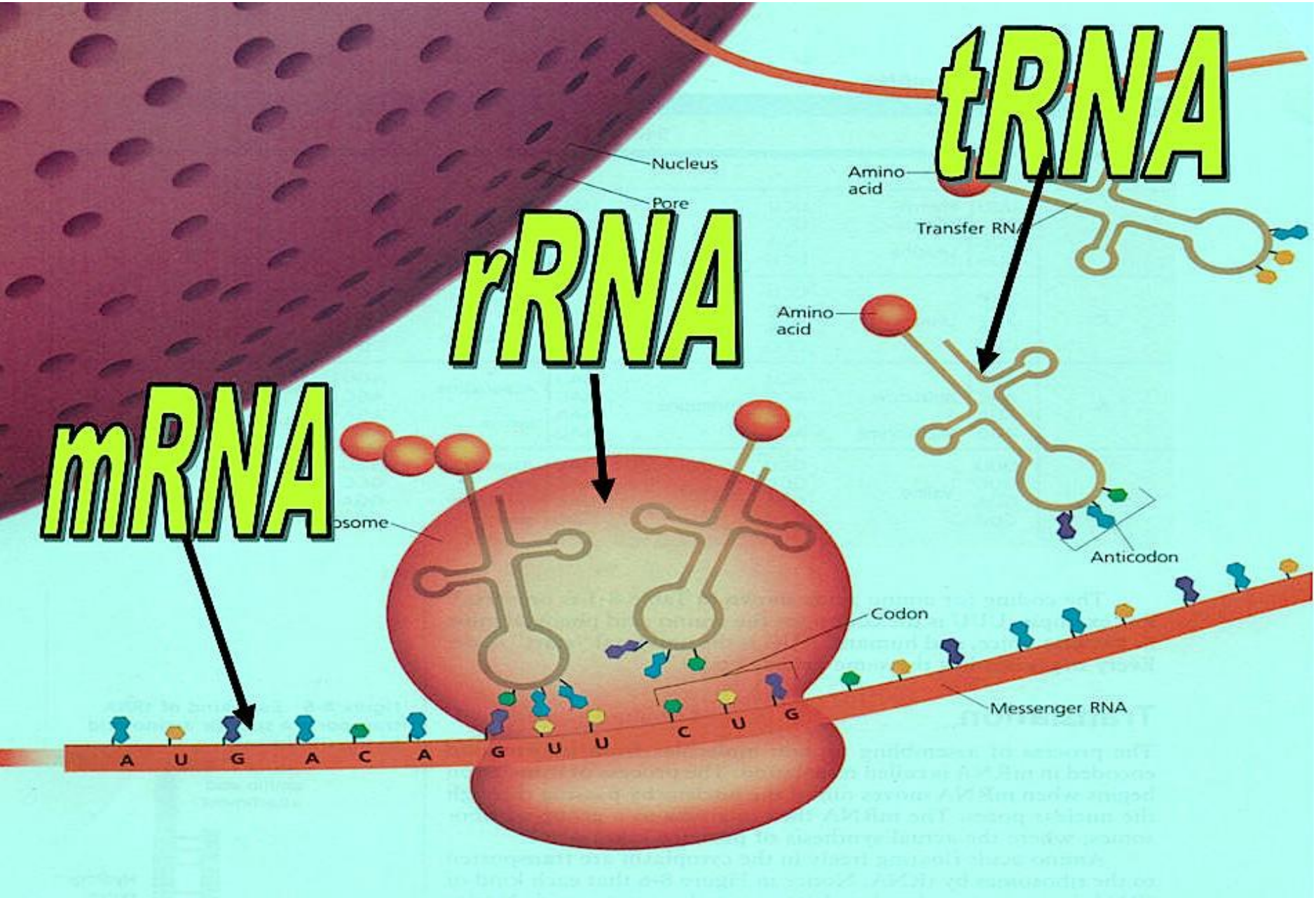
Transcription to translation



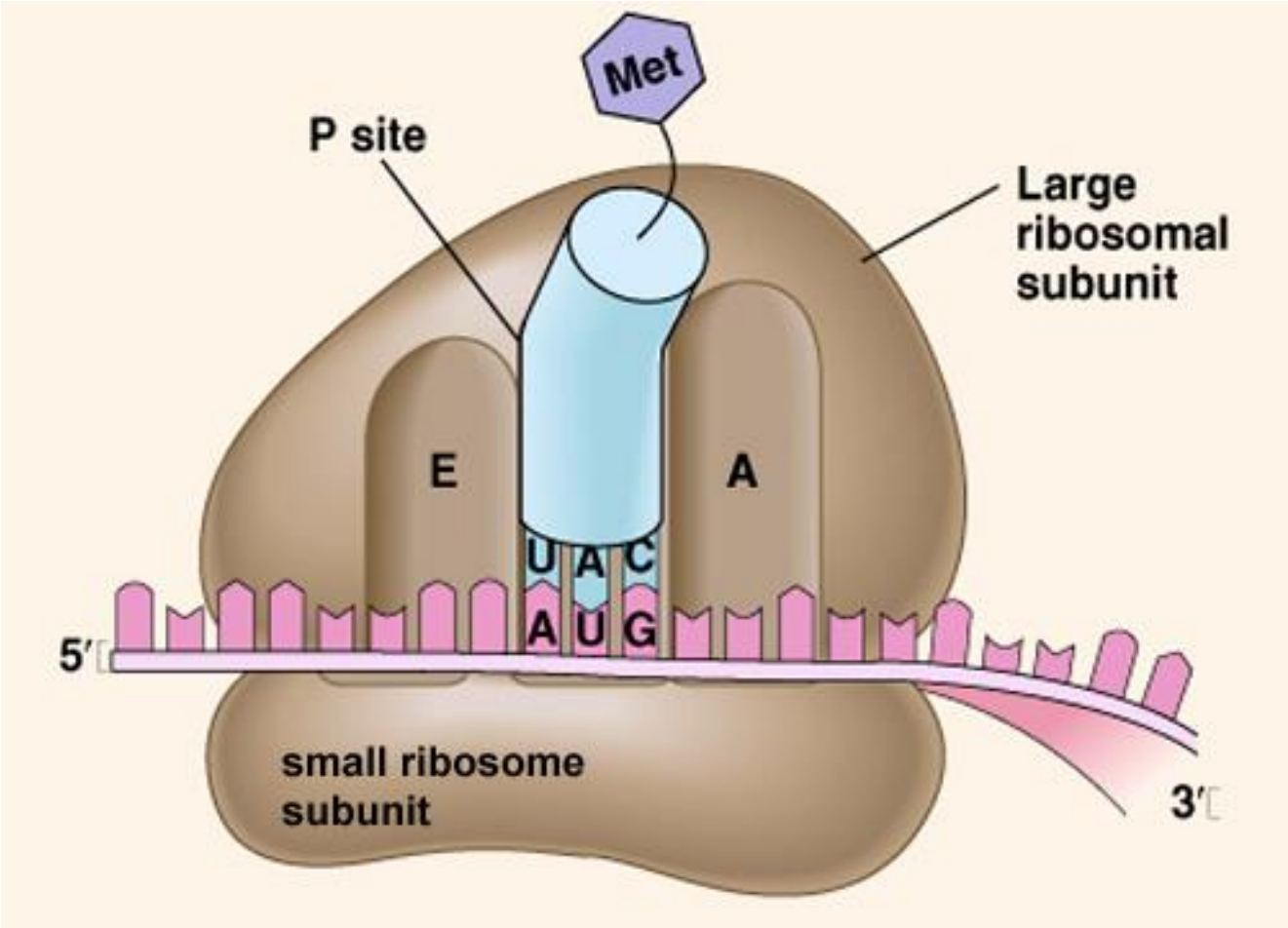
Splicing process



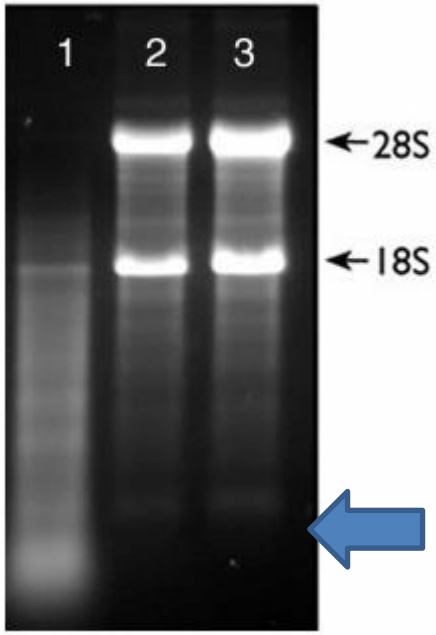
Other type of RNA



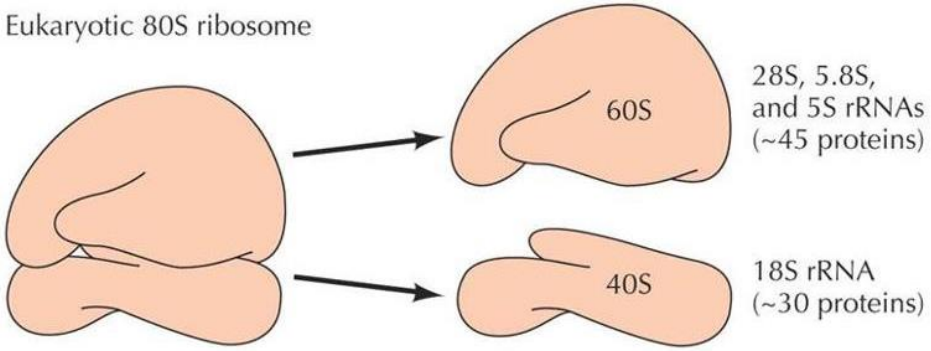
rRNA_Polymerase I



RNA Quality by Denaturing gel



5S - tRNA



1 = Degraded RNA

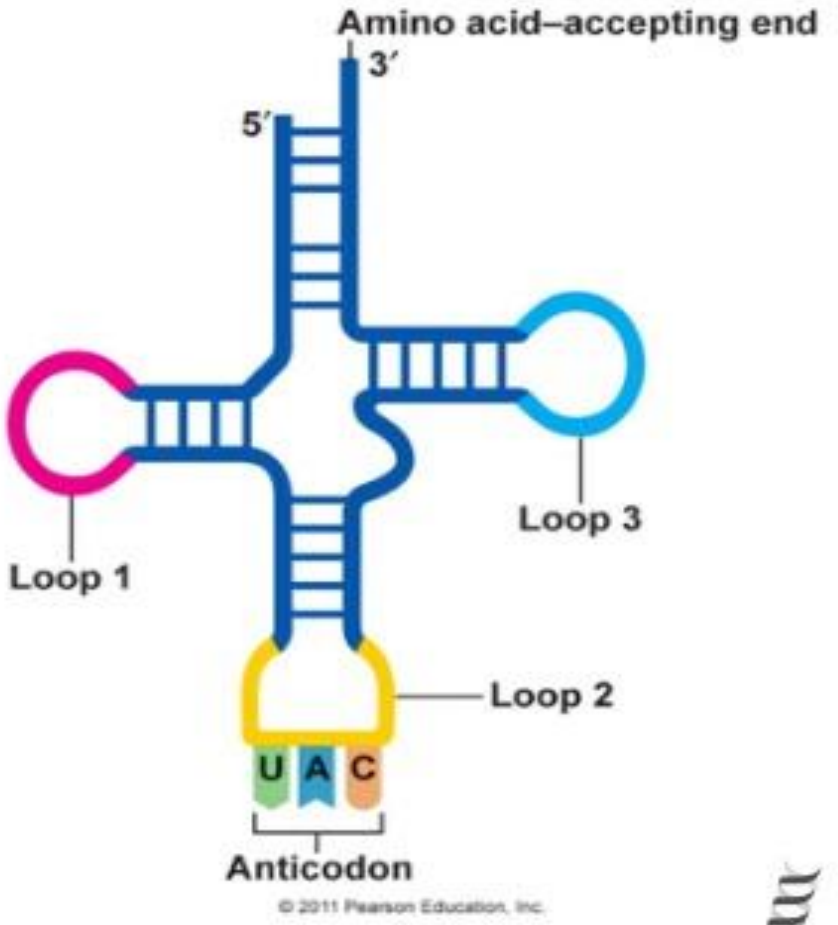
2= Good RNA

3 = Good RNA

tRNA_Polymerase III

Transfer RNA (tRNA)

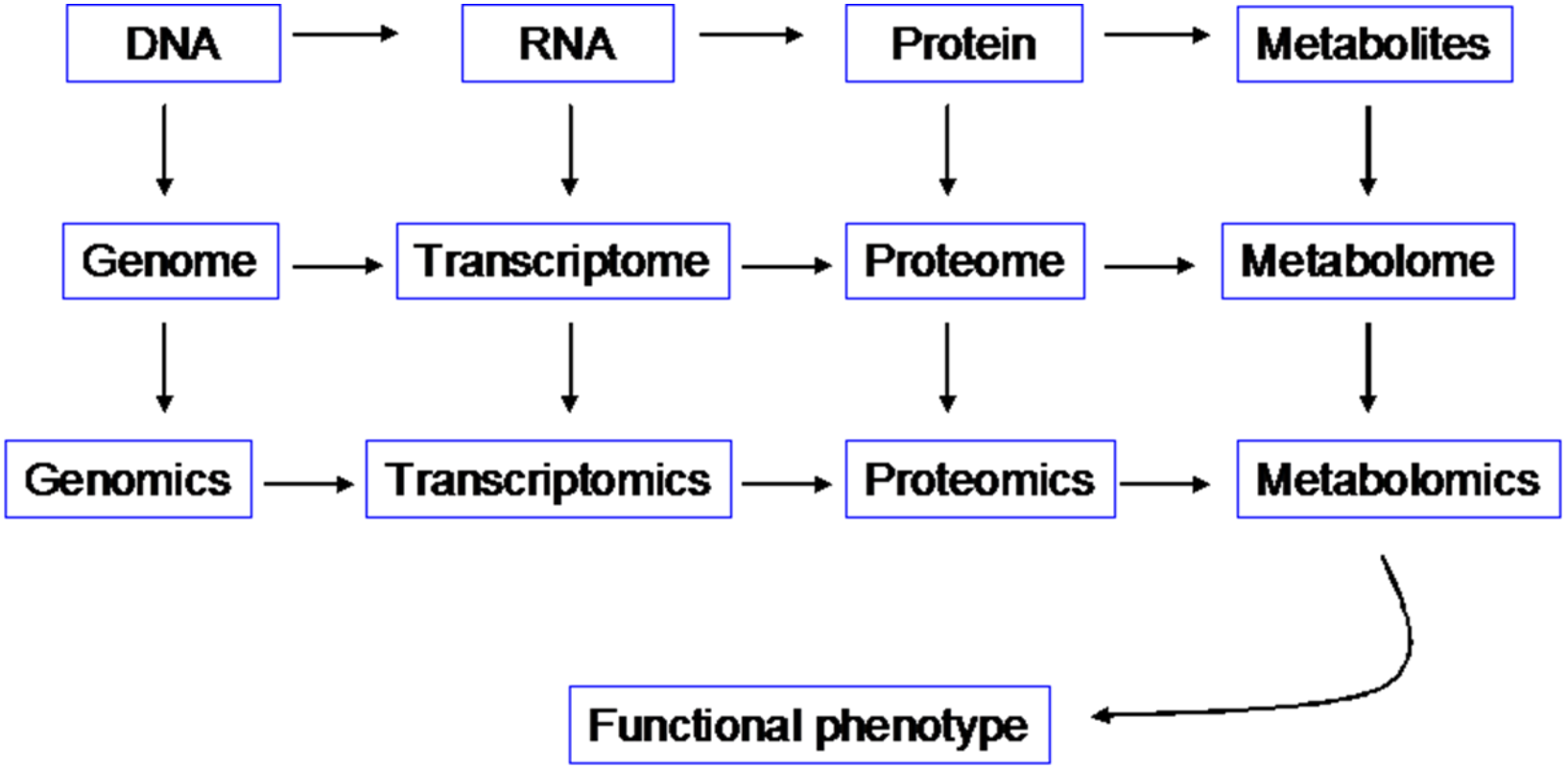
- tRNA carries the amino acid to the ribosome to make protein.
- There are specific tRNA for each codon and amino acid.



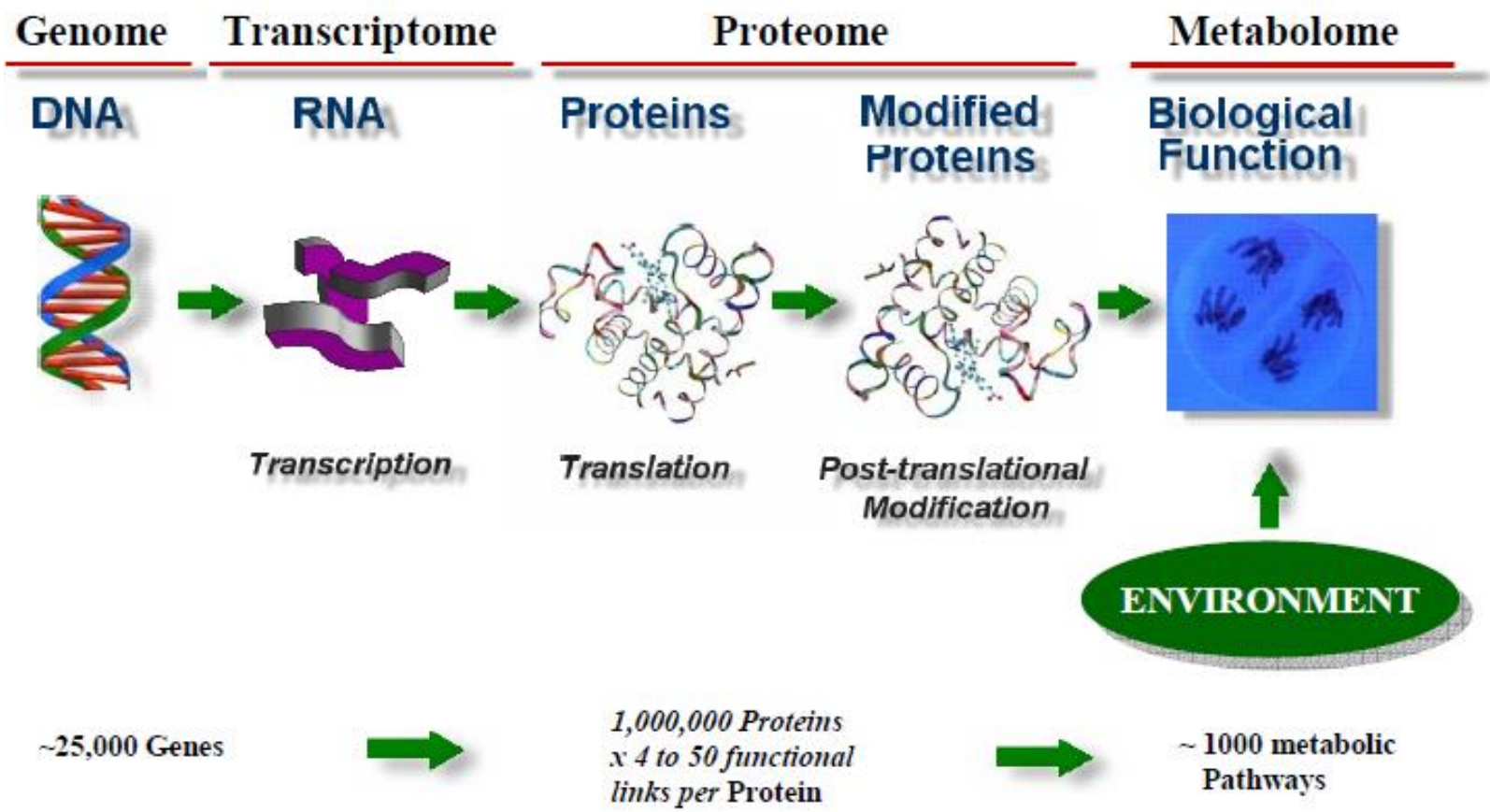
Gene Expression Termination

- Termination in eukaryotes is more complicated, involving the addition of additional adenine nucleotides at the 3' of the RNA transcript (a process referred to as **polyadenylation**)

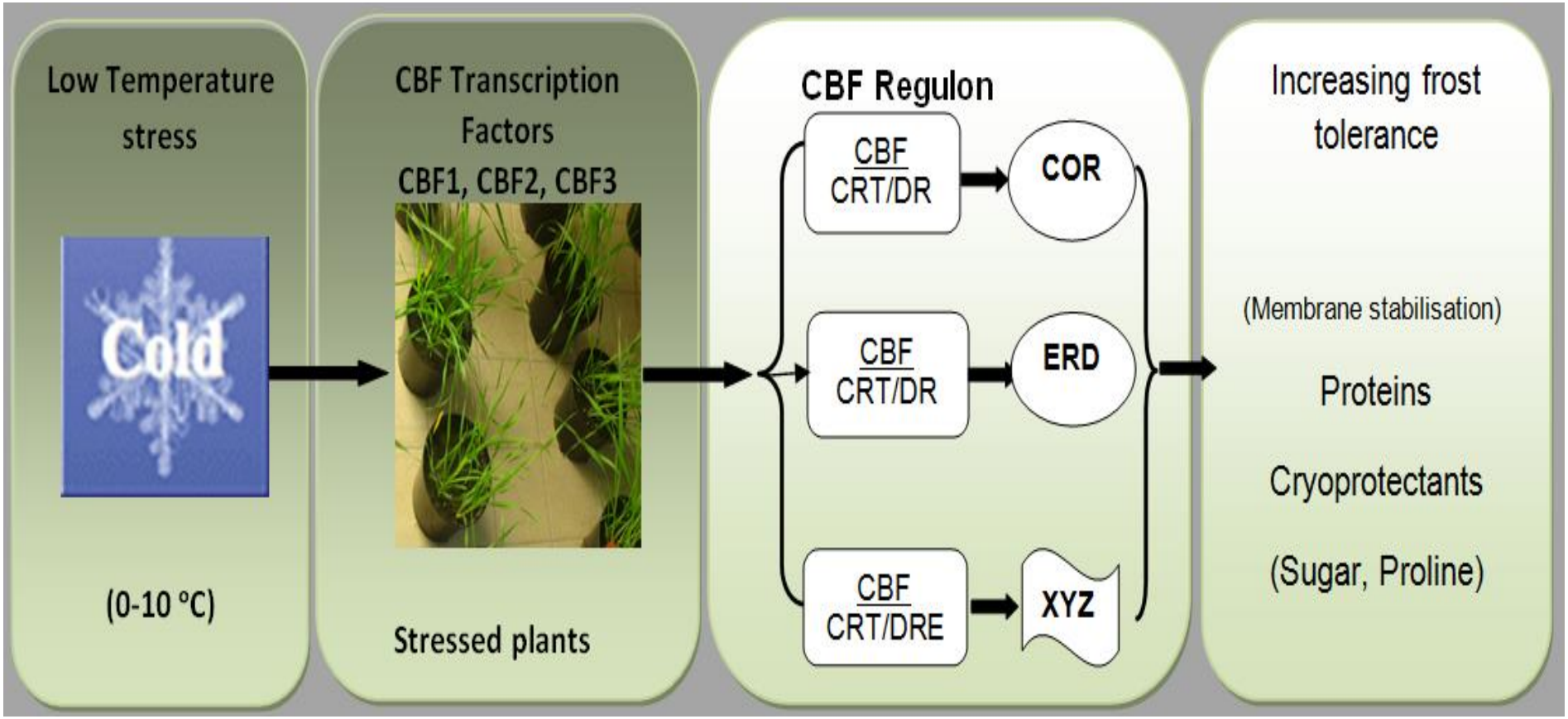
The “omics”


DNA
RNA
Protein
Metabolites
Genome
Transcriptome
Proteome
Metabolome
Genomics
Transcriptomics
Proteomics
Metabolomics
Functional phenotype

The Genomic Revolution

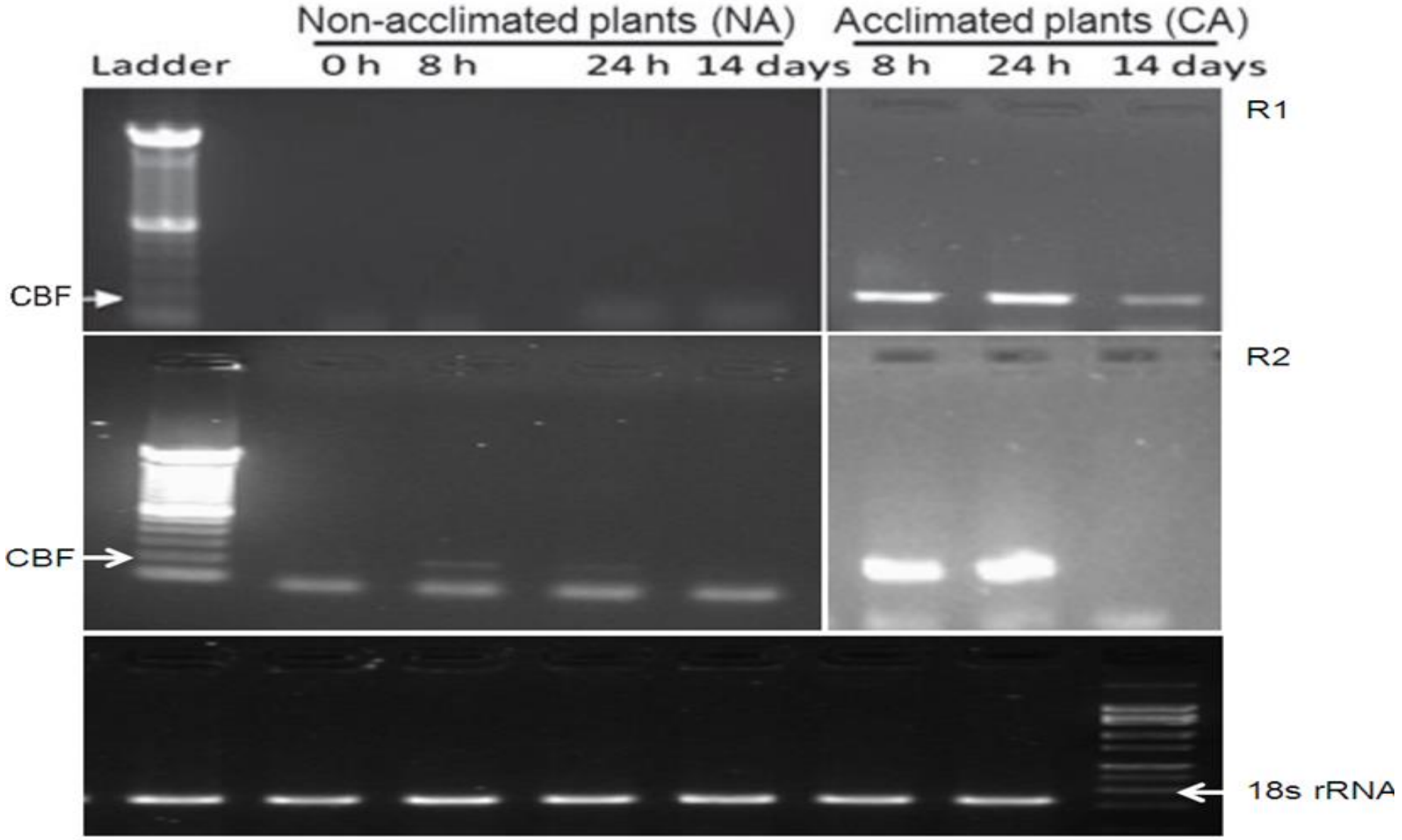


Molecular analysis of the expression of the CBF transcription factor and COR15a in Iraqi and European wheats.

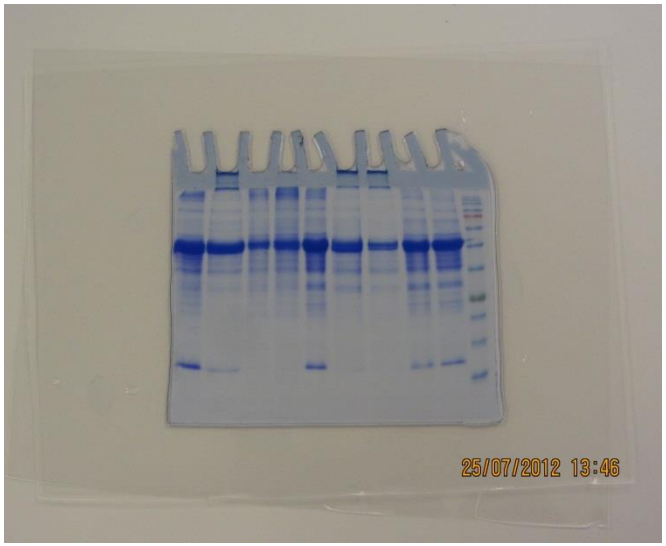


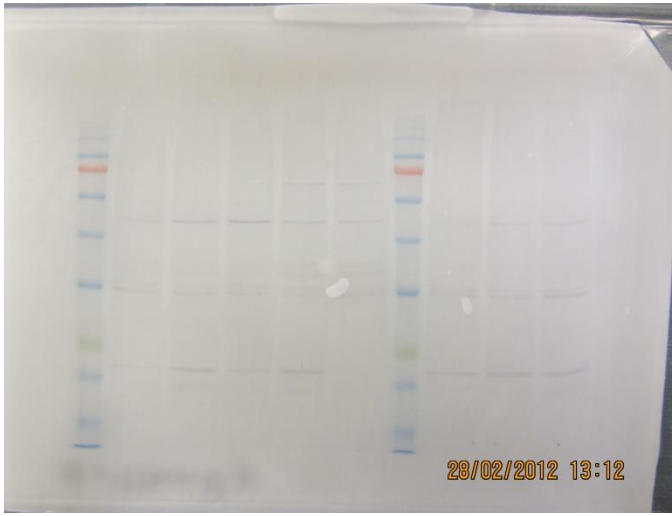
*Adapted from (**Thomashow, 1999**)*

CBF expression in vegetative wheat (3-4 Leaves stage)

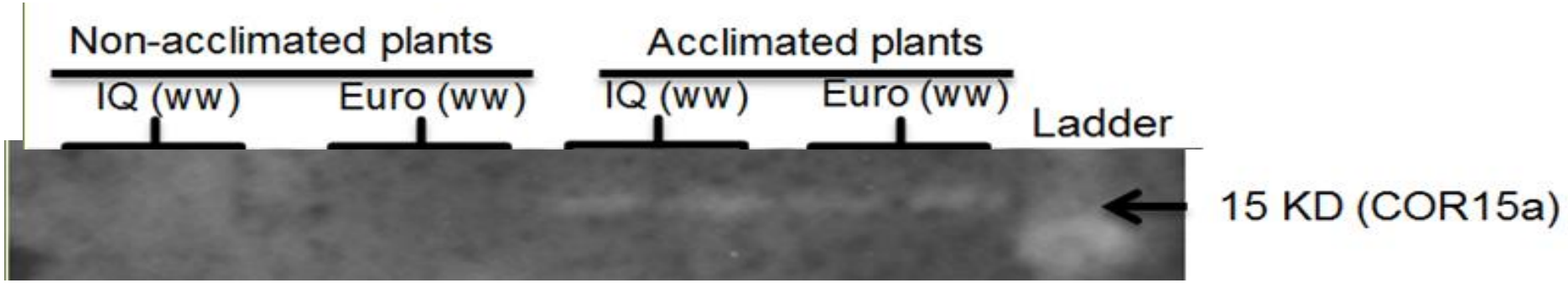


Western blotting-protein expression

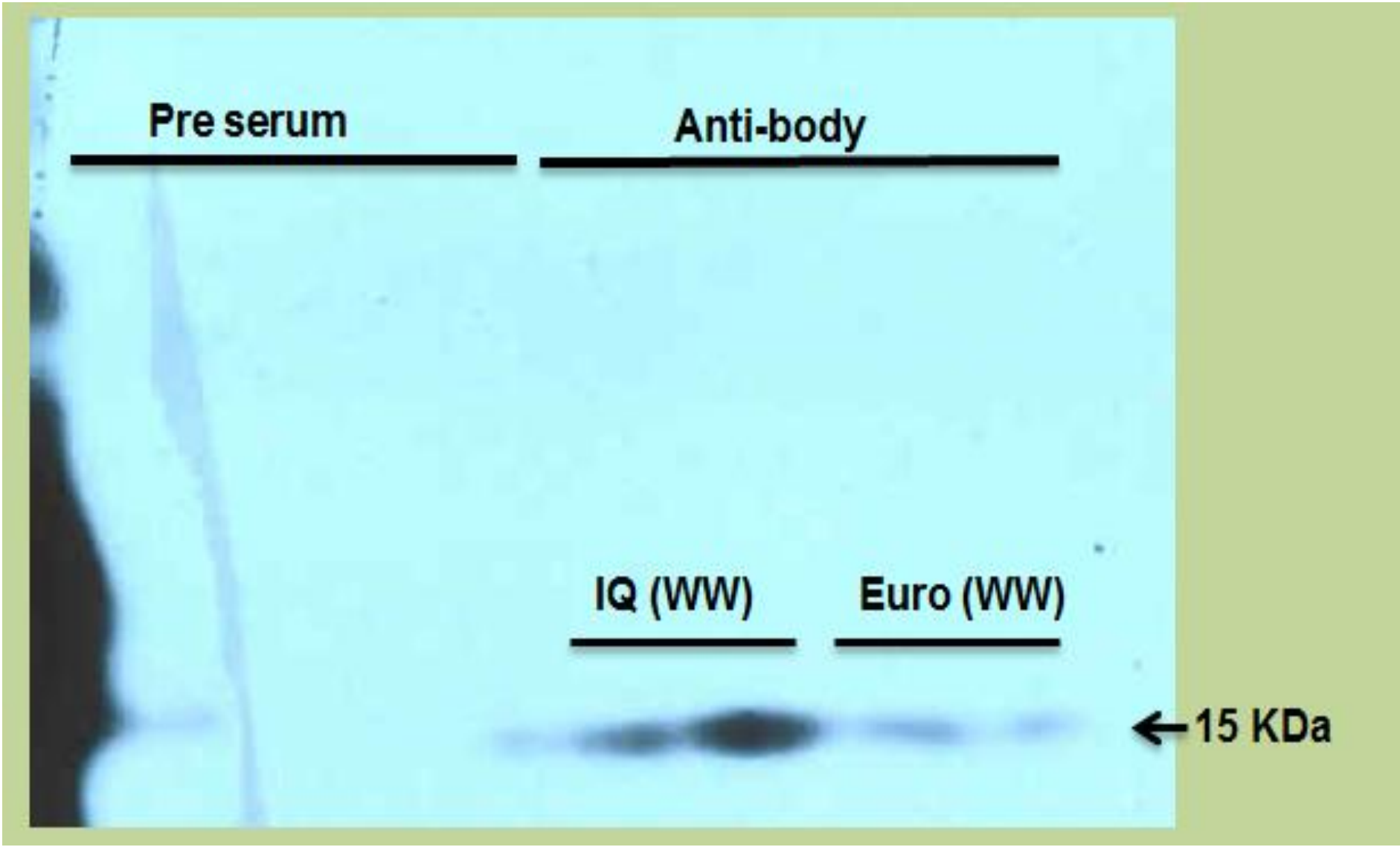




COR15a protein expression in vegetative wheat



COR15a protein expression in wheat during flowering (GSA)



Mo as activator to abiotic stress tolerance in plants

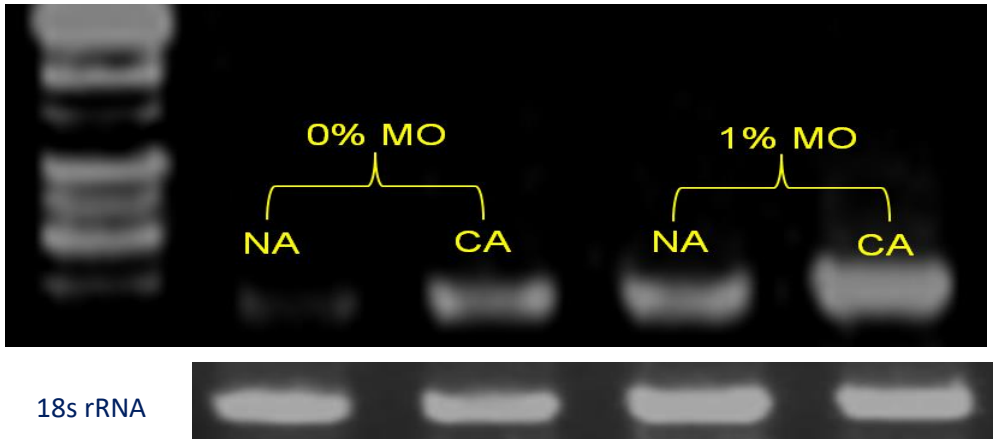
AO- which has been found to catalyse the final step of ABA biosynthesis

NR- is the key step of inorganic assimilation of nitrogen

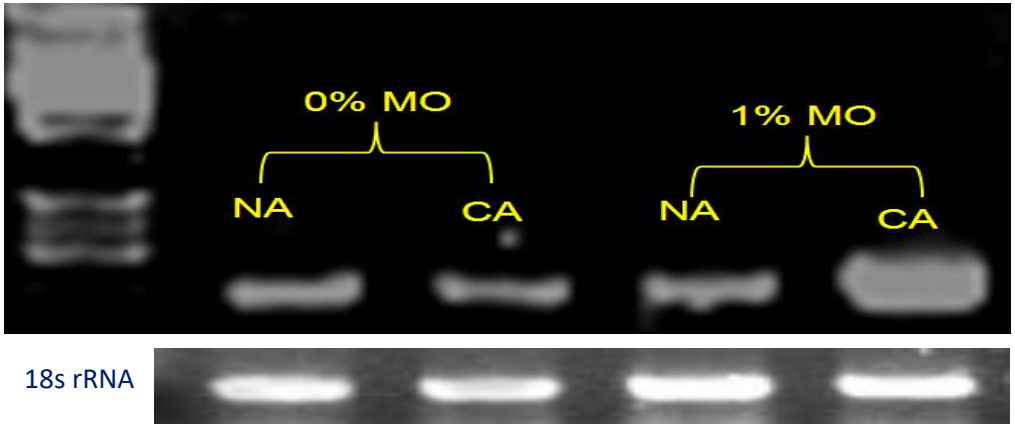
SOD- which is probably involved in detoxifying excess sulphate

XDH- has been found to be involved in purine catabolism and stress reactions

Foliar application of 15 PPM Mo

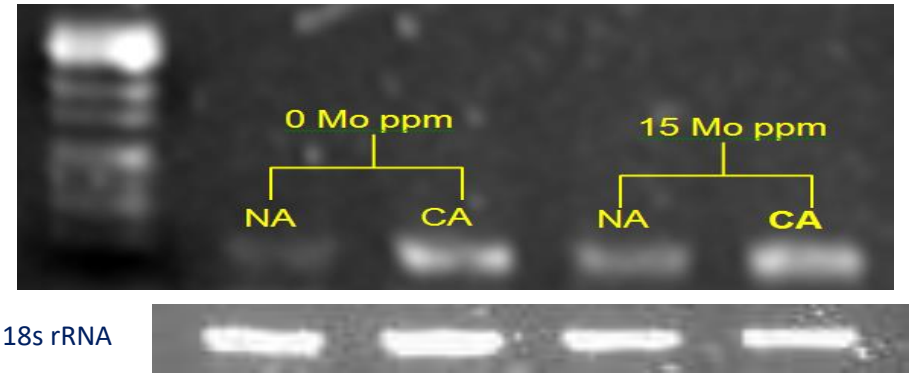


Winter wheat



Spring wheat

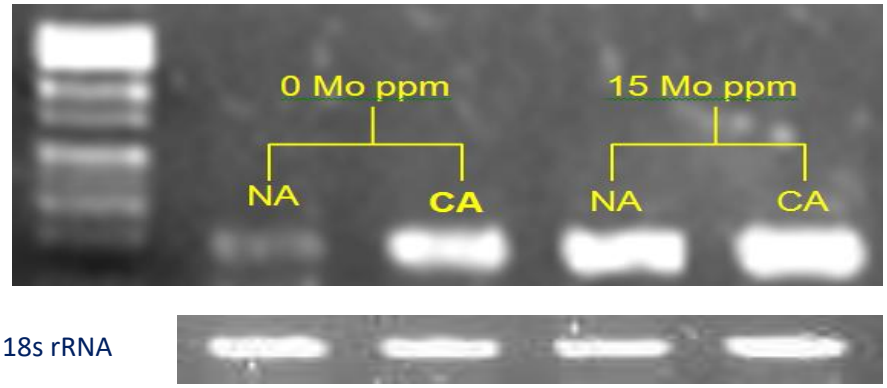
Results: Seed treatment with 1% Mo



CBF

18s rRNA

Winter wheat



CBF

18s rRNA

Spring wheat

The effect of Molybdenum on CBF expression

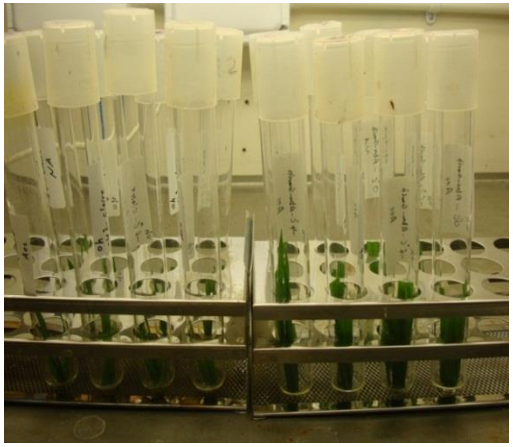
Seed treatments

Seedlings to pots

Pots to greenhouse

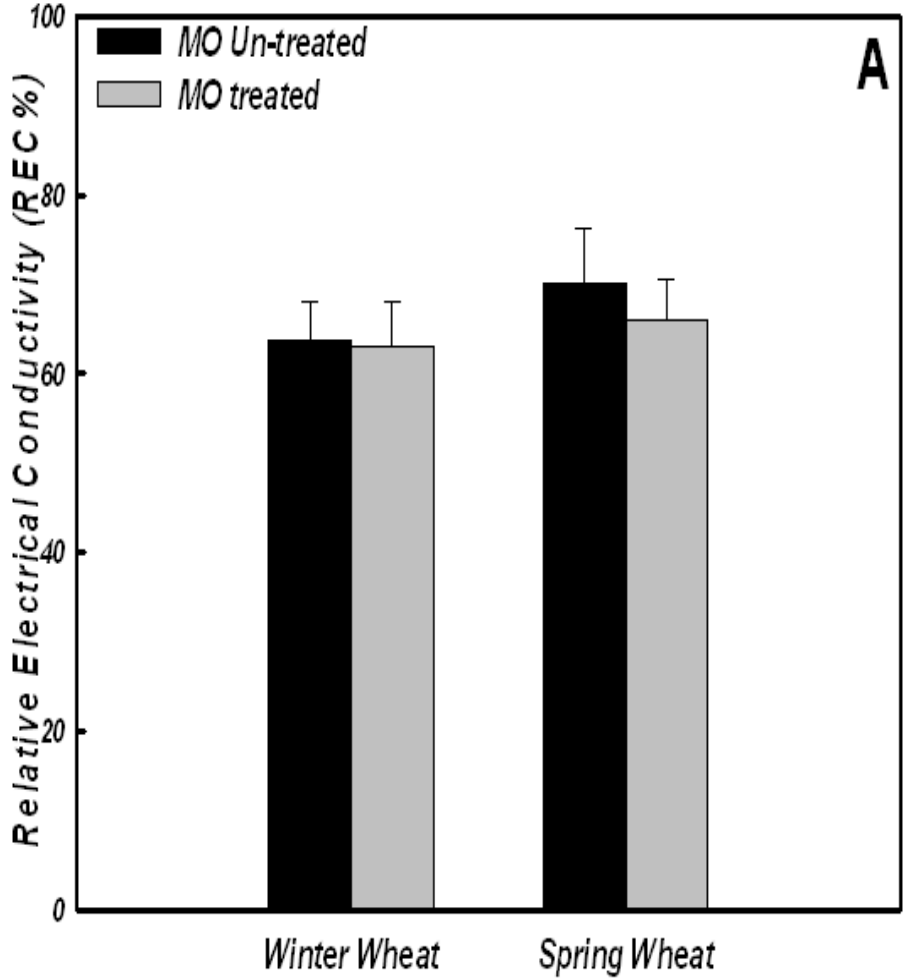
Temperature treatments(20 , 4 C)

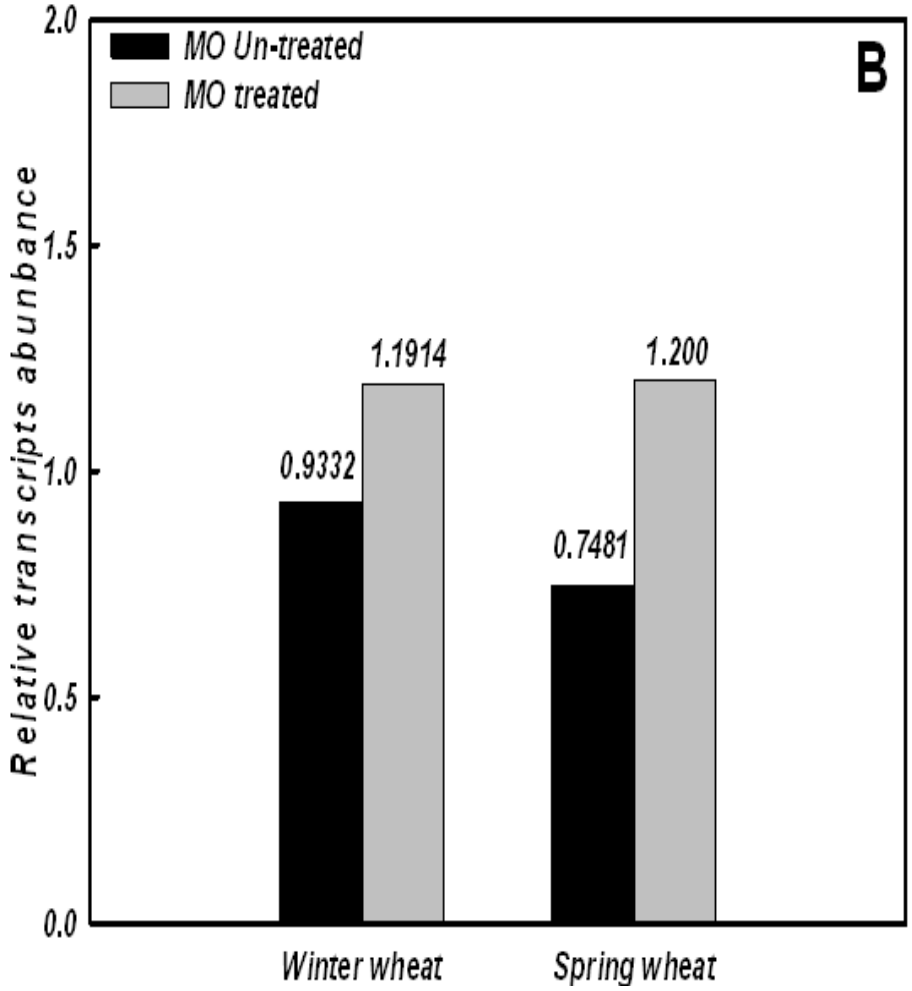
Frost damage (REC%)



CBF, COR15a expression

In absence of acclimating temperatures, Mo increases frost tolerance slightly

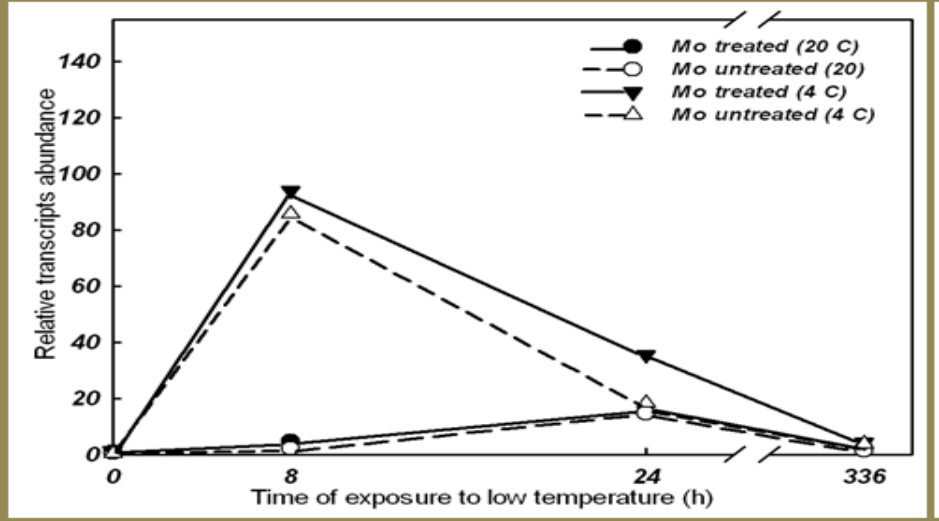


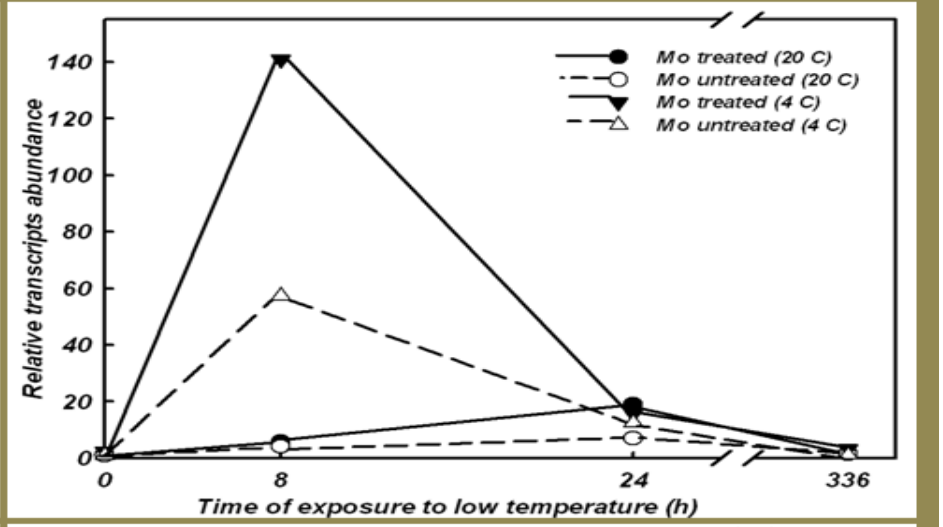


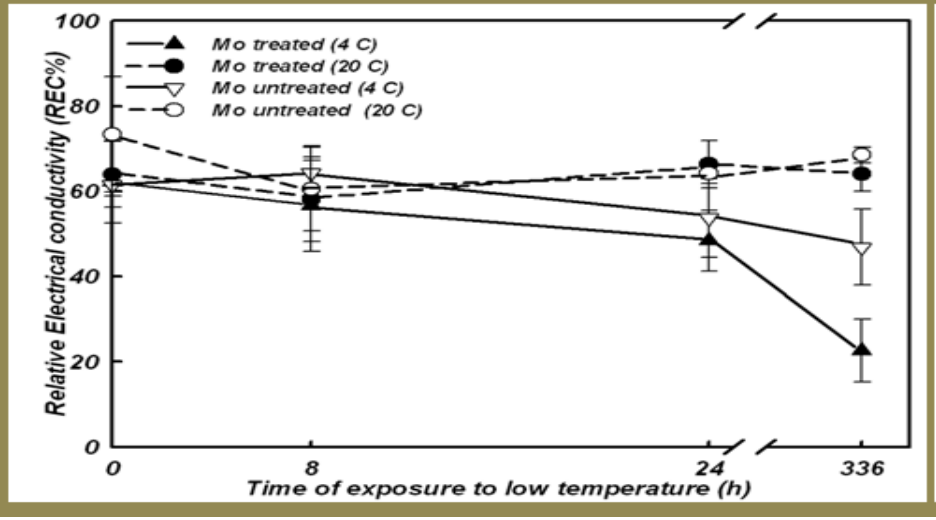
Mo increases frost tolerance significantly under low temperature

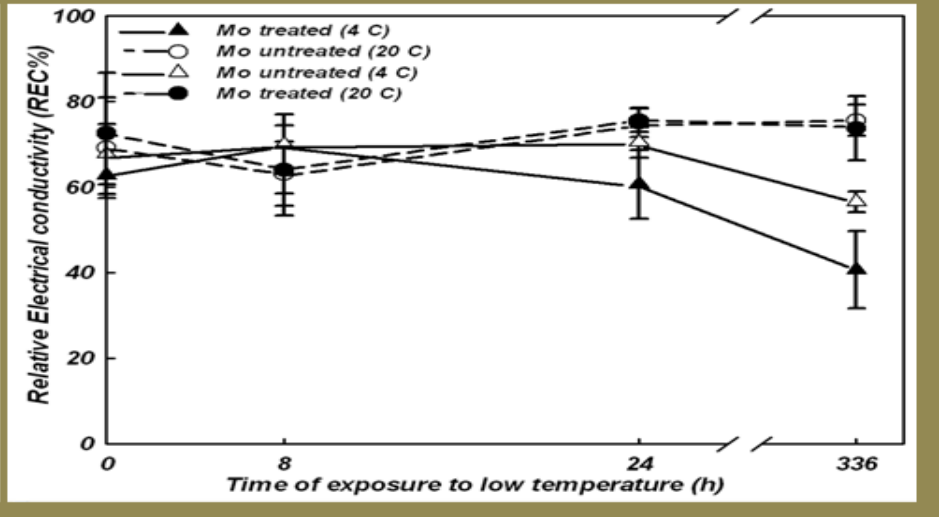
European wheat

Iraqi wheat

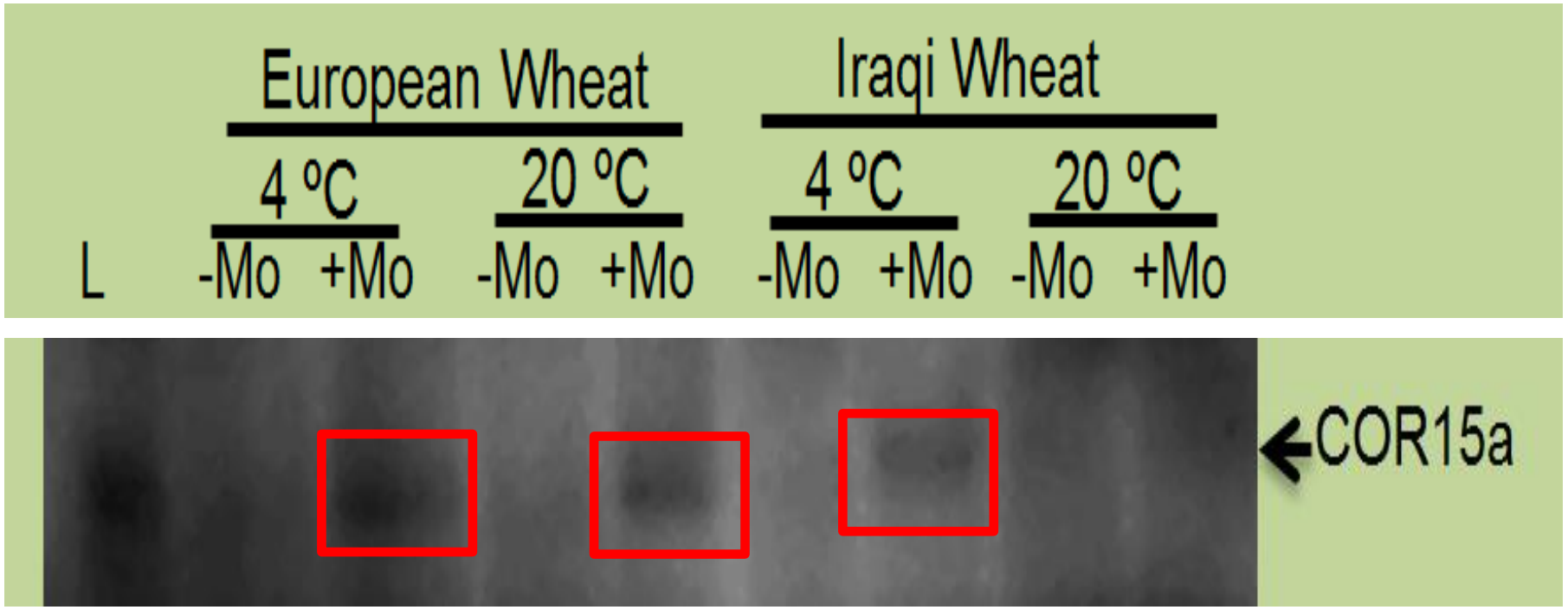




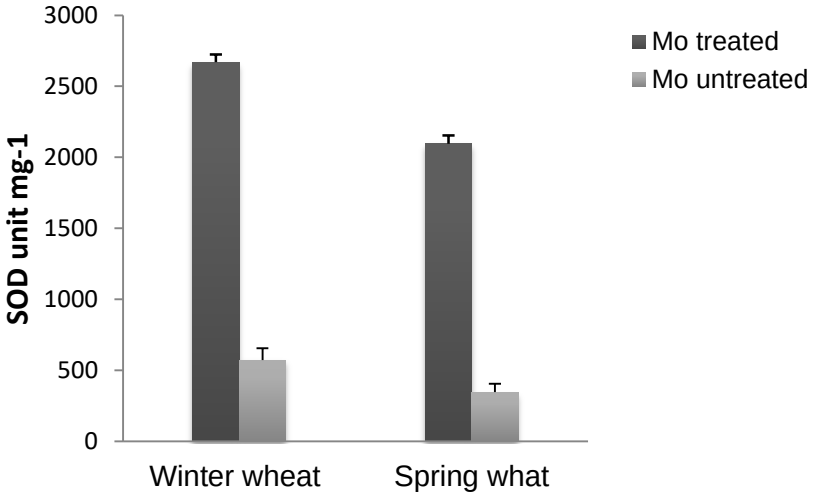


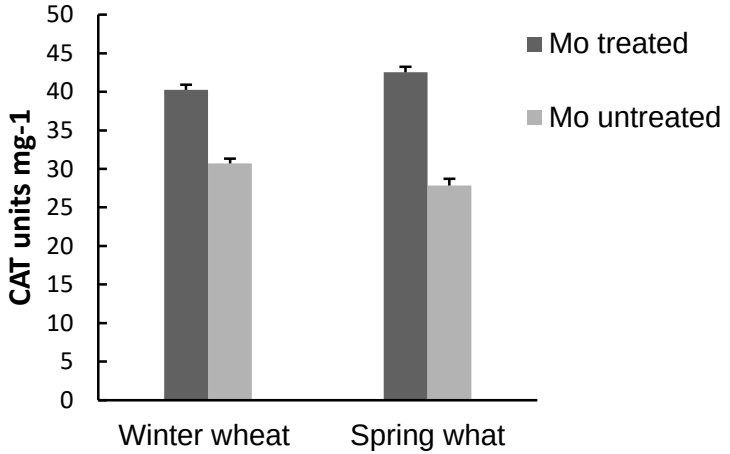


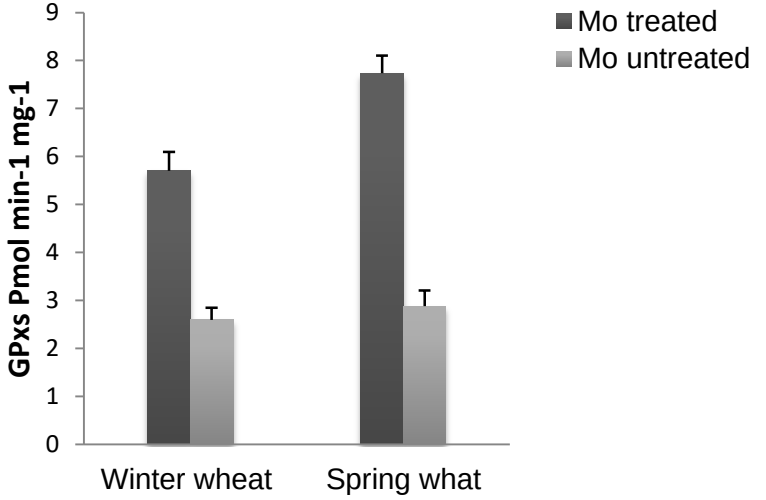
COR15a protein expression under Mo and CA treatments



Effects of Mo on anti-Oxidants

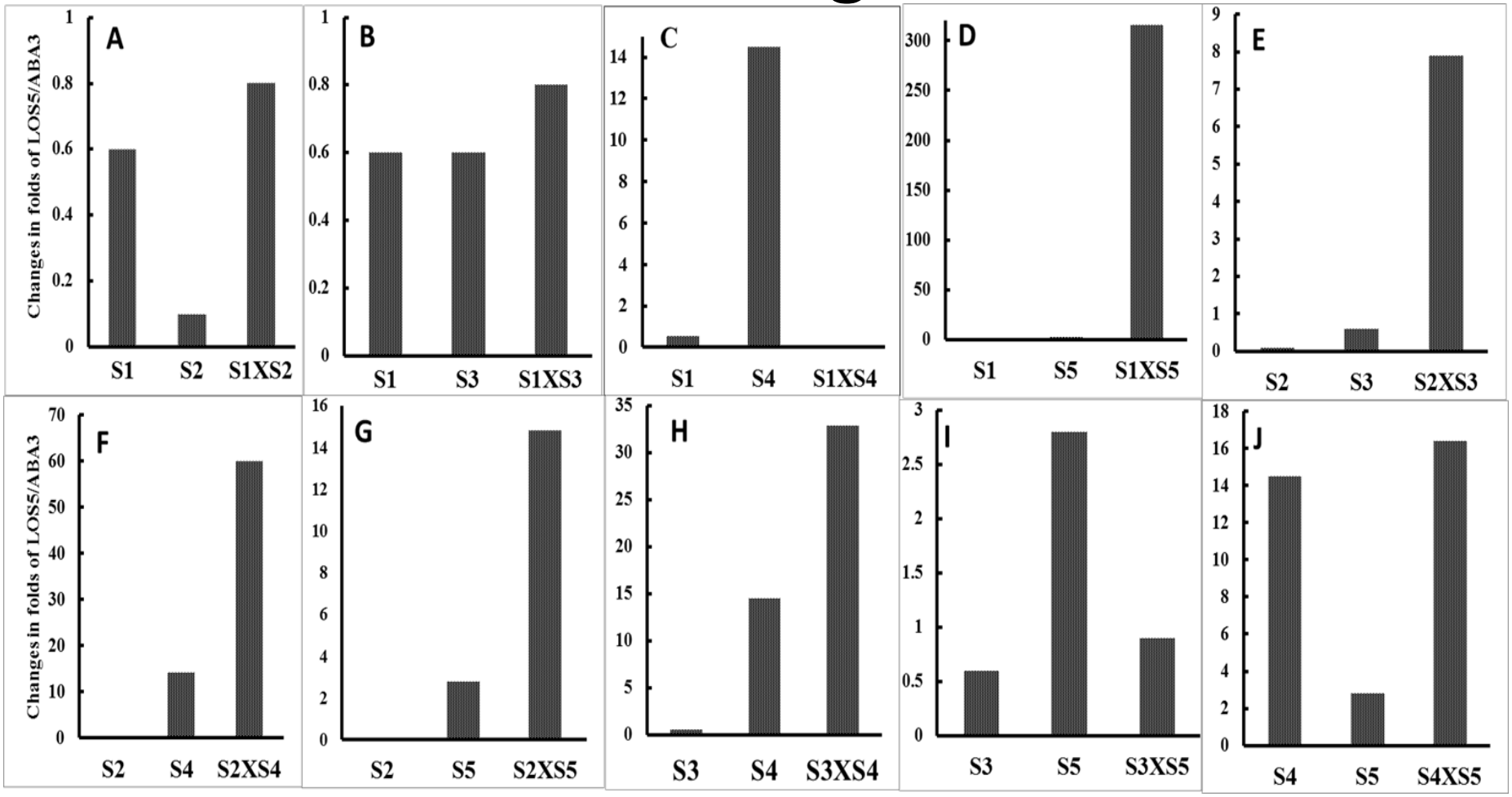






published data

LOS5/ABA3 is activated under effects of drought



Summary

- Plants are in continuous reaction with environmental
- Plants will adjust their biological process with any new condition
- Genes are involved in all plants activities, genes can be activated from different pathways
- A gene is the region of DNA that codes for a specific protein
- Protein synthesis results from:
  - transcription of the gene into mRNA
  - followed by translation of the mRNA into proteins at the ribosome.
- Enzymes are also implicated in stress responses in plant
- It is very important to investigate effect of (e.g. Molybdoenzymes)

Mission: Possible

http://www.economist.com/node/5323362