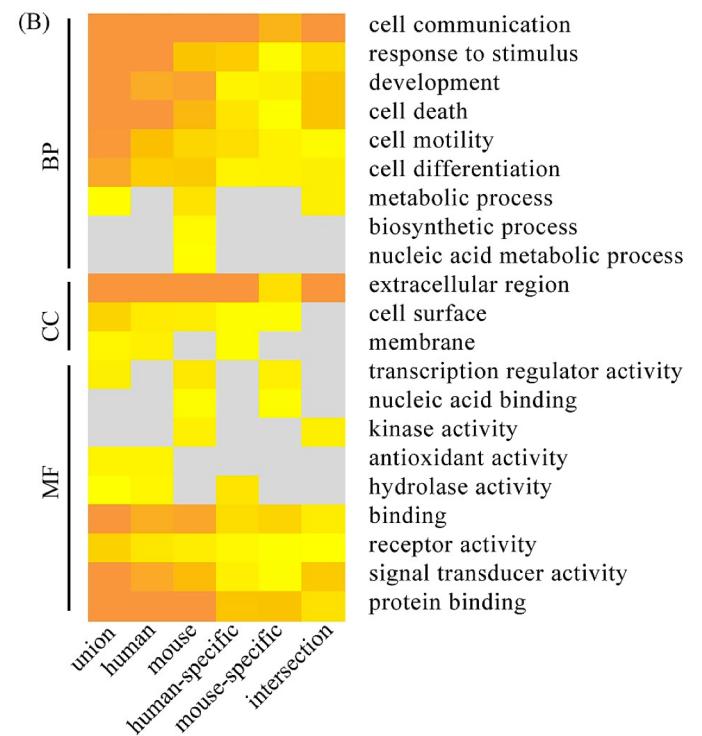
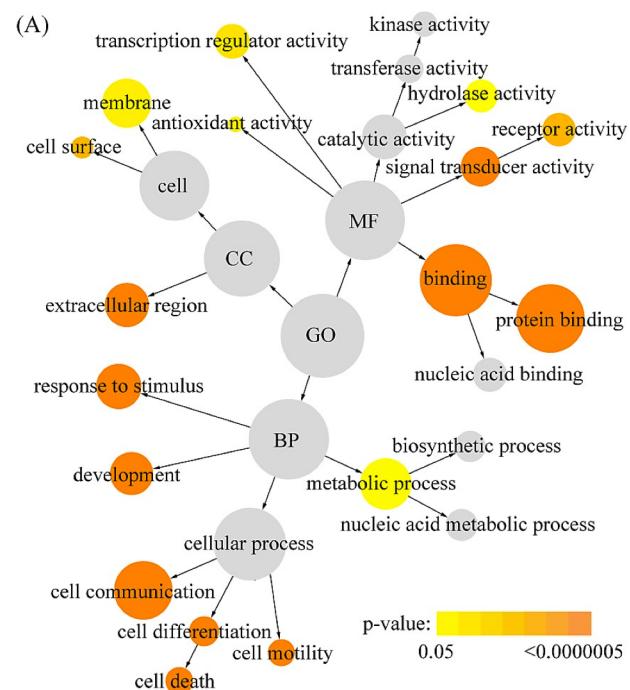
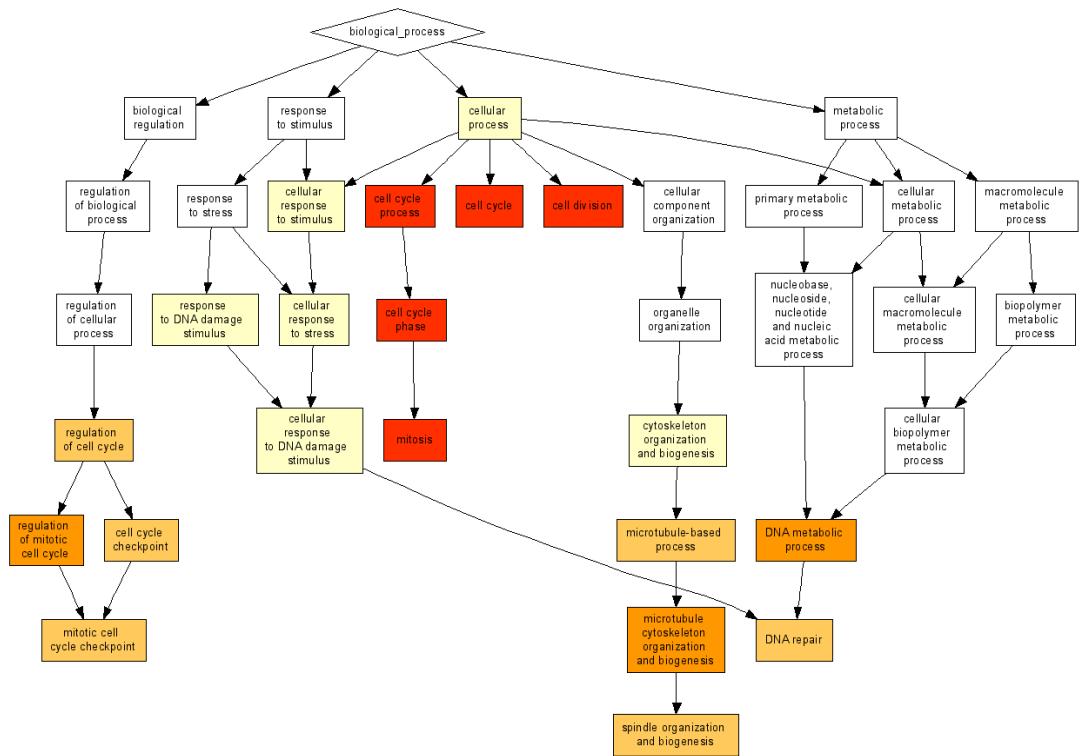


GO enrichment analysis



What do the genes do?

- Prupe.1G012200 -----> AT2G32120 - heat shock protein
 - 50 peach genes
 - 1,000 genes -----> gene ontology terms
- BLAST
- <https://www.arabidopsis.org/servlets/TairObject?name=AT2G32120&type=locus>

What is GO?

- The Gene Ontology (GO) describes our knowledge of the biological domain.



- AT2G32120

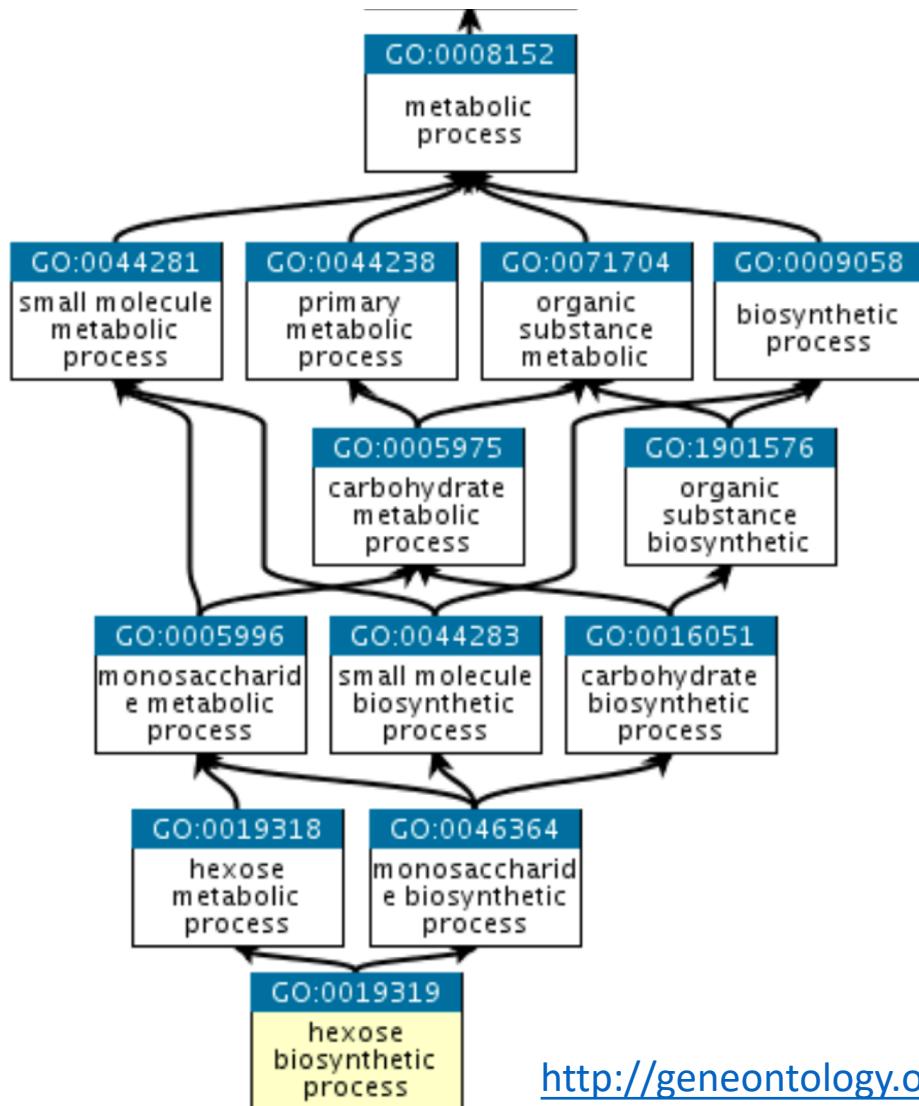
keyword

[cellular response to heat](#), [cellular response to unfolded protein](#), [chaperone cofactor-dependent protein refolding](#), [protein folding](#), [protein refolding](#), [response to heat](#), [response to unfolded protein](#)

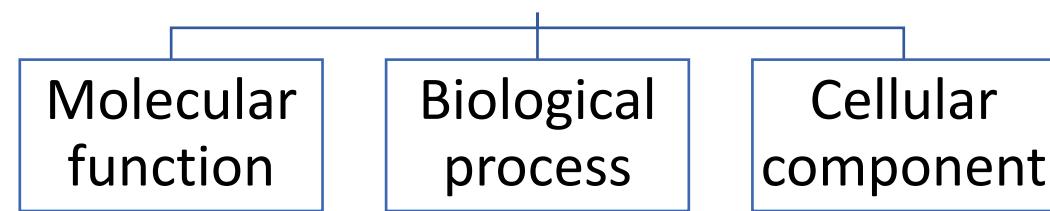
[cytoplasm](#)

[ATP binding](#), [ATPase activity](#), [ATPase activity, coupled](#), [heat shock protein binding](#), [misfolded protein binding](#), [protein folding chaperone](#), [unfolded protein binding](#)

Gene ontology structure



Three independent root ontology term



GO is loosely hierarchical, with 'child' terms being more specialized than their 'parent' terms

GO term

	category	keyword
AT2G32120	GO Biological Process	cellular response to heat , cellular response to unfolded protein , chaperone cofactor-dependent protein refolding , protein folding , protein refolding , response to heat , response to unfolded protein
	GO Cellular Component	cytoplasm
	GO Molecular Function	ATP binding , ATPase activity , ATPase activity, coupled , heat shock protein binding , misfolded protein binding , protein folding chaperone , unfolded protein binding

Peach example

locusName	GO term
Prupe.1G001400	GO:0016747, GO:0008610, GO:0016020, GO:0006633
Prupe.1G006600	GO:0046983
Prupe.1G012200	
Prupe.1G012900	
Prupe.1G031300	GO:0003676
Prupe.1G031800	GO:0006468, GO:0005524, GO:0004672
Prupe.1G033800	GO:0006468, GO:0005524, GO:0004672
Prupe.1G034000	GO:0006468, GO:0005524, GO:0004672
Prupe.1G035500	GO:0055114, GO:0016491

GO enrichment

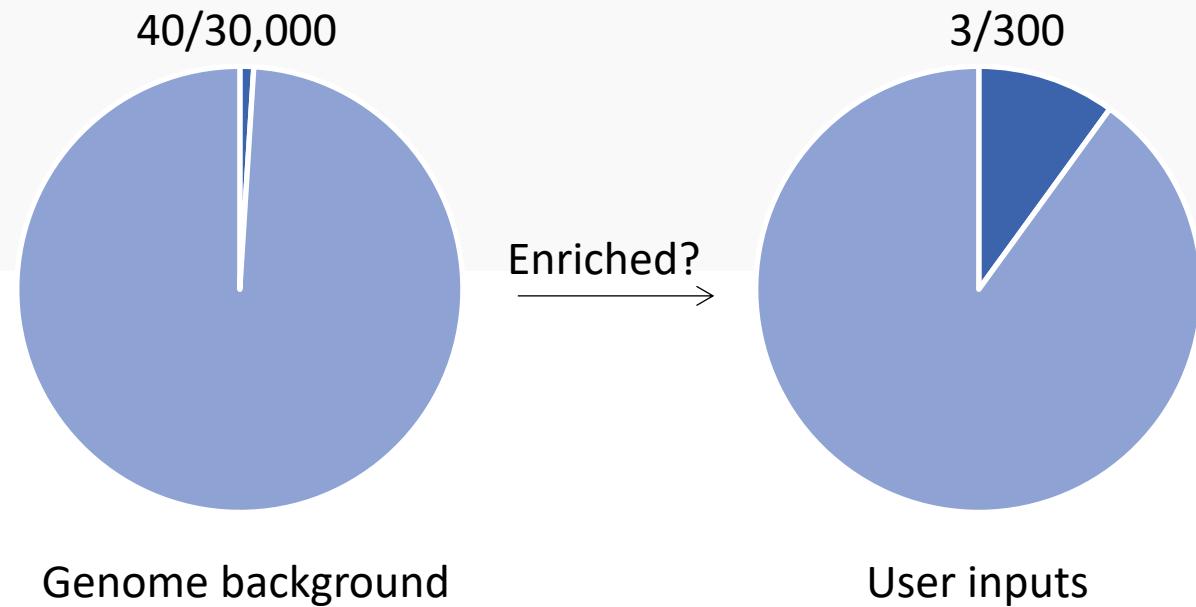


A Hypothetical Example:

In human genome background (30,000 gene total), 40 genes are involved in p53 signaling pathway. A given gene list has found that 3 out of 300 belong to p53 signaling pathway. Then we ask the question if 3/300 is more than random chance comparing to the human background of 40/30000.

A 2x2 contingency table is built on above numbers:

	User Genes	Genome
In Pathway	3-1	40
Not In Pathway	297	29960



https://david.ncifcrf.gov/content.jsp?file=functional_annotation.html

Other ontology databases

- KEGG - Kyoto Encyclopedia of Genes and Genomes
- COG – Clusters of Orthologous Groups
- KOG – Eukaryote Orthologous Groups

<https://www.genome.jp/kegg/>

<https://www.ncbi.nlm.nih.gov/COG/>

GO enrichment tools

- [AgriGO](#) – plant genomes
- [BiNGO](#) – model organisms, Cytoscape plugin
- [Gorilla](#) – model organisms
- [DAVID](#) – human and animal genomes

AgriGO enrichment output

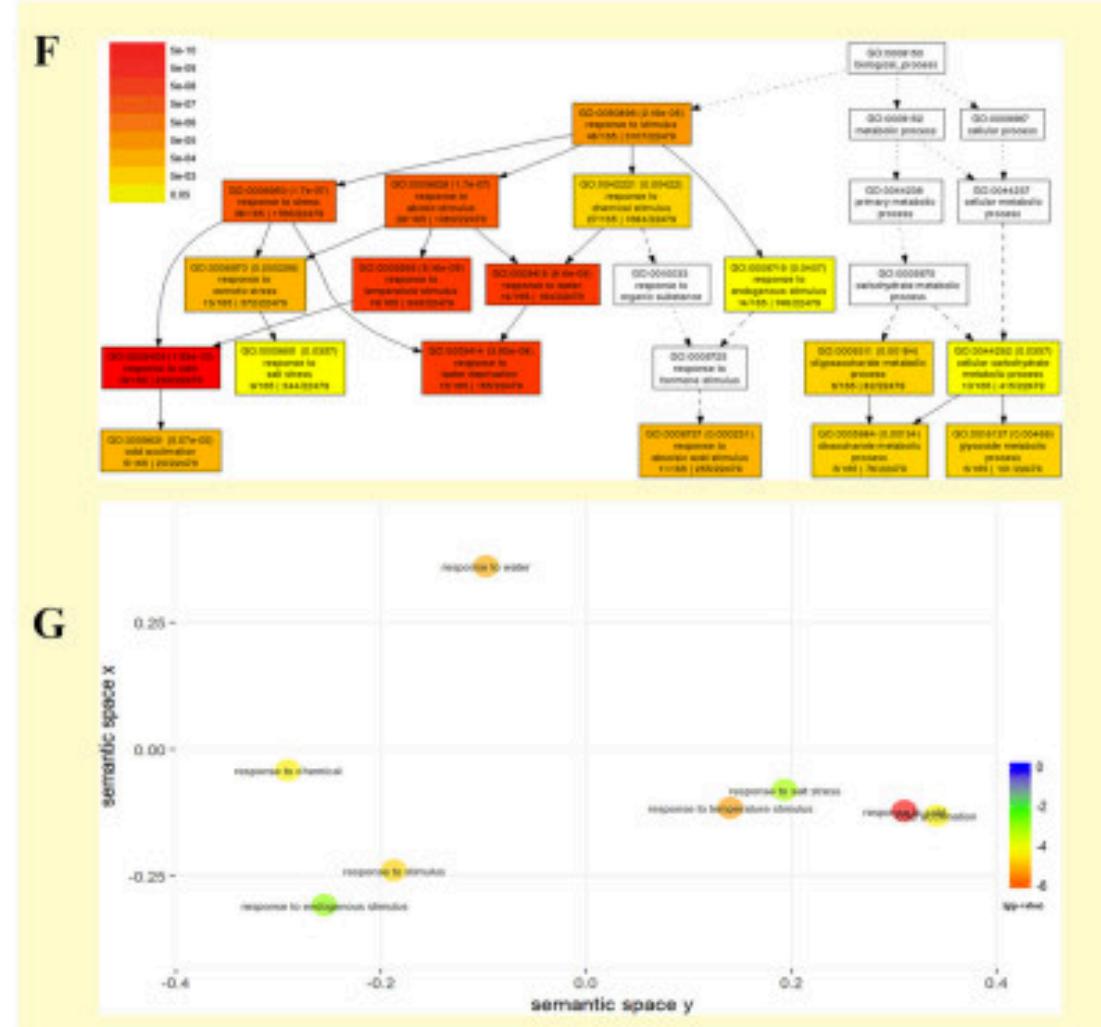
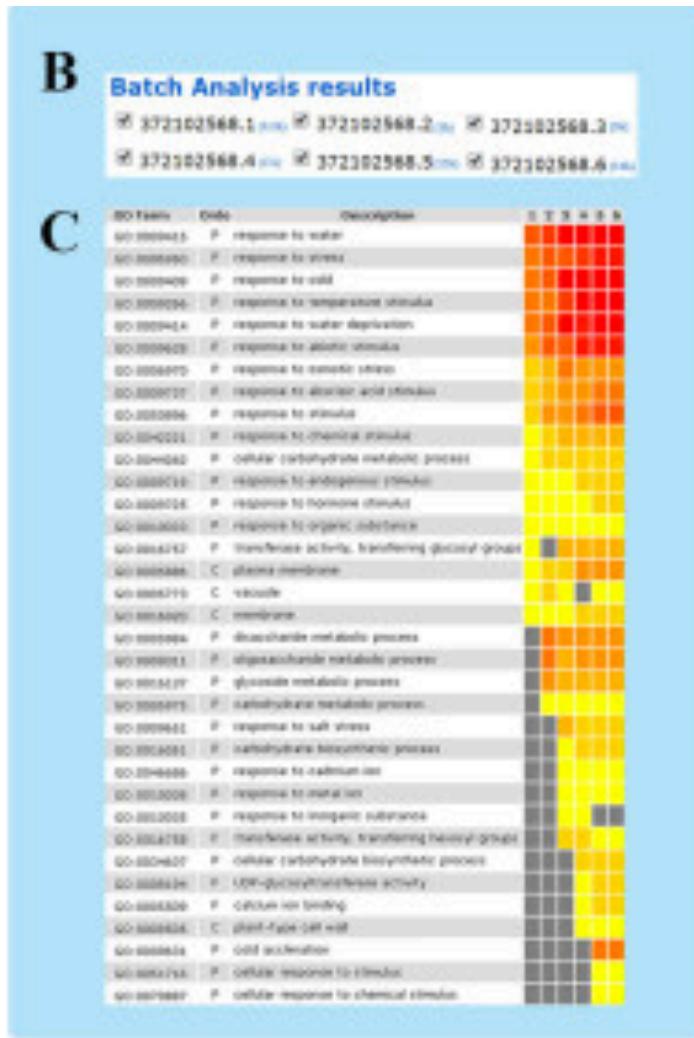
Detail information

You can [ Browse in tree traversing mode] [ Browse all GO terms] [ Download]

Or select from following significant terms to [Draw graphical results] [Create bar chart] [Scatter Plots analysis]

<input type="checkbox"/> GO term	Ontology	Description	Number in input list	Number in BG/Ref	p-value	FDR
<input type="checkbox"/> GO:0005985	P	sucrose metabolic process	9	44	4.1e-08	4.9e-05
<input type="checkbox"/> GO:0043038	P	amino acid activation	13	140	7.8e-07	0.00023
<input type="checkbox"/> GO:0043039	P	tRNA aminoacylation	13	140	7.8e-07	0.00023
<input type="checkbox"/> GO:0006418	P	tRNA aminoacylation for protein translation	13	138	6.6e-07	0.00023
<input type="checkbox"/> GO:0055067	P	monovalent inorganic cation homeostasis	7	35	1.6e-06	0.00031
<input type="checkbox"/> GO:0005984	P	disaccharide metabolic process	10	84	1.5e-06	0.00031
<input type="checkbox"/> GO:0045490	P	pectin catabolic process	6	26	3.7e-06	0.00062
<input type="checkbox"/> GO:0000272	P	polysaccharide catabolic process	8	69	2e-05	0.003
<input type="checkbox"/> GO:0009311	P	oligosaccharide metabolic process	10	117	2.9e-05	0.0038
<input type="checkbox"/> GO:0006771	P	riboflavin metabolic process	5	24	4.1e-05	0.0041

GO enrichment visualization



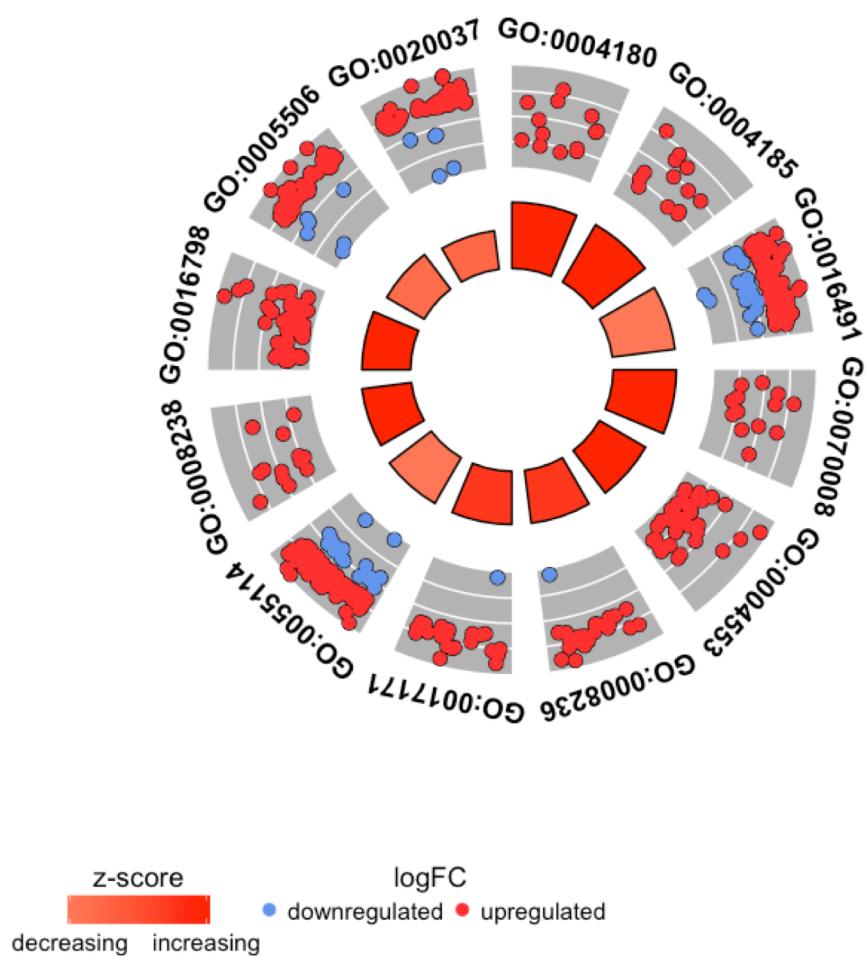
AgriGO demo

<http://systemsbiology.cau.edu.cn/agriGOv2/>

- DEG list:

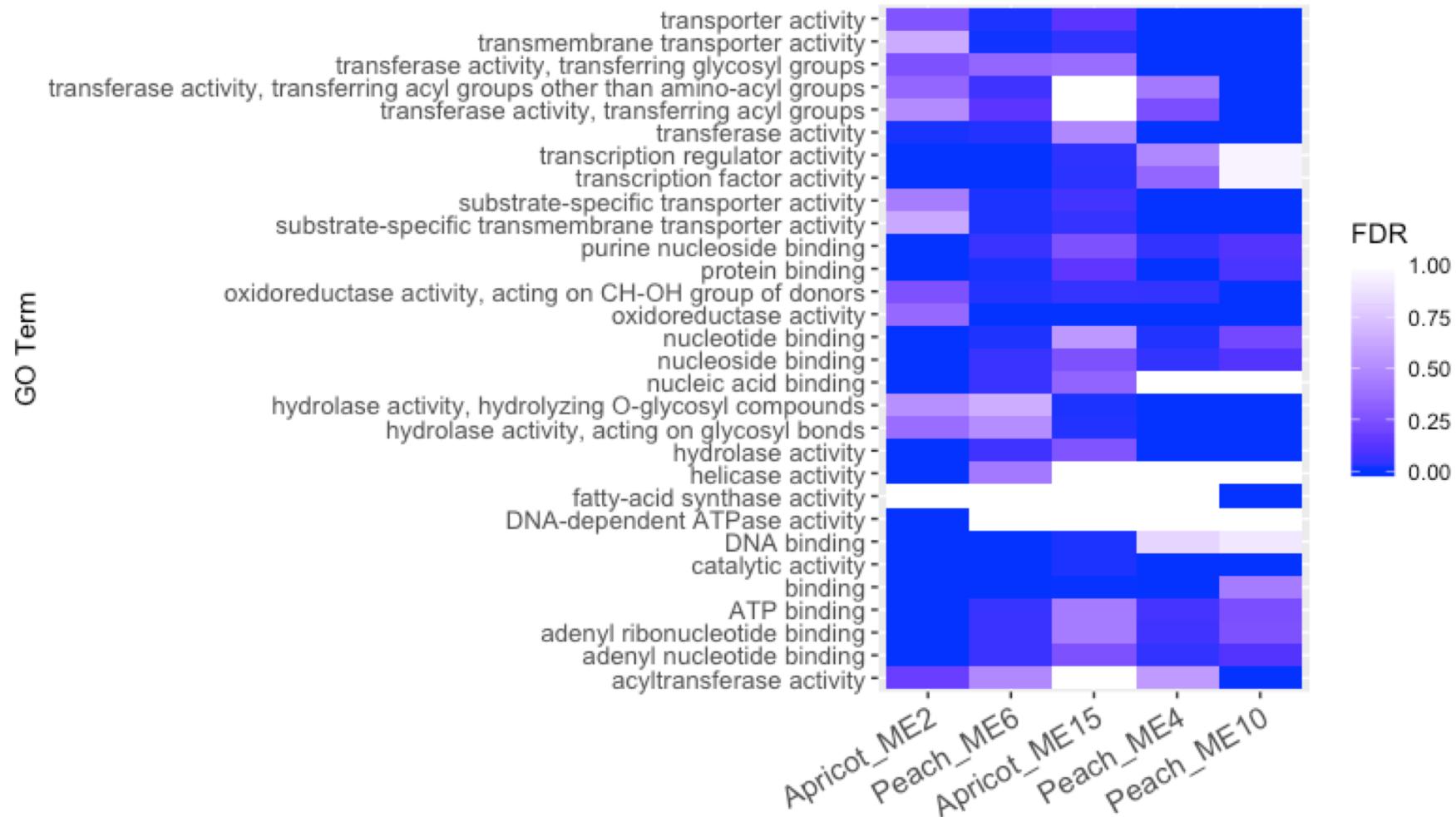
Use the DEG file generated by DESeq2 (as a backup, you can also download the file from
https://raw.githubusercontent.com/statonlab/rnaseq_workshop/master/2019/DEG_sig.csv)

Make your own figures with the results

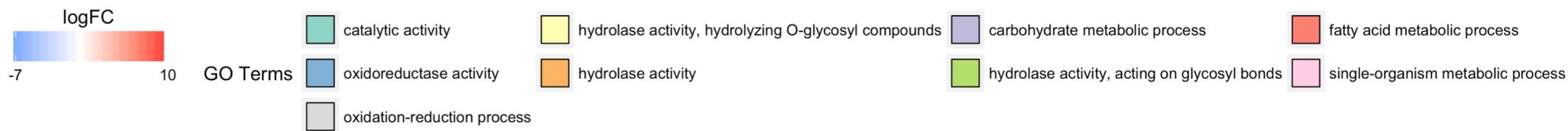


ID	Description
GO:0004180	carboxypeptidase activity
GO:0004185	serine-type carboxypeptidase activity
GO:0016491	oxidoreductase activity
GO:0070008	serine-type exopeptidase activity
GO:0004553	hydrolase activity, hydrolyzing O-glycosyl compounds
GO:0008236	serine-type peptidase activity
GO:0017171	serine hydrolase activity
GO:0055114	oxidation reduction
GO:0008238	exopeptidase activity
GO:0016798	hydrolase activity, acting on glycosyl bonds
GO:0005506	iron ion binding
GO:0020037	heme binding

Make your own figures with the results



Make your own figures with the results



Reference

- <http://geneontology.org/>
- <https://david.ncifcrf.gov/>
- Tian T, Liu Y, Yan H, et al. agriGO v2.0: a GO analysis toolkit for the agricultural community, 2017 update. *Nucleic Acids Res.* 2017;45(W1):W122–W129. doi:10.1093/nar/gkx382