Bioinformatics analysis of Psy Gene in golden rice

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- Background
- Basic annotation information
- Evolutionary relationship

Background

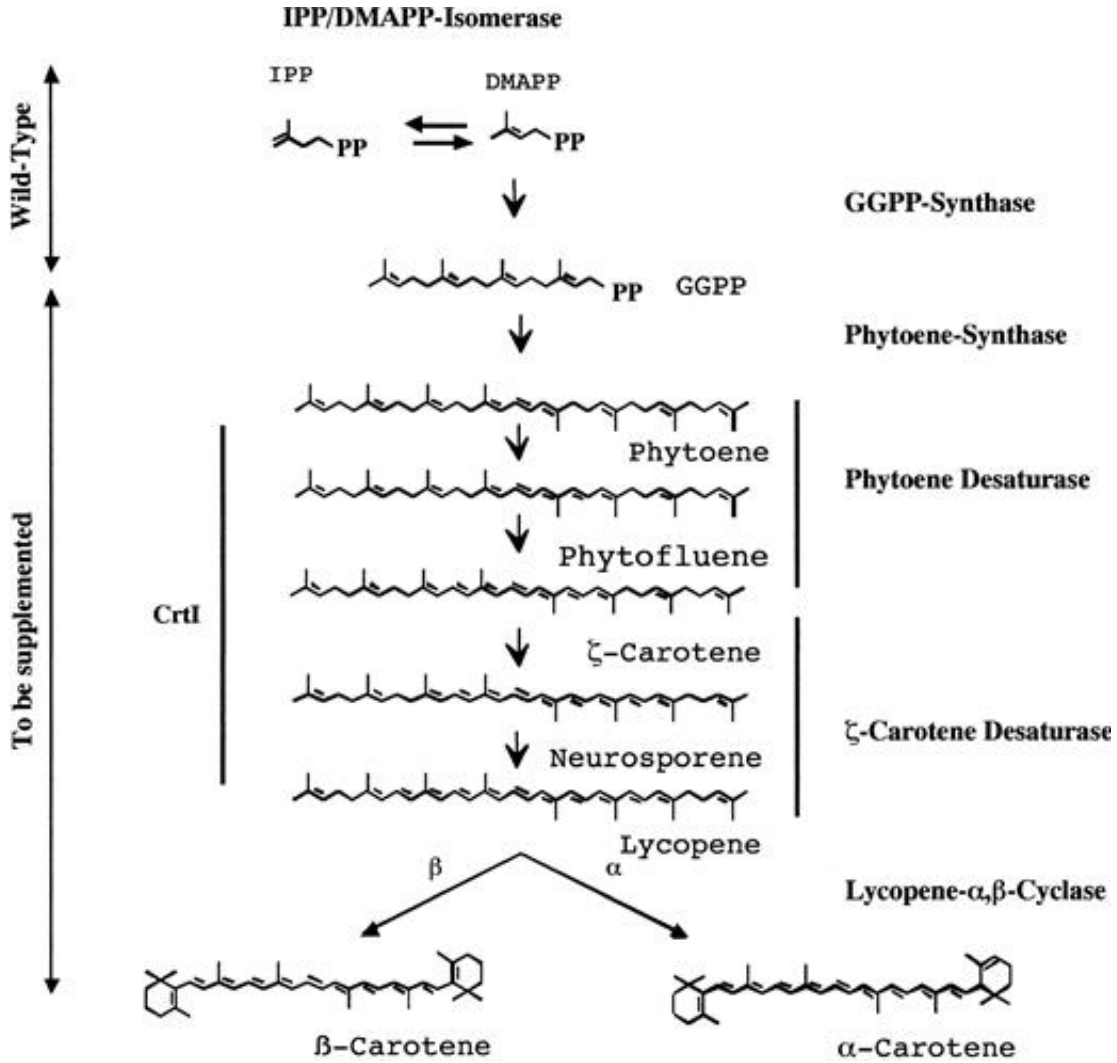
这项实验是由Potrykus（瑞士联邦理工学院）和 Beyer（德国弗莱堡大学）等人于 1999 年研究所得，并于次年公布研究结果。 这类通过外源基因调控食物中微量元素合成的实验被称为“生物营养强化”。

英国先正达公司最早获得培育黄金大米的专利，并免费向亚洲部分地区的实验室提供这种大米品种， 供它们进行试种和推广，以解决这些以大米为主食的发展中国家儿童 VA 缺乏症和营养不良问题。

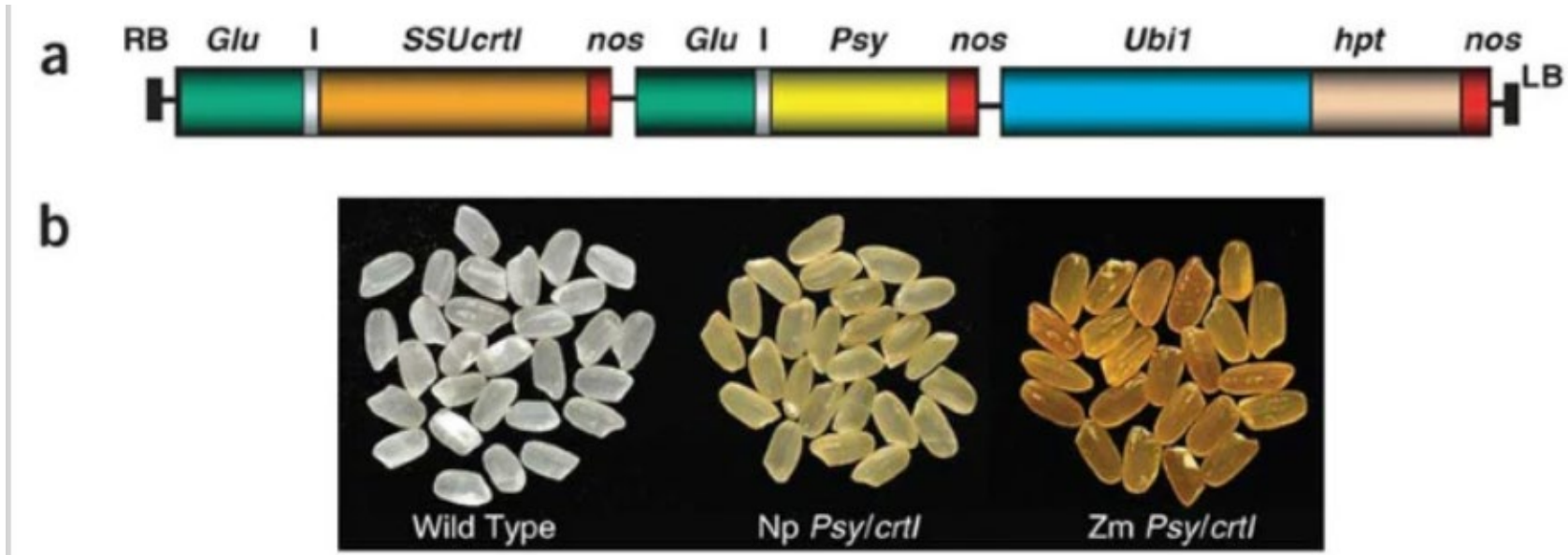
Background

黄金大米（Golden Rice）是一种新型转基因大米，黄金大米是黄色由于积累β胡萝卜素（前维生素A）和叶黄素。

- 黄金大米中使用的两个类胡萝卜素生物合成转基因，八氢番茄红素合酶（PSY）和细菌性胡萝卜素去饱和酶（CRTI）。
- 黄金大米的开发是为了帮助解决维生素A缺乏症的问题，这种问题在发展中国家普遍存在，影响了数百万人。维生素A缺乏症会导致儿童死亡和发育迟缓，并经常损害视力，导致失明。它也通过干扰铁的生物利用度间接促成贫血。
- 八氢番茄红素合酶（PSY）催化类胡萝卜素生物合成途径的第一步。



Beyer P, Al-Babili S, Ye X, Lucca P, Schaub P, Welsch R, Potrykus I. Golden Rice: introducing the beta-carotene biosynthesis pathway into rice endosperm by genetic engineering to defeat vitamin A deficiency. J Nutr. 2002 Mar;132(3):506S-510S. doi: 10.1093/jn/132.3.506S. PMID: 11880581.



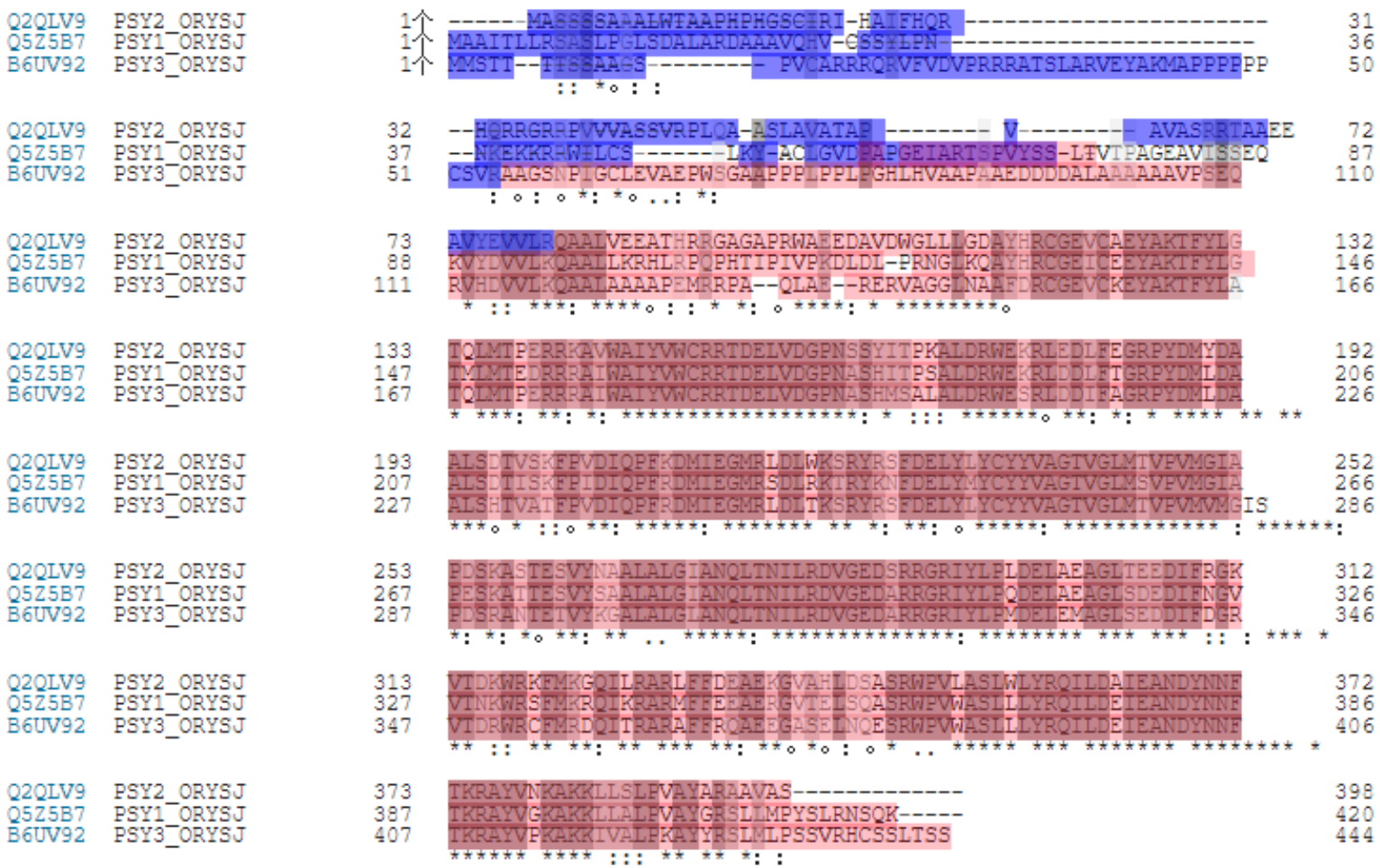
（a）用于产生转基因水稻植物的T-DNA的示意图。
（b）含有T-DNA的抛光野生型和转基因水稻籽粒（如上）的照片，其中的水仙花蛋白（Np）或玉米蛋白（Zm）由于类胡萝卜素的积累而显示出改变的颜色。

Paine JA, Shipton CA, Chaggar S, Howells RM, Kennedy MJ, Vernon G, Wright SY, Hinchliffe E, Adams JL, Silverstone AL, Drake R. Improving the nutritional value of Golden Rice through increased pro-vitamin A content. Nat Biotechnol. 2005 Apr;23(4):482-7. doi: 10.1038/nbt1082. Epub 2005 Mar 27. PMID: 15793573.

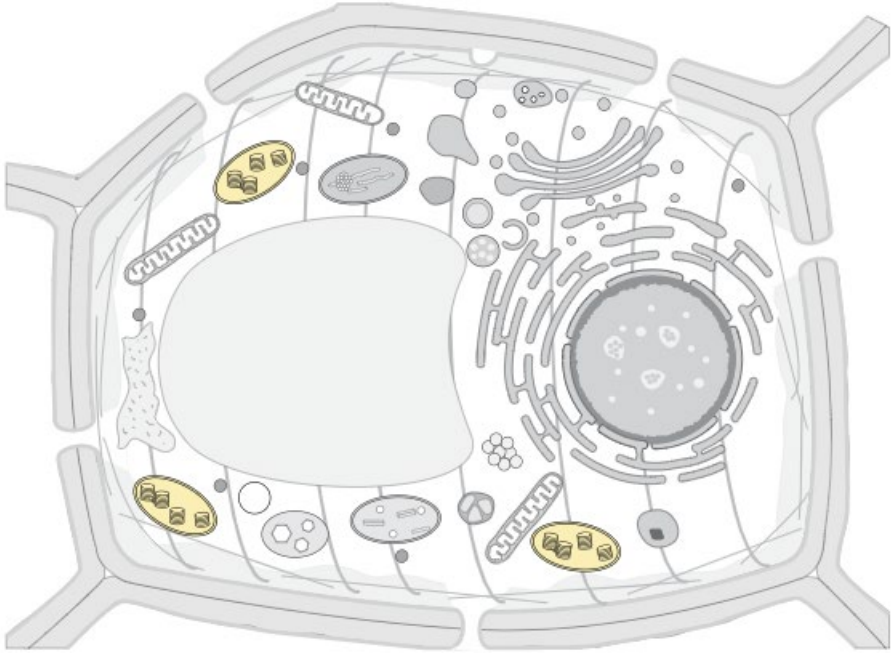
Basic annotation information

BLAST | Align | Download | Add to basket | Columns | 1 to 3 of 3 | Show 25

Entry	Entry name		Protein names	Gene names	Organism	Length	Protein families
Q2QLV9	PSY2_ORYSJ		**Phytoene synthase 2, chloroplastic**	**PSY2** Os12g0626400, LOC_Os12g43130	Oryza sativa subsp. japonica (Rice)	398	Phytoene/squalene synthase family
Q5Z5B7	PSY1_ORYSJ		**Phytoene synthase 1, chloroplastic**	**PSY1** Os06g0729000, OsJ_22735, OSJNBa0069C14.4-1	Oryza sativa subsp. japonica (Rice)	420	Phytoene/squalene synthase family
B6UV92	PSY3_ORYSJ		**Phytoene synthase 3, chloroplastic**	**PSY3** Os09g0555500, LOC_Os09g38320	Oryza sativa subsp. japonica (Rice)	444	Phytoene/squalene synthase family


Q2QLV9 PSY2_ORYSJ
Q5Z5B7 PSY1_ORYSJ
B6UV92 PSY3_ORYSJ

Subcellular localization

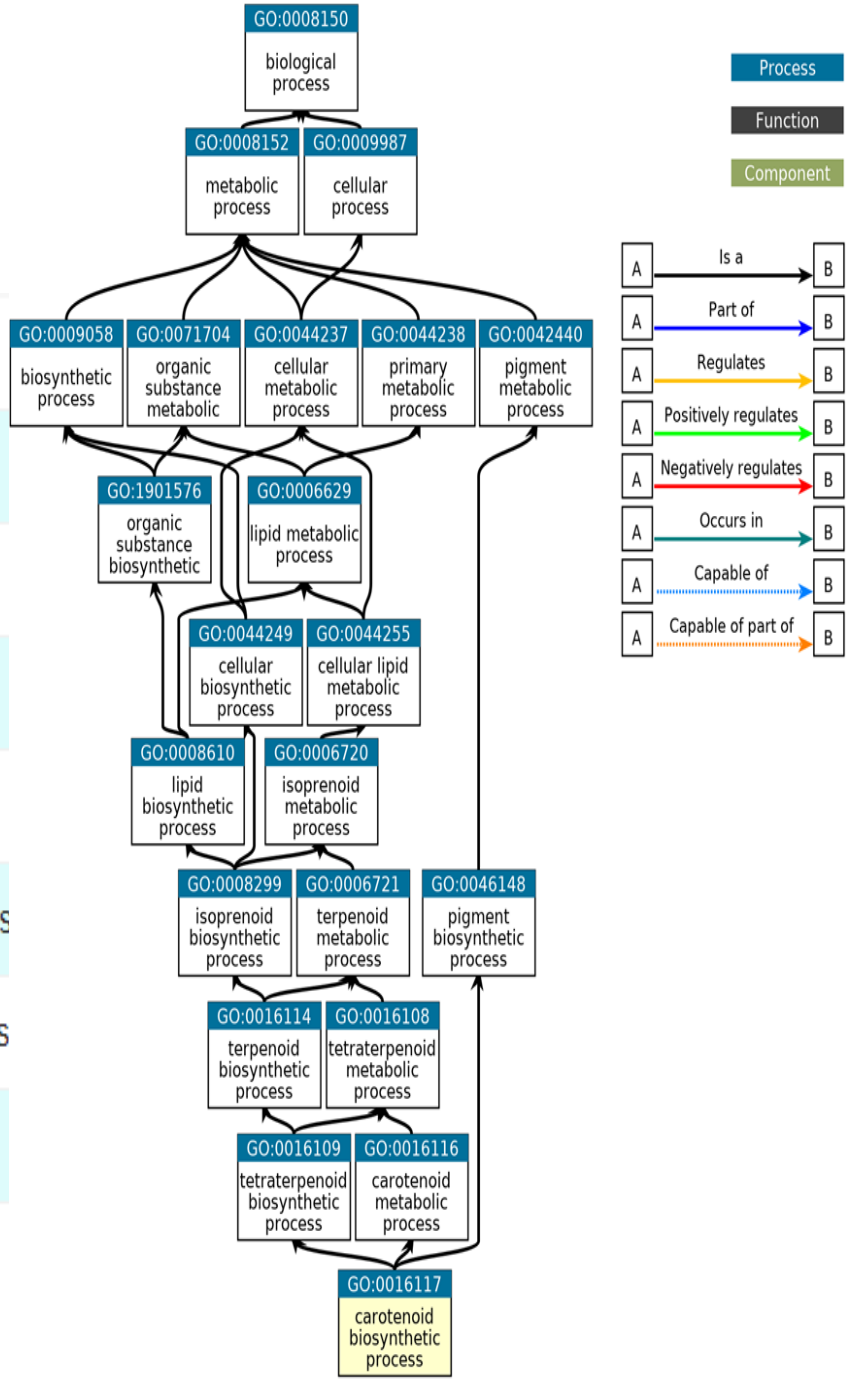


Chloroplast
Membrane
Plastid

PSY2功能注释

QuickGO

GO:0016123	P	xanthophyll biosynthetic process
GO:1901812	P	beta-carotene biosynthetic process
GO:1901824	P	delta-carotene biosynthetic process
GO:0140630	F	all-trans-phytoene synthase activity
GO:1901821	P	alpha-zeacarotene biosynthetic process
GO:1901830	P	zeaxanthin bis(beta-D-glucoside) biosynthetic process
GO:1904142	P	negative regulation of carotenoid biosynthetic process
GO:1904143	P	positive regulation of carotenoid biosynthetic process
GO:1901818	P	beta-zeacarotene biosynthetic process



psy2参与的通路

KEGG

REACTOME

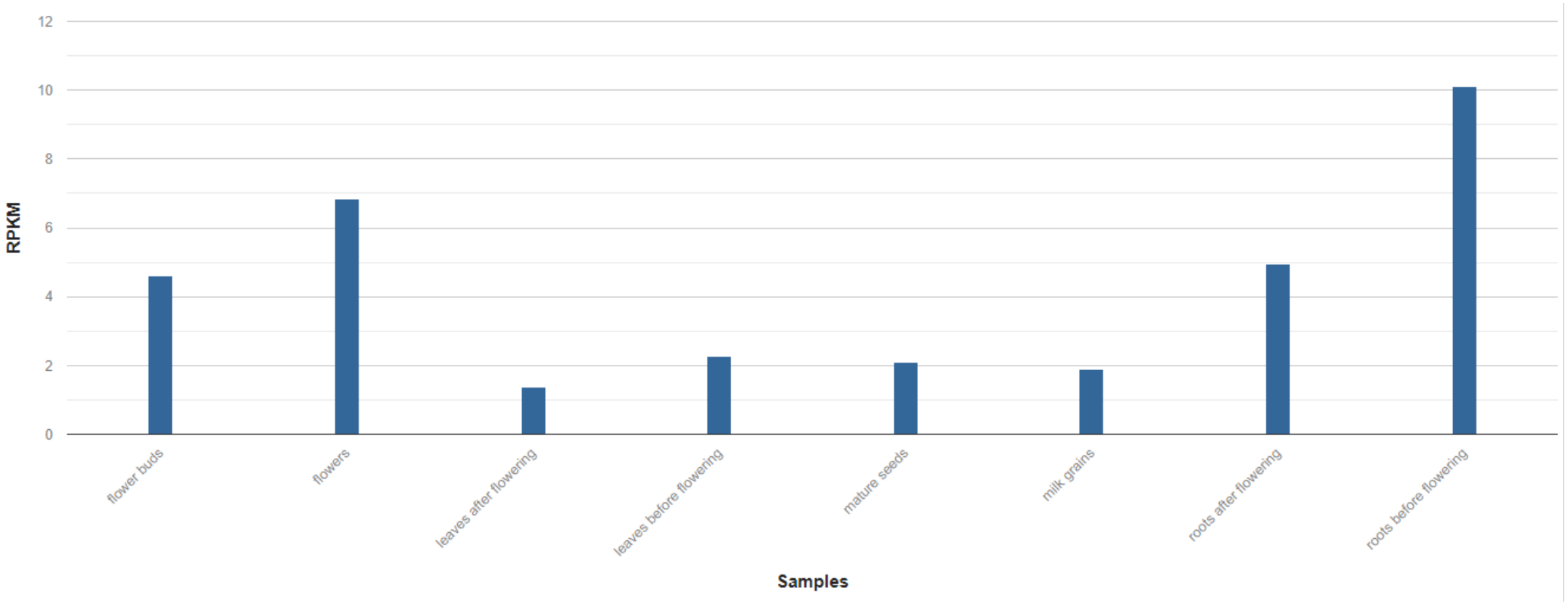
Entry	4352846 CDS T01015
Definition	(RefSeq) phytoene synthase 2, chloroplastic
KO	K02291 15-cis-phytoene synthase [EC:2.5.1.32]
Organism	osa Oryza sativa japonica (Japanese rice) (RefSeq)
Pathway	osa00906 Carotenoid biosynthesis osa01100 Metabolic pathways osa01110 Biosynthesis of secondary metabolites
Module	osa_M00097 beta-Carotene biosynthesis, GGAP => beta-carotene
Brite	KEGG Orthology (KO) [BR:osa00001] 09100 Metabolism 09109 Metabolism of terpenoids and polyketides 00906 Carotenoid biosynthesis 4352846 09180 Brite Hierarchies 09181 Protein families: metabolism 01006 Prenyltransferases [BR:osa01006] 4352846 Enzymes [BR:osa01000] 2. Transferases 2.5 Transferring alkyl or aryl groups, other than methyl groups 2.5.1 Transferring alkyl or aryl groups, other than methyl groups (o 2.5.1.32 15-cis-phytoene synthase 4352846 Prenyltransferases [BR:osa01006] Terpene biosynthesis Squalene/phytoene synthase 4352846

KEGG PATHWAY

osa00906 Carotenoid biosynthesis - Oryza sativa japonica (Japanese rice) (RefSeq)

osa01100 Metabolic pathways - Oryza sativa japonica (Japanese rice) (RefSeq)

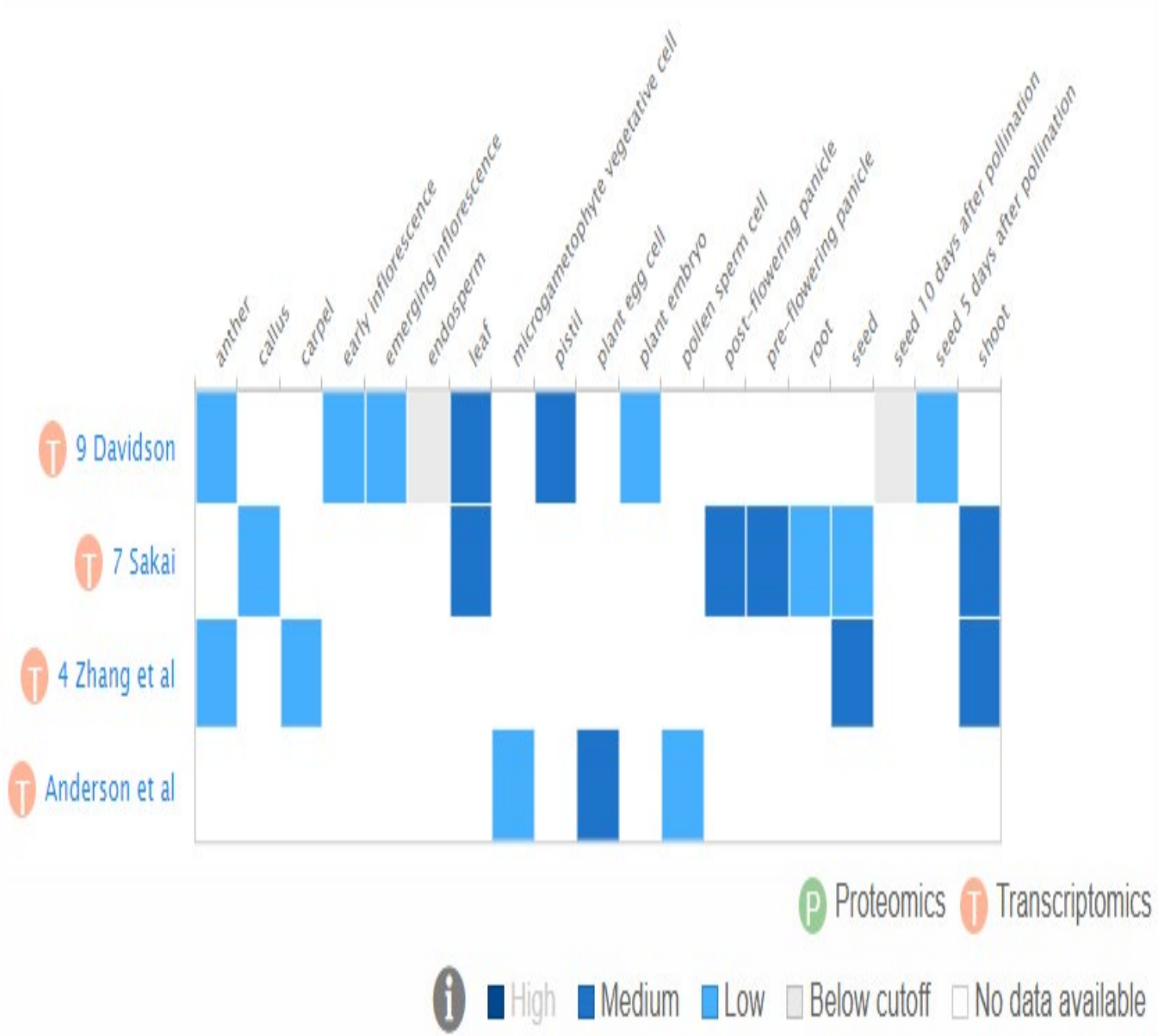
osa01110 Biosynthesis of secondary metabolites - Oryza sativa japonica (Japanese rice)

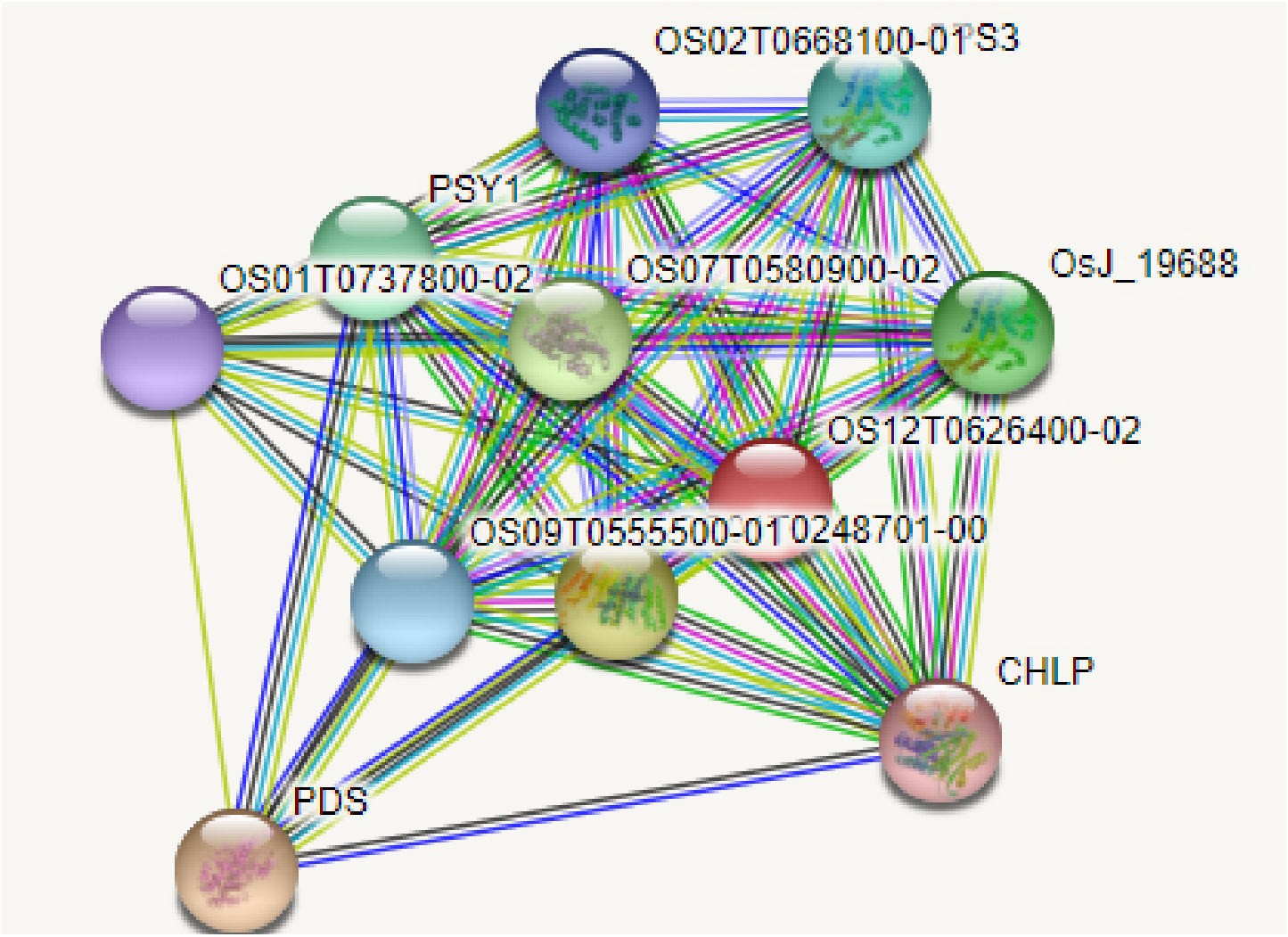


花蕾，花，叶后开花，叶前开花，成熟的种子，花后根，花前根

psy2表达特征


inflorescence
leaf
root


anther
callus
carpel
early inflorescence
emerging inflorescence
endosperm
leaf
microgametophyte vegetative cell
pistil
plant egg cell
plant embryo
pollen sperm cell
post-flowering panicle
pre-flowering panicle
root
seed
seed 10 days after pollination
seed 5 days after pollination
shoot
9 Davidson
7 Sakai
4 Zhang et al
Anderson et al
Proteomics
Transcriptomics
High
Medium
Low
Below cutoff
No data available

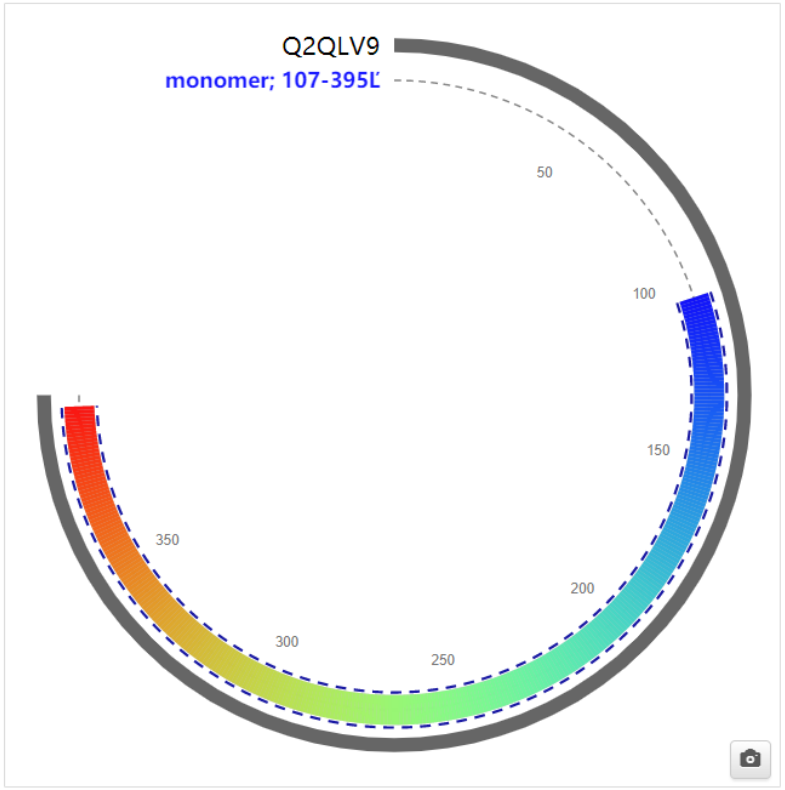


Protein-protein interaction

Protein-protein interaction

PDS	*Phytoene dehydrogenase, chloroplastic/chromoplastic; This enzyme converts phytoene into zeta-carotene via...*	0.983
OS01T0248701-00	*Os01g0248701 protein; Putative geranylgeranyl pyrophosphate synthase ; Belongs to the FPP/GGPP synthase...*	0.941
OS07T0580900-02	*Os07g0580900 protein; Putative geranylgeranyl diphosphate synthase; cDNA clone:J023007O22, full insert se...*	0.941
OsJ_19688	*Solanesyl-diphosphate synthase 2, chloroplastic; Involved in providing solanesyl diphosphate for plastoquinon...*	0.909
PSY1	*cDNA clone:J023057D05, full insert sequence; Phytoene synthase-like*	0.904
SPS3	*Probable solanesyl-diphosphate synthase 3, chloroplastic; Involved in providing solanesyl diphosphate for pla...*	0.904
OS09T0555500-01	*Os09g0555500 protein*	0.902
OS02T0668100-01	*Putative geranylgeranyl diphosphate synthase; cDNA clone:001-204-C07, full insert sequence; cDNA clone:00...*	0.894
OS01T0737800-02	*Os01g0737800 protein; cDNA clone:J033029E14, full insert sequence*	0.887
CHLP	*Geranylgeranyl diphosphate reductase, chloroplastic; Catalyzes the reduction of geranylgeranyl diphosphate t...*	0.881

Predicted protein 3D structure



Molecule Processing

Homology Model

Template: 5iys.1.A *"Crystal structure of a dehydrosqualene synthase in complex with ligand"* *I6T9U8*

SMTL Version: 2021-03-31

Seq Identity: 29.39%

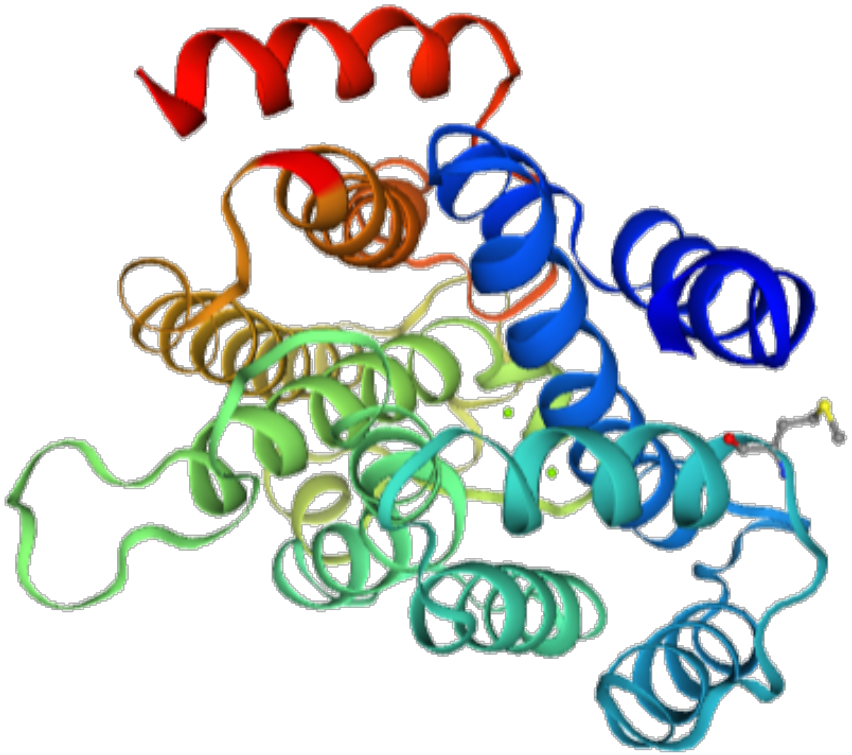
Seq Similarity: 0.35

2 x MAGNESIUM ION

Coordinates:

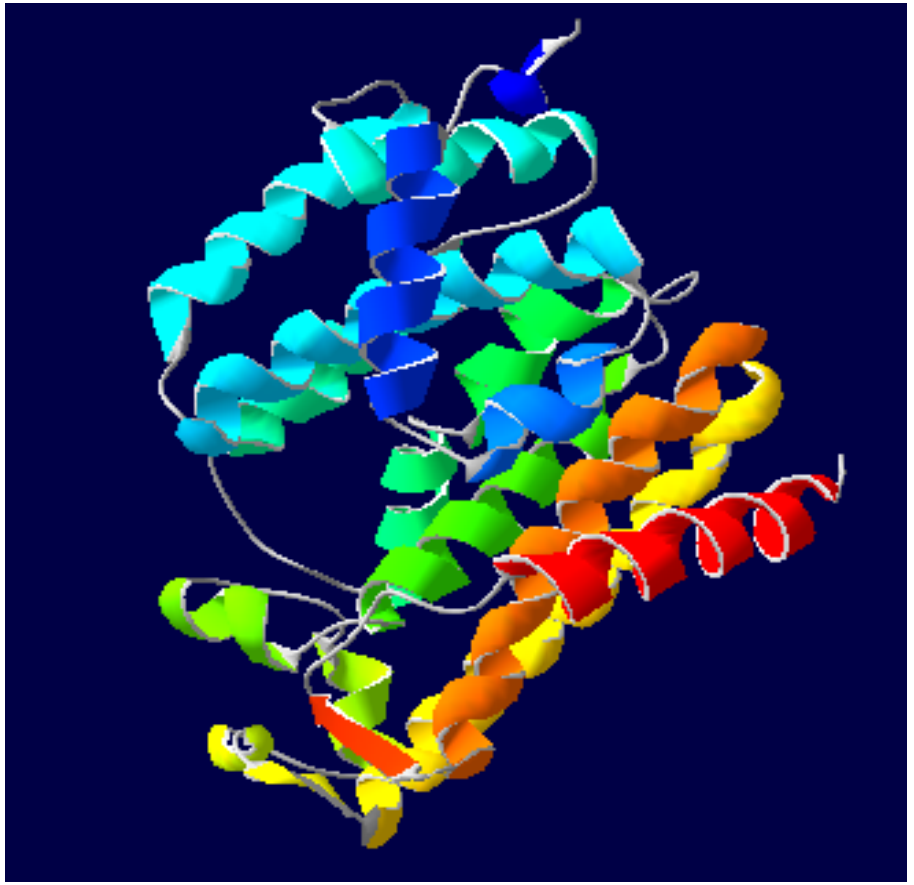
Model Quality Estimate

QMEAN	-2.64
Cβ	-1.70
All Atom	0.21
solvation	0.89
torsion	-2.85



模板（5IYS）

PDB



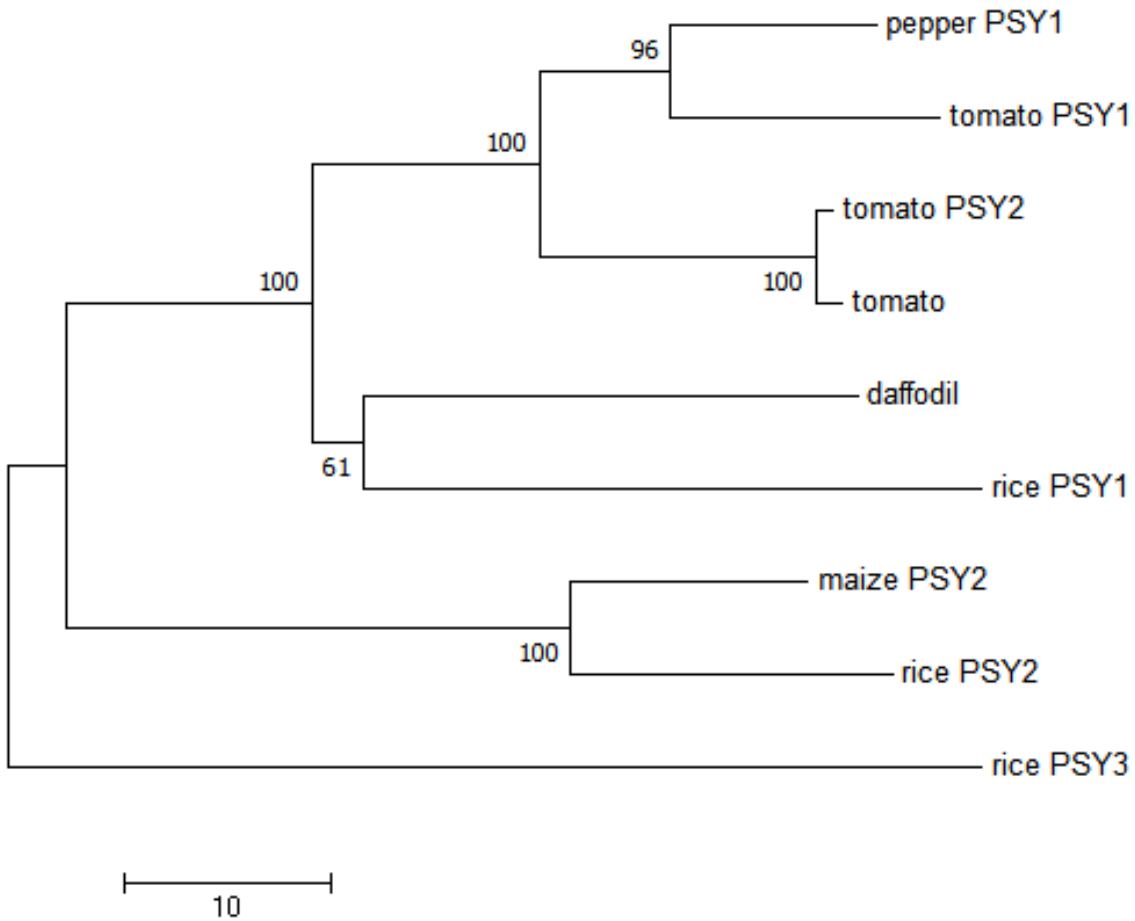
分子功能

- 苯并合酶
- 催化活性
- 异戊二烯转移酶活性
- 转移酶活性
- 转移酶活性，转移烷基或芳基（甲基除外）
- 角鲨烯合酶活性

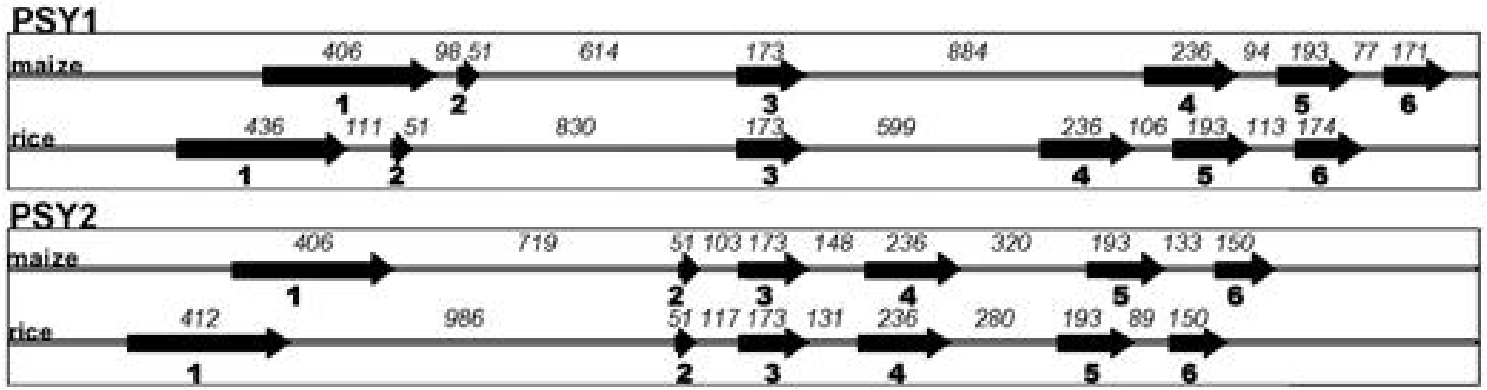
```
#
# Length: 410
# Identity:     331/410 (80.7%)
# Similarity:   347/410 (84.6%)
# Gaps:          20/410 ( 4.9%)
# Score: 1616.5
#
#
#
```

```
#
# Length: 450
# Identity:     259/450 (57.6%)
# Similarity:   307/450 (68.2%)
# Gaps:          79/450 (17.6%)
# Score: 1284.0
#
#
```

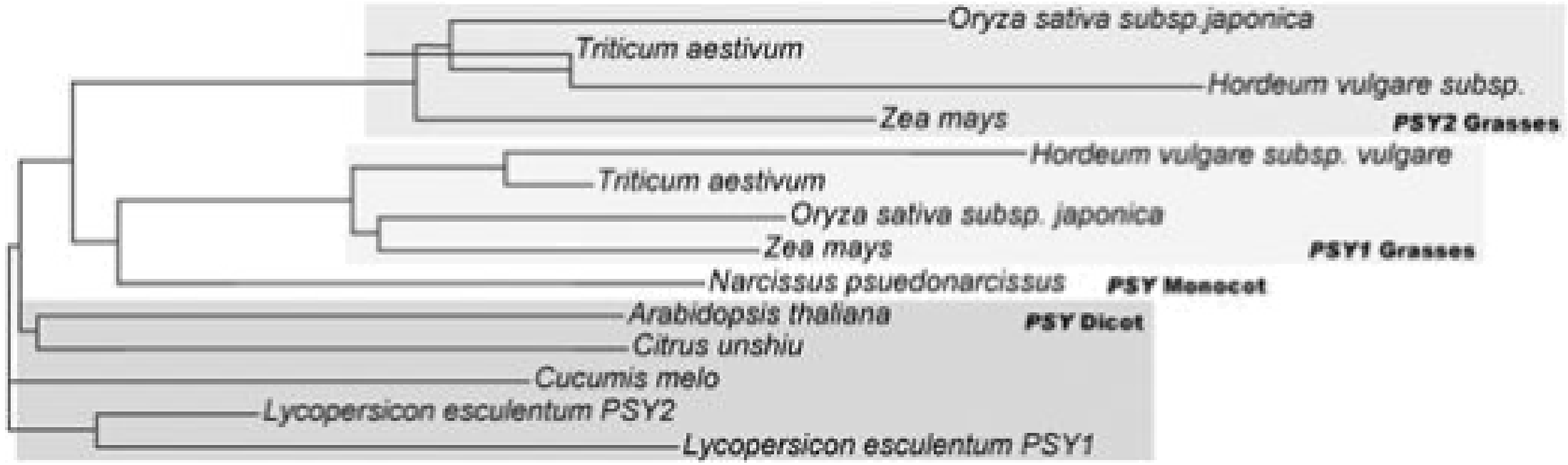
2000年开发的第一代的黄金大米（Golden Rice）里总共转进去三个基因，分别是从黄水仙花中获得的八氢番茄红素合成酶（phytoene synthase, psy）、从噬夏孢欧文菌中获得的八氢番茄红素去饱和酶或β-胡萝卜素去饱和酶（phytoene desaturase, crtI），以及从黄水仙花中获得的番茄红素β-环化酶（lycopene β-cyclase, lcy）。其中前两个基因是功能基因用来产生类胡萝卜素（主要是β-胡萝卜素），第三个基因则用来确定转基因成功与否因此不是必须的。由于水仙花的八氢番茄红素合成酶效率不高，因此2005年改良后的第二代黄金大米，是从玉米里获得相应的psy基因


pepper PSY1
tomato PSY1
tomato PSY2
tomato
daffodil
rice PSY1
maize PSY2
rice PSY2
rice PSY3
96
100
100
100
61
100
10

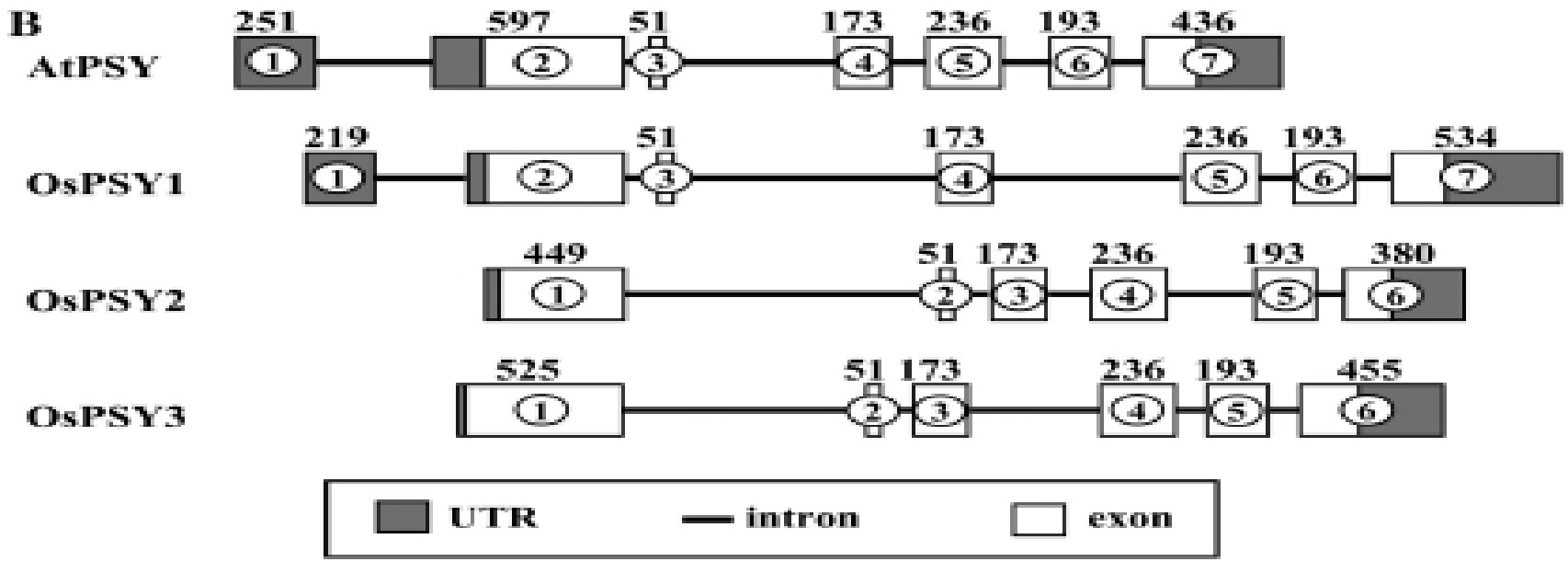
长期以来人们认为玉米和水稻中具有编码PSY的单一基因，但目前已有研究表明，玉米和水稻都具有重复的PSY基因，它们编码在异源细菌系统中测试时发挥功能的结构独特的酶。此外，PSY重复在整个禾本科中普遍存在，这表明该遗传事件先于禾本科的进化。



Gallagher CE, Matthews PD, Li F, Wurtzel ET. Gene duplication in the carotenoid biosynthetic pathway preceded evolution of the grasses. Plant Physiol. 2004 Jul;135(3):1776-83. doi: 10.1104/pp.104.039818. Epub 2004 Jul 9. PMID: 15247400; PMCID: PMC519089.



Gallagher CE, Matthews PD, Li F, Wurtzel ET. Gene duplication in the carotenoid biosynthetic pathway preceded evolution of the grasses. Plant Physiol. 2004 Jul;135(3):1776-83. doi: 10.1104/pp.104.039818. Epub 2004 Jul 9. PMID: 15247400; PMCID: PMC519089.


B
AtPSY
251
597
51
173
236
193
436
OsPSY1
219
51
173
236
193
534
OsPSY2
449
51
173
236
193
380
OsPSY3
525
51
173
236
193
455
UTR
intron
exon

总结

- PSY基因存在冗余现象
- PSY2和PSY3可能是从PSY1进化来的
- PSY控制的类胡萝卜素合成与其他生物合成过程相联系
- PSY基因的亚细胞定位在叶绿体、质体、膜
- PSY基因的表达具有选择性
- PSY的基因分化早于物种分化

公众往往担心转基因食品有害健康，但科学界的共识是此类转基因作物及其副产品的健康安全风险并不高于传统食品，也就是说转基因作物的安全性是可以保证的。对转基因食品的安全评估始于鉴定该食品是否与同类非转基因食品"实质等同"，后者是那些已经被确认无害的传统食品。目前还没有报告宣称转基因食品在人身上造成疾病。虽然针对转基因生物产品的标注在许多国家是强制性的，但美国和加拿大并不执行类似政策，在市场上转基因食品和传统食品是没有差别的

THANK YOU !