

# Στοιχοι της βιοτεχνολογίας φυτών σήμερα “food, feed, fiber”



Φυτά για παραγωγή φαρμακευτικών και άλλων τεχνικών προϊόντων

Plant –made pharmaceuticals και plant-made industrial products  
MP(I)P

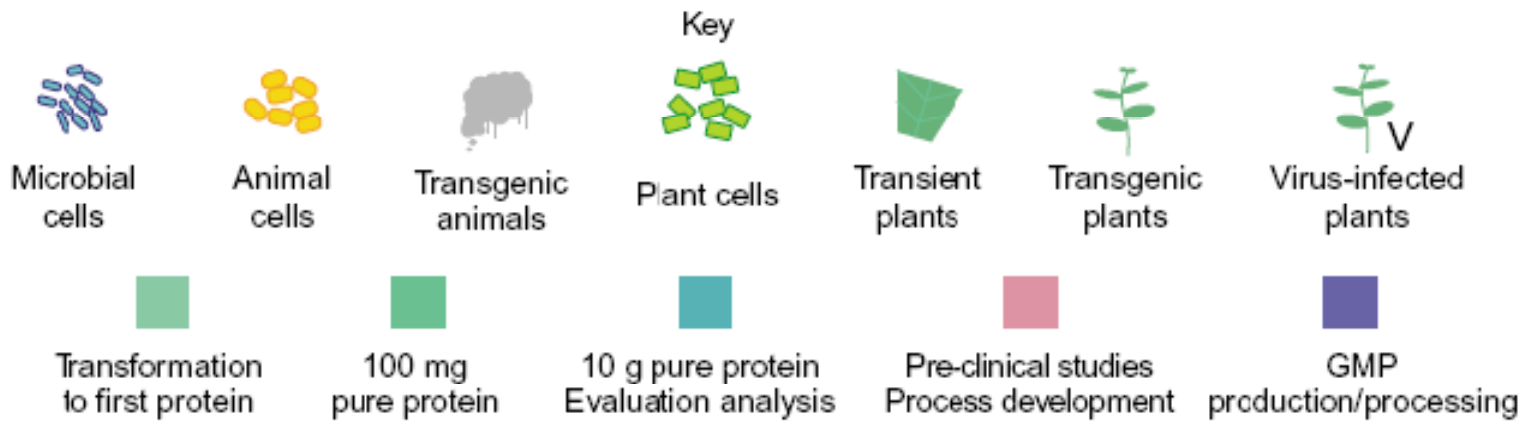
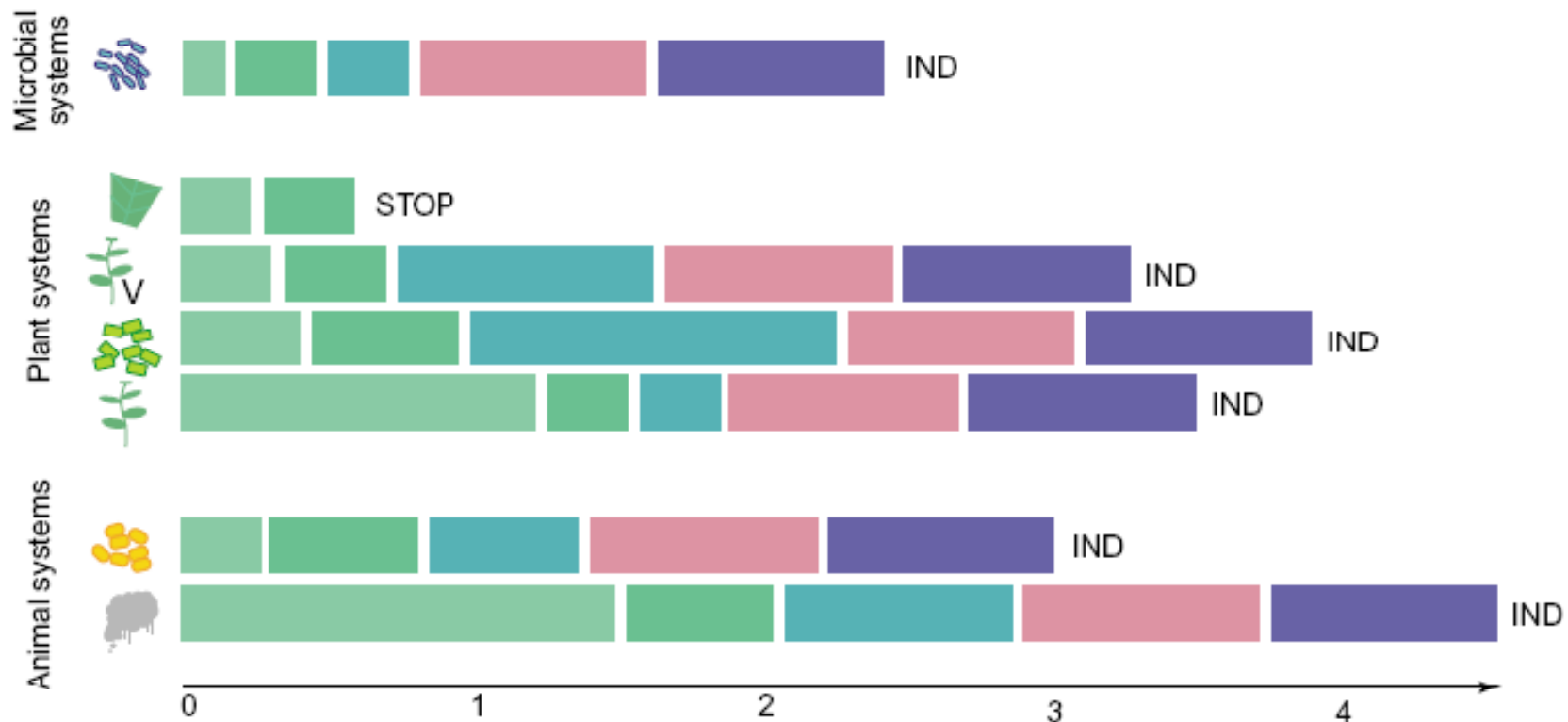
# Βιοτεχνολογικές εφαρμογές- Γ

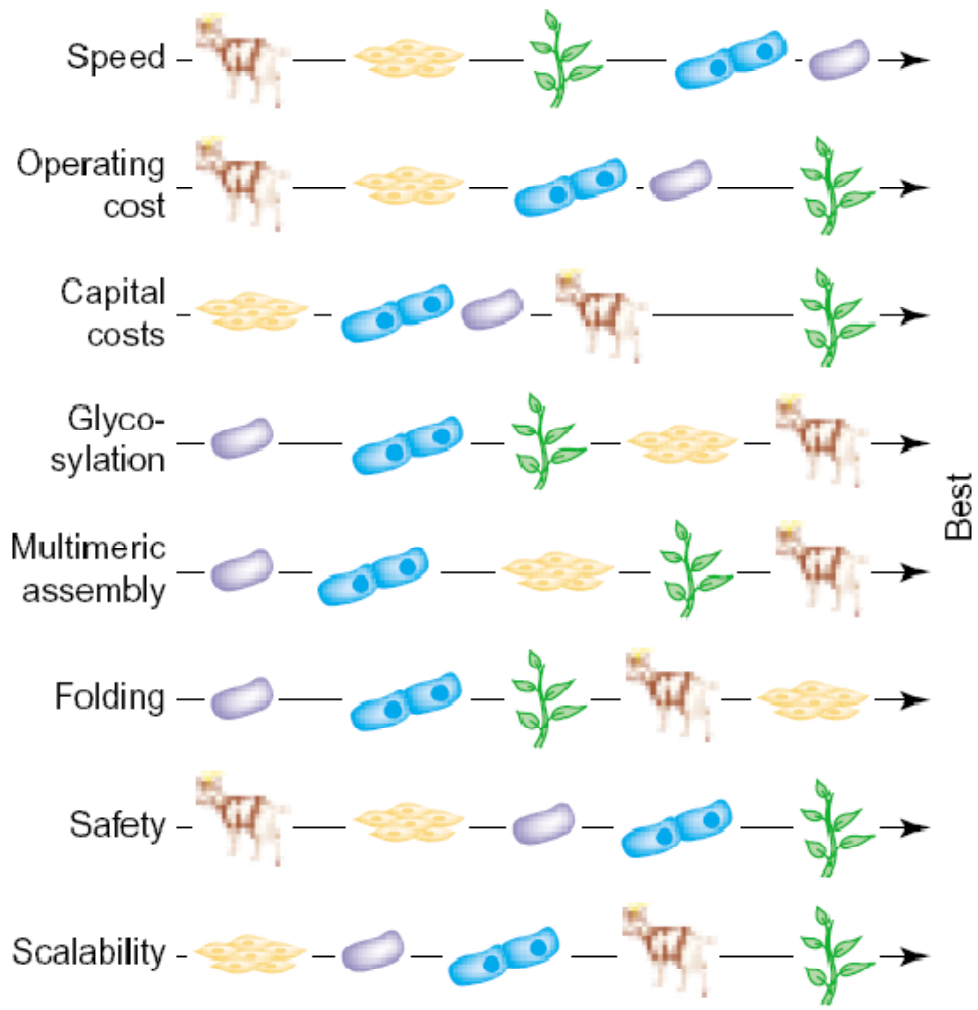
Διαγονιδιακά φυτά για παραγωγή προϊόντων  
(molecular farming/ μοριακή αγροκαλλιέργεια)




- ✓ Εμβόλια- Αντισώματα- άλλα Φαρμακευτικά προϊόντα
- ✓ Βιομηχανικά ένζυμα
- ✓ Βιοπλαστικά

## Πλεονεκτήματα

- ✓ Μεγάλη βιομάζα με μικρό κόστος επέκτασης παραγωγής
- ✓ Απουσία παθογόνων και μη επιθυμητών DNA αλληλουχιών
- ✓ Ορθή μετα-μεταφραστική τροποποίηση πρωτεϊνών (αναδίπλωση, αποθήκευση για σταθερότητα, γλυκοσυλίωση??? κτλ)
- ✓ Ο καθαρισμός δεν είναι απαραίτητος





 Bacteria     
  Yeast     
  Plants  
 Mammalian cell culture     
  Transgenic animals

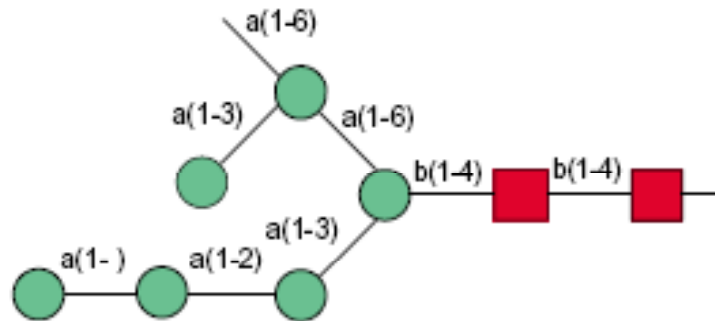
## Προβλήματα

- ✓ Γλυκοσυλίωση
- ✓ Διαφυγή διαγονιδίων και επιπτώσεις στο περιβάλλον
- ✓ Είσοδος στις τροφικές αλυσίδες

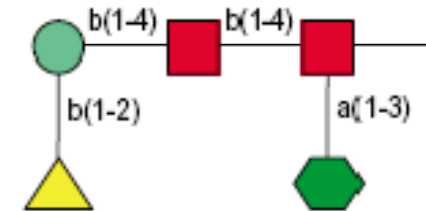


- περιορισμός στις μονάδες παραγωγής
- χρήση επαγωγικών συστημάτων έκφρασης
- χρήση φαινοτυπικών δεικτών

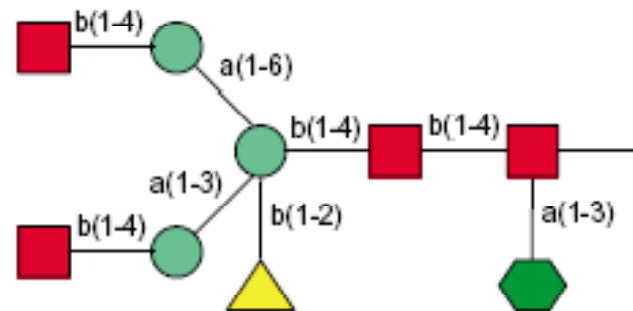
(a) High-mannose type



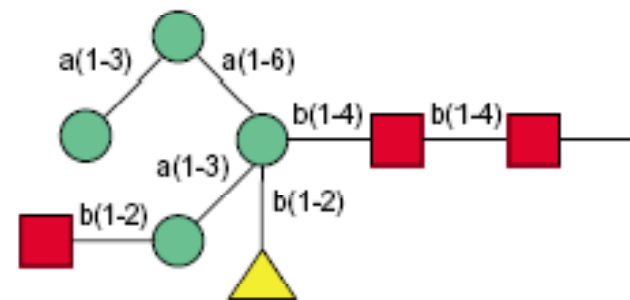
(b) Short-chain complex type



(c) Long-chain complex type



(d) Hybrid type



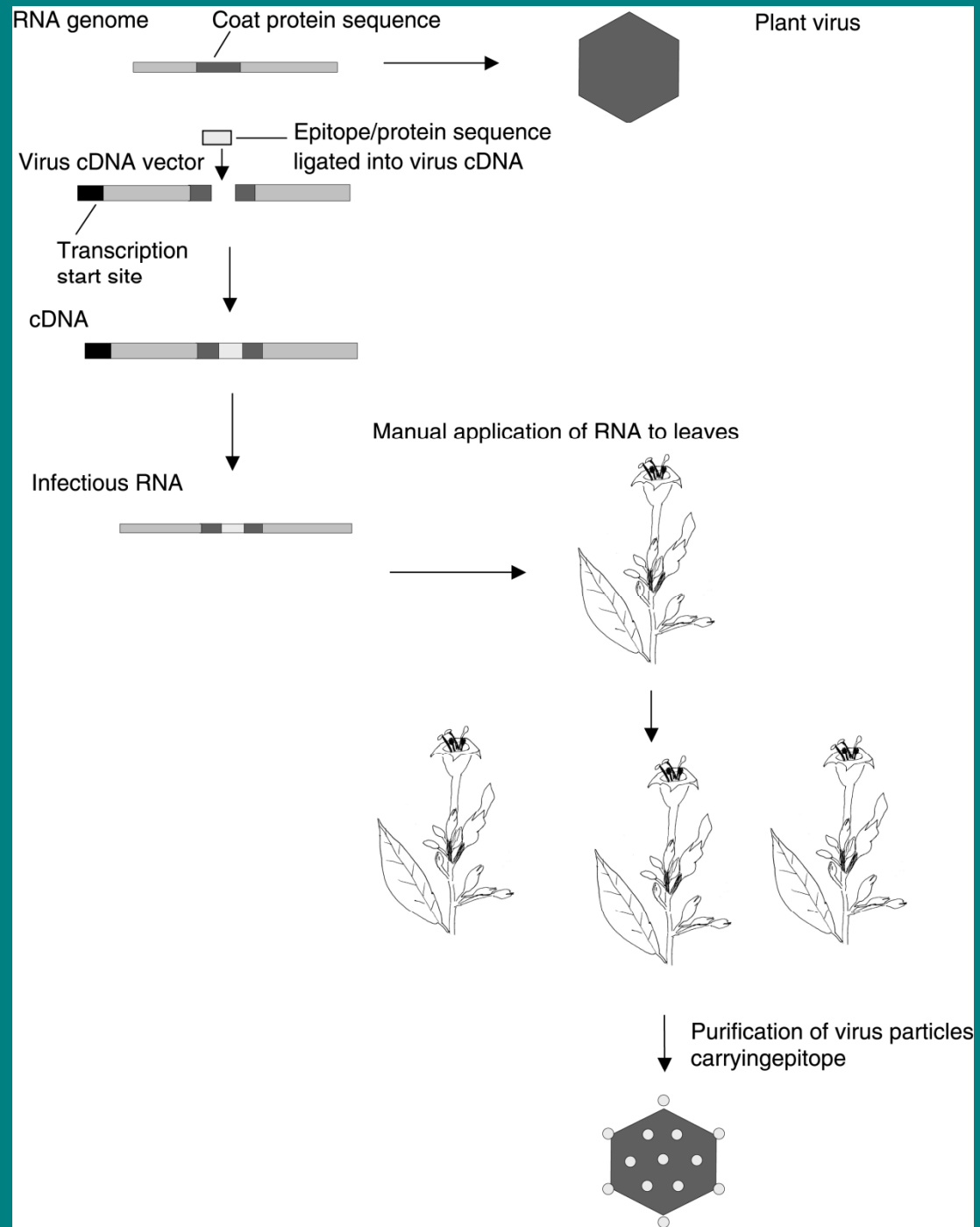
## Στρατηγικές για μαζική παραγωγή πρωτεϊνών

✘ Σταθερή έκφραση κυρίως υπό εξειδικευμένους για ιστούς και υποκυτταρικά οργανίδια προαγωγείς (σπόροι, κόνδυλοι, ER, πλαστίδια, σύντηξη με πρωτεΐνες έκκρισης, ολεοσίνες κτλ)

Πχ παραγωγή hirudin σε ελαιοσωμάτια *Brassica napus* σε σύντηξη με ολεοσίνη από *Arabidopsis*

✘ Παροδική έκφραση με χρήση ιών ως φορείς

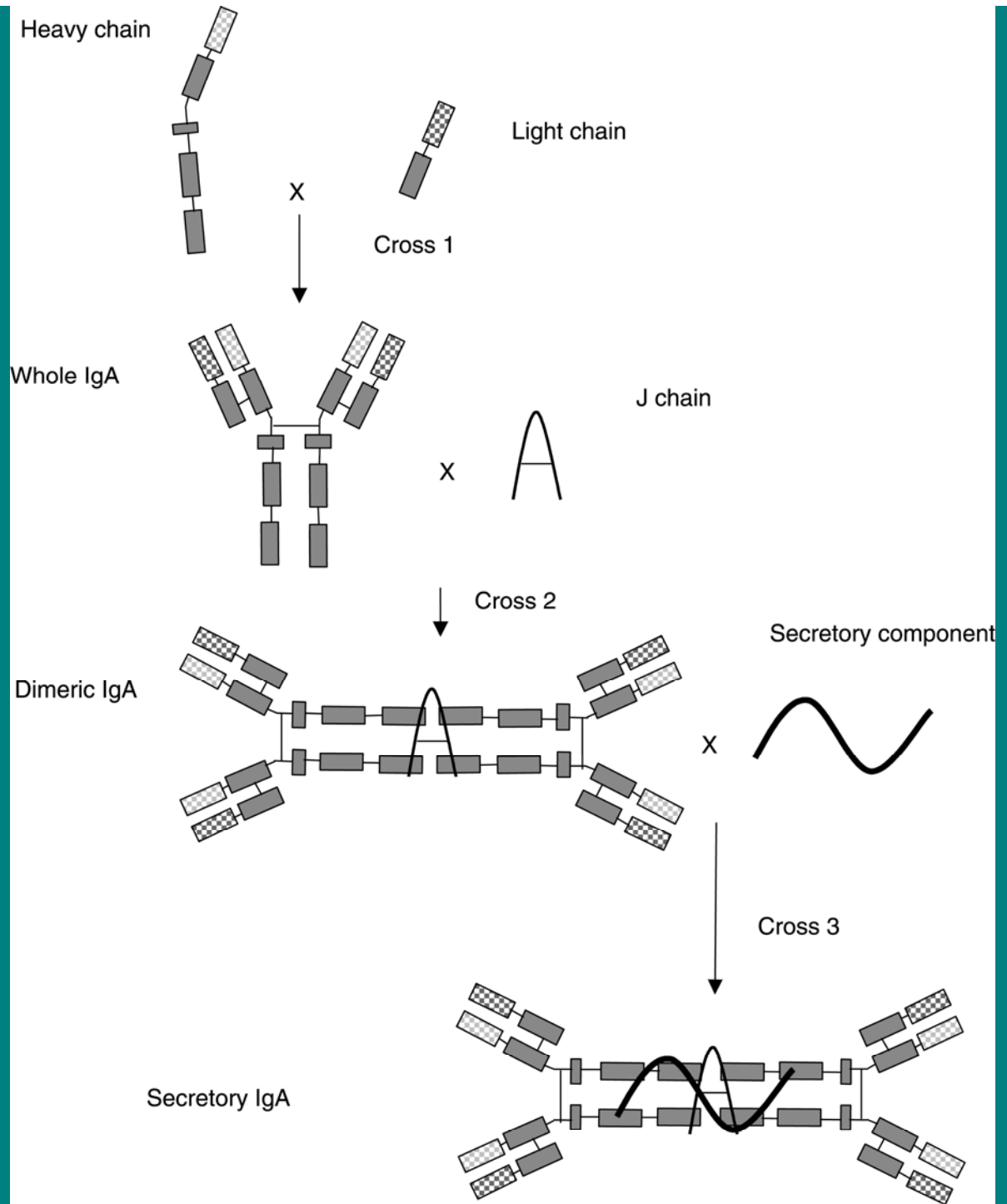


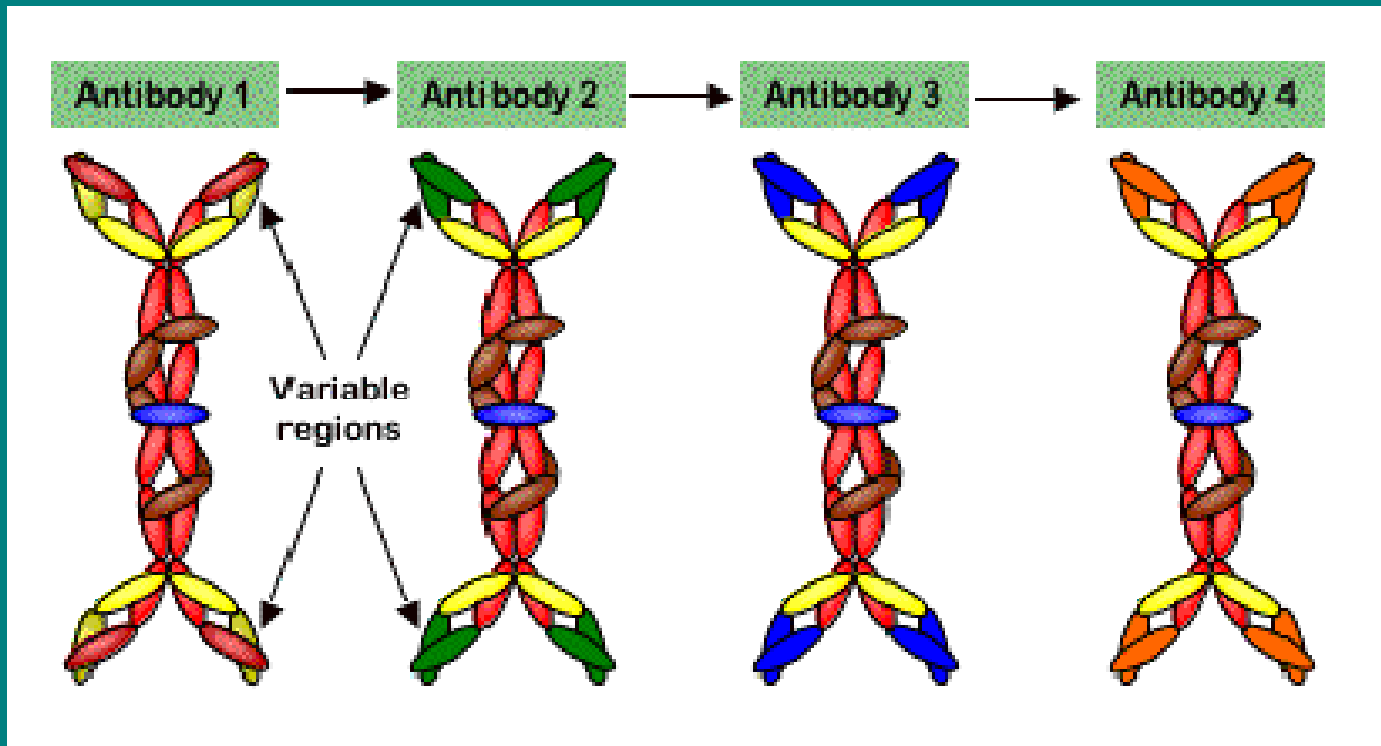


# Παραγωγή sIgA

Σταθερή έκφραση υπό 35S και στόχευση στο ER για ορθή σύνδεση, γλυκοσυλίωση κτλ

## Plantibodies





DoxoRx™

RhinoRx™ *Planet Biotechnology*

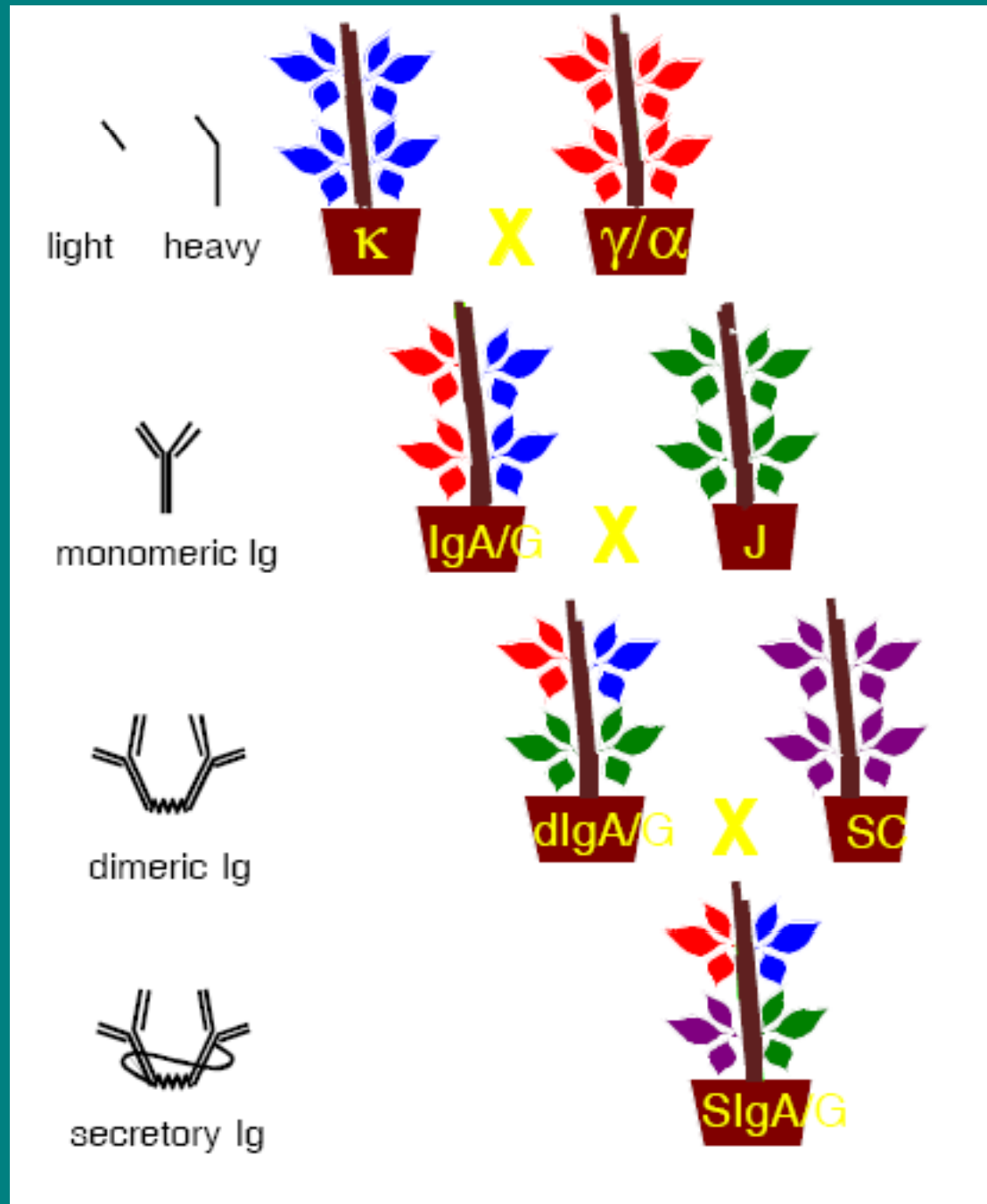
CaroRx™

*Planet Biotechnology*

**DoxoRx™**

**RhinoRx™**

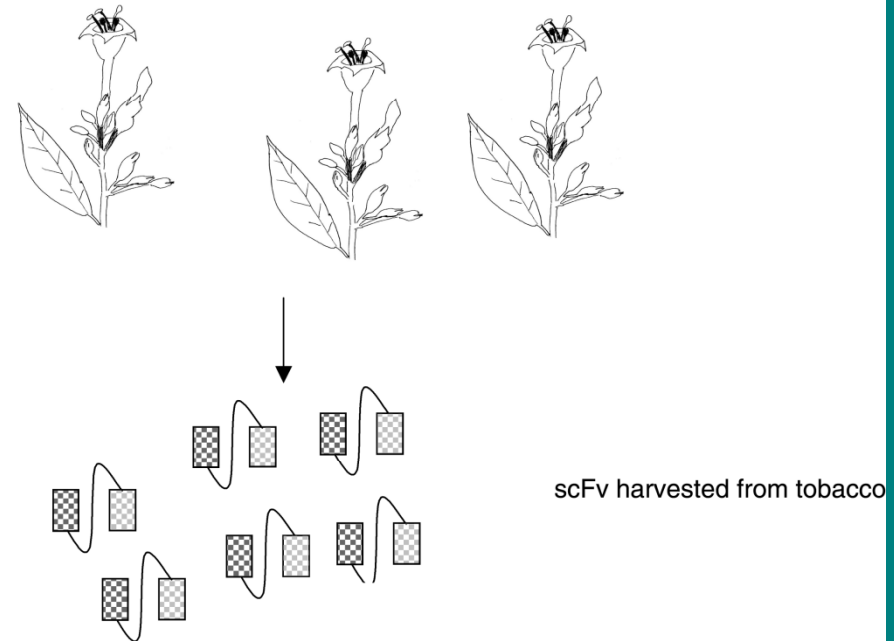
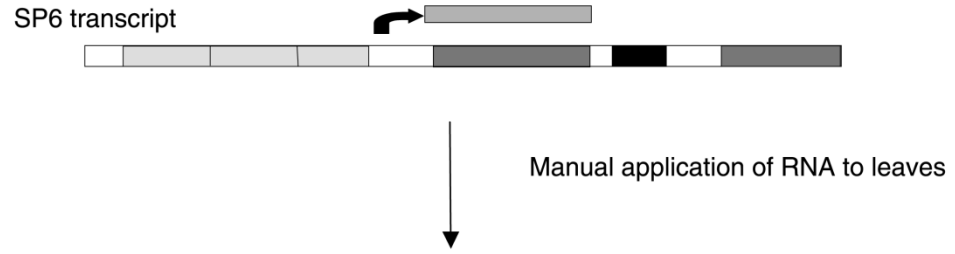
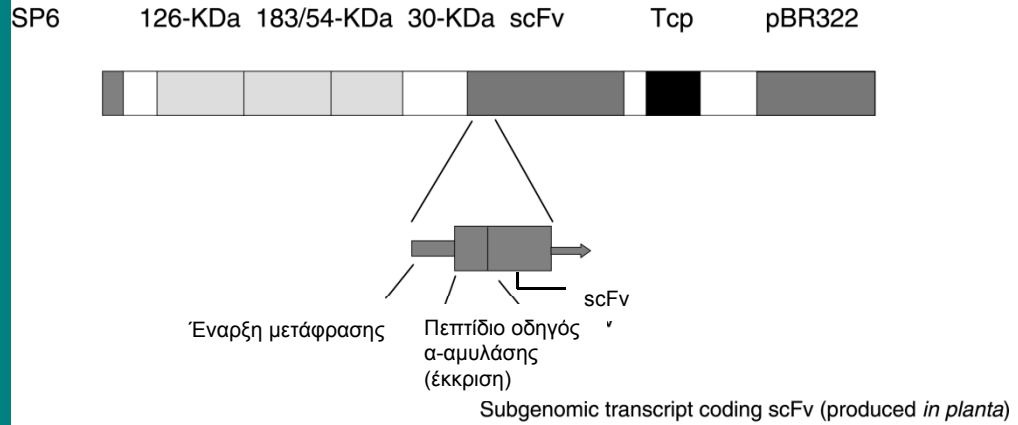
**CaroRx™**

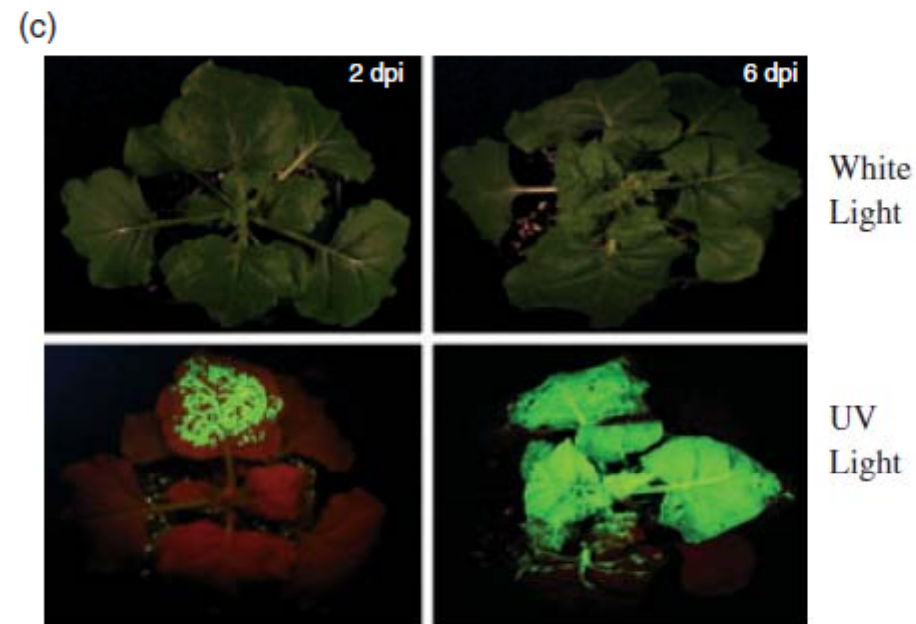
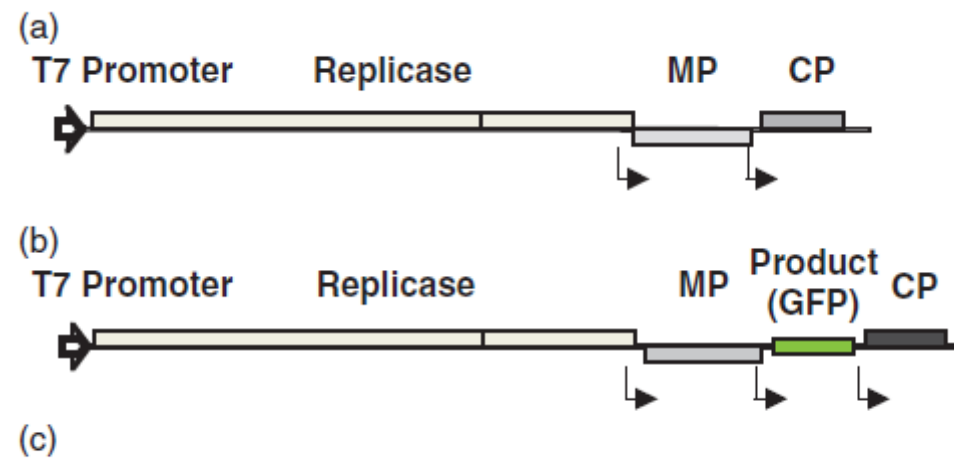


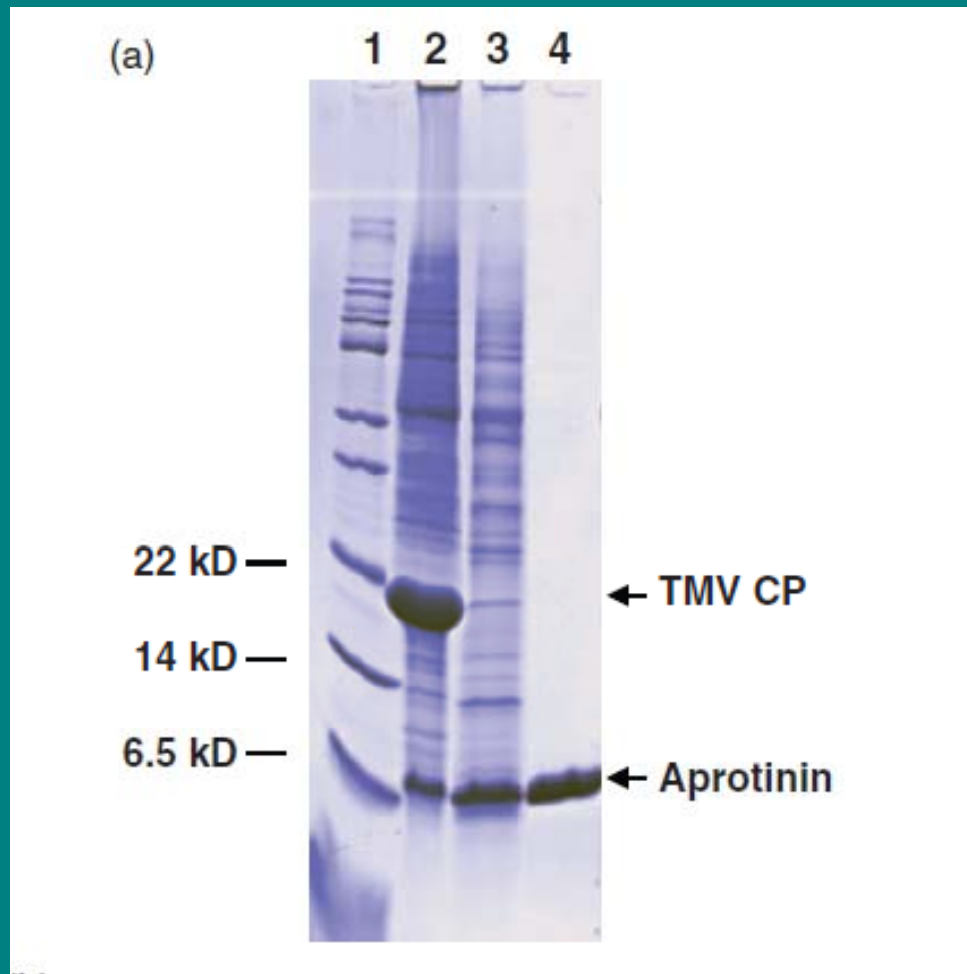
# Παραγωγή scFv

Παροδική έκφραση με  
χρήση ιικού TMV φορέα σε  
μη διαγονιδιακά φυτά

Modified TTO1A TMV chimeric vector containing scFv sequence







**From the Cover: Rapid high-yield expression of full-size IgG antibodies in plants coinfecting with noncompeting viral vectors**

Anatoli Giritch, Sylvestre Marillonnet, Carola Engler, Gerben van Eldik, Johan Botterman, Victor Klimyuk, and Yuri Gleba

*PNAS* 2006;103;14701-14706; originally published online Sep 14, 2006;  
doi:10.1073/pnas.0606631103

## Monoclonal antibodies from plants: A new speed record

Andrew Hlatt\* and Michael Pauly

*Mapp Biopharmaceutical, Inc., 6160 Lusk Boulevard, CT05, San Diego, CA 92121*

**T**he medical use of mAbs has grown tremendously since the first mAb, Orthoclone, was approved in 1986 for treatment of transplant rejection. In addition to immunosuppressive therapy, mAbs have proven useful as treatments for rheumatoid arthritis, transplant rejection, inflammatory diseases, and a variety of cancers. The market for medical mAbs

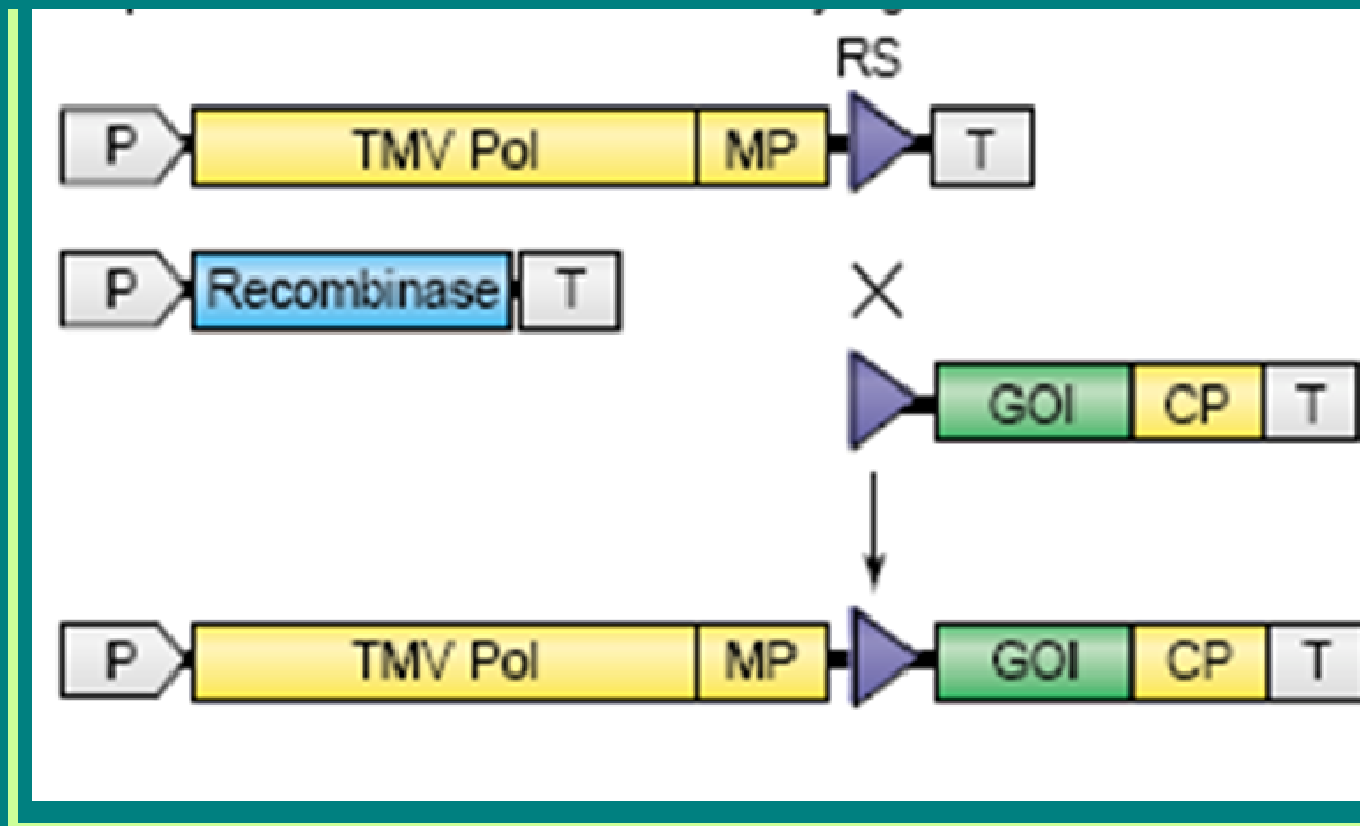
Table 1. Transient plant technology: The advantage of magnification

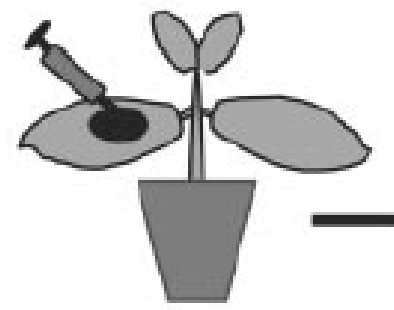
| Expression system        | Time to milligrams of mAb | Time to grams of mAb |
|--------------------------|---------------------------|----------------------|
| Mammalian cell culture*  | 2–6 months                | 6–12 months          |
| Transgenic animals       | >12 months                | >12 months           |
| Stable transgenic plants | 12 months                 | >24 months           |
| Magnification            | 14 days                   | 14–20 days           |

\*Values are based on direct quotes from contract manufacturers.

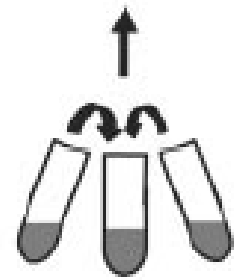


Σύστημα προ-φορέα για τη συγκρότηση ικών amplicons *in planta* μετά τη μεταφορά με *Agrobacterium*

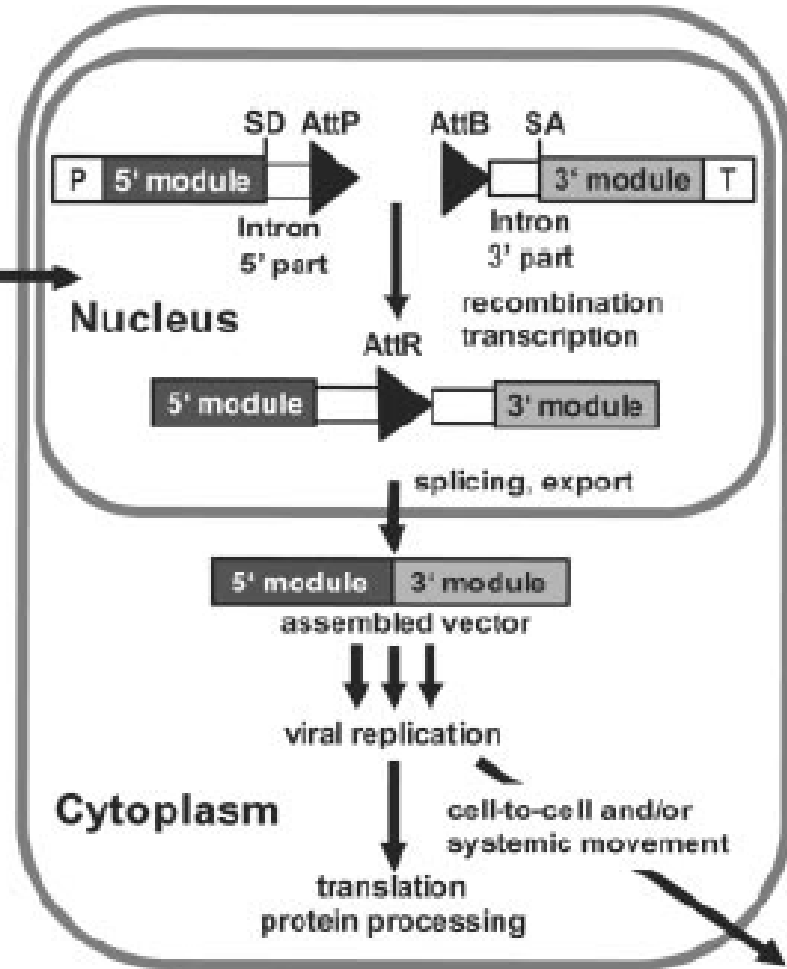




agroinfiltration of *Nicotiana benthamiana*



mixing of *Agrobacterium* strains carrying provector modules



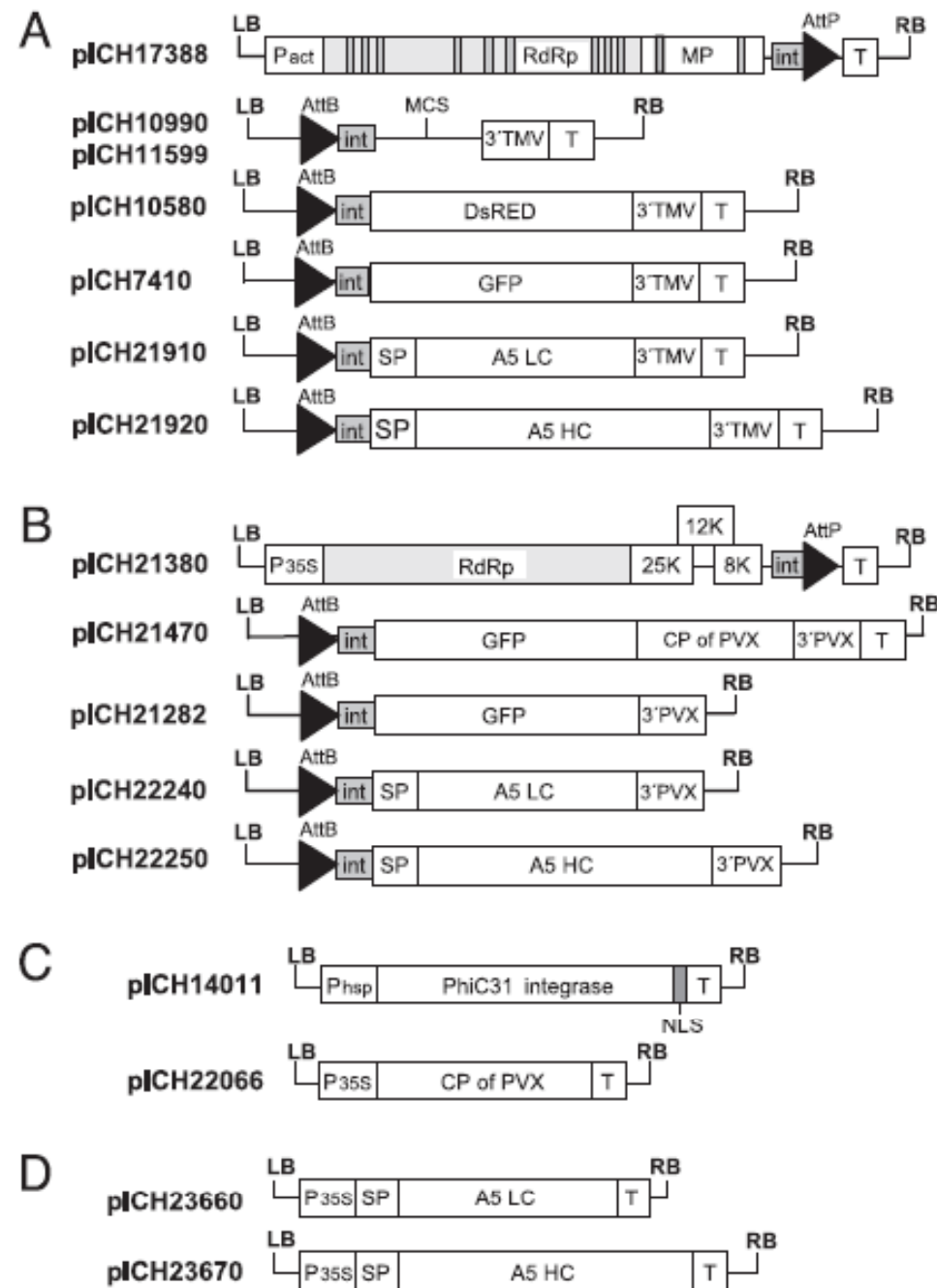
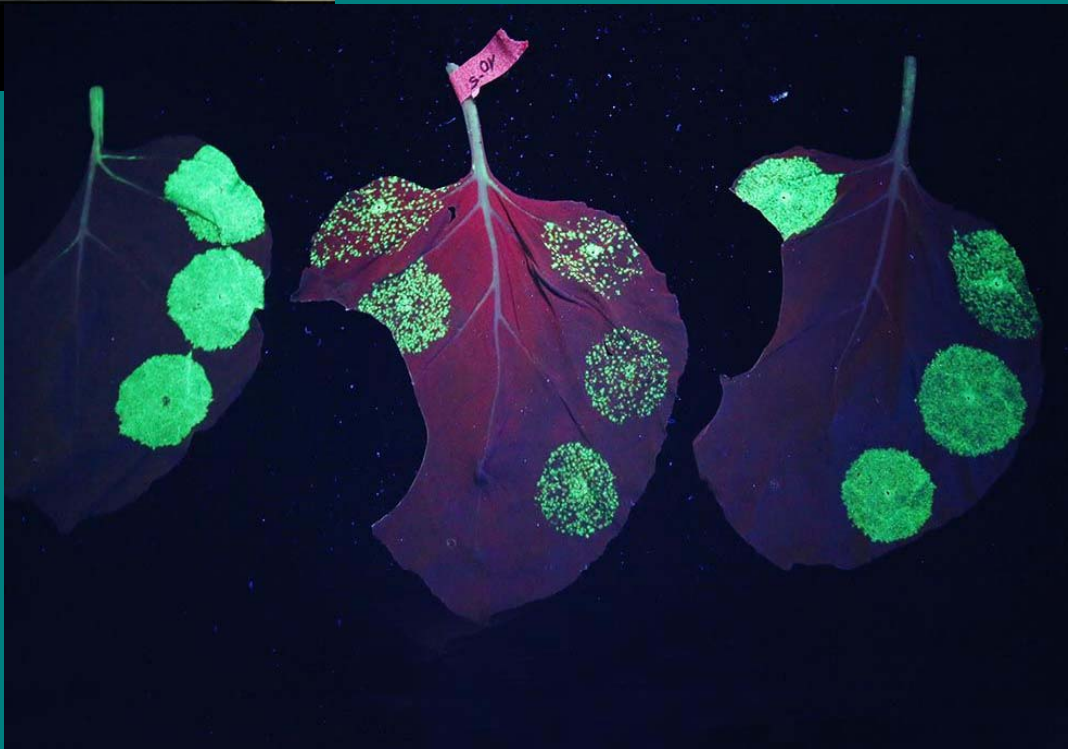
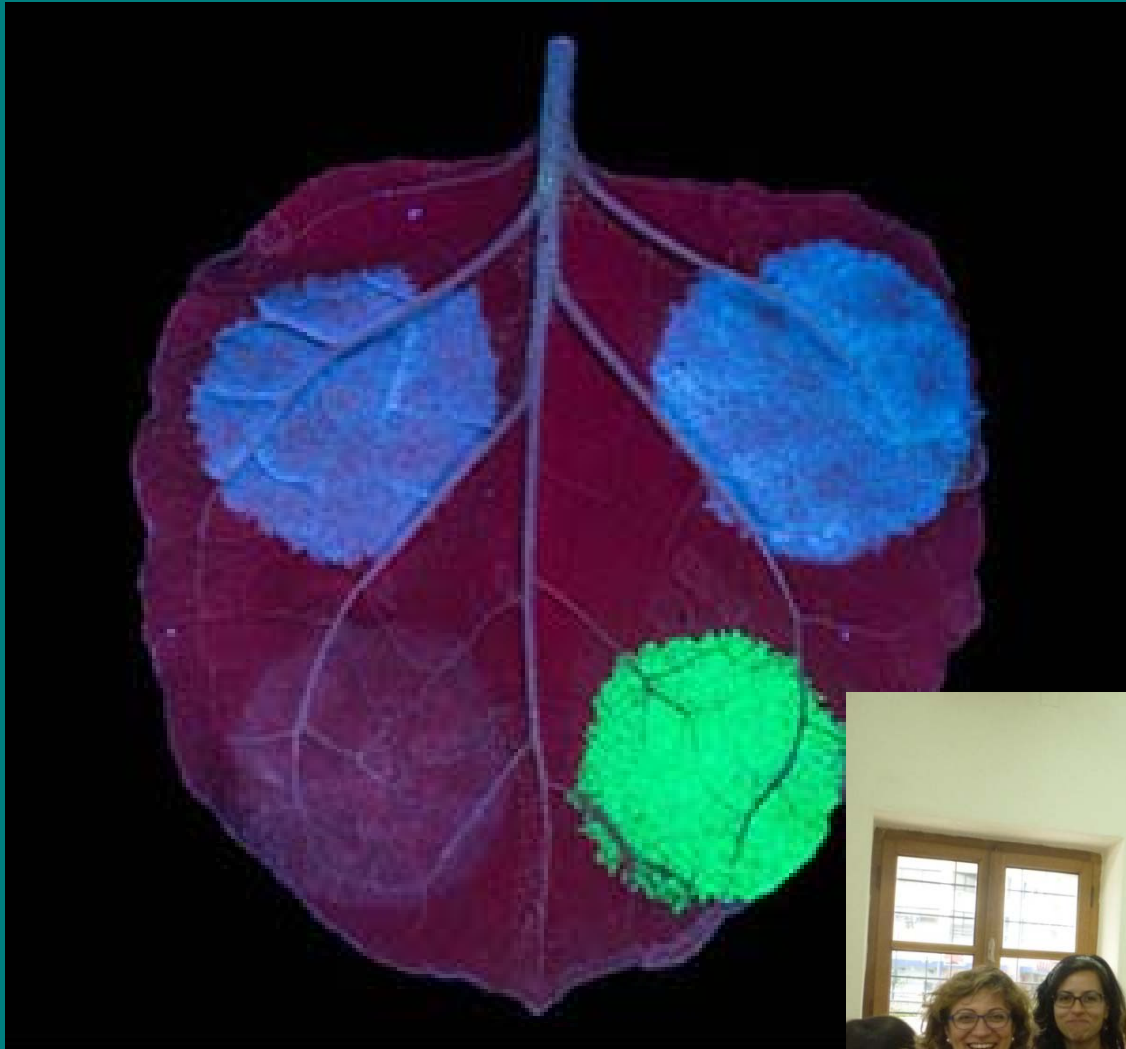


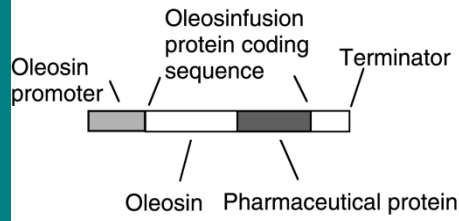
Fig. 1. Plasmid constructs. (A) TMV-based provectors: 5' module pICH17388



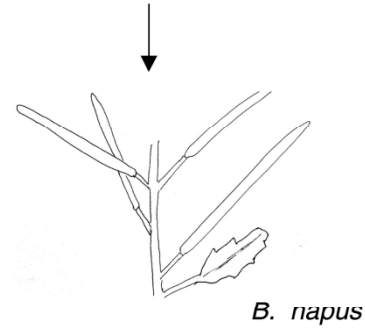




Structure of transgene inserted into *B. napus*



Expression in transgenic plant-  
protein targeted to oil bodies



Crushed siliqua

Plant material



Centrifuge



Plant debris

Oil body

Transferred to fresh tube

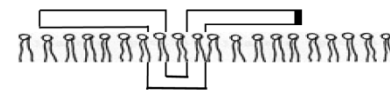
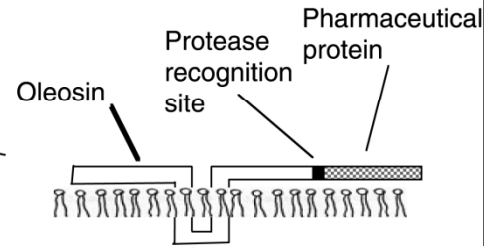


Treated with protease



Oil body at surface

Pharmaceutical  
protein in  
soluble  
fraction



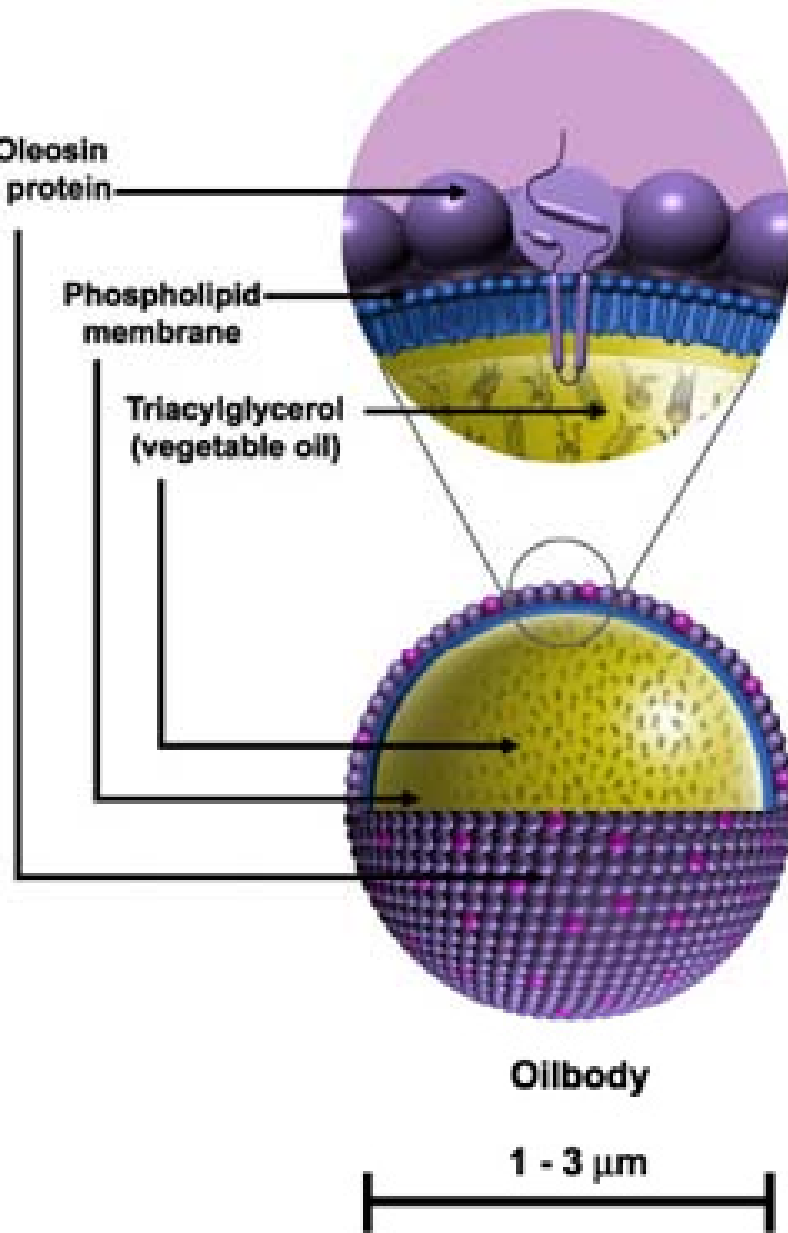
Oleosin  
protein

Phospholipid  
membrane

Triacylglycerol  
(vegetable oil)

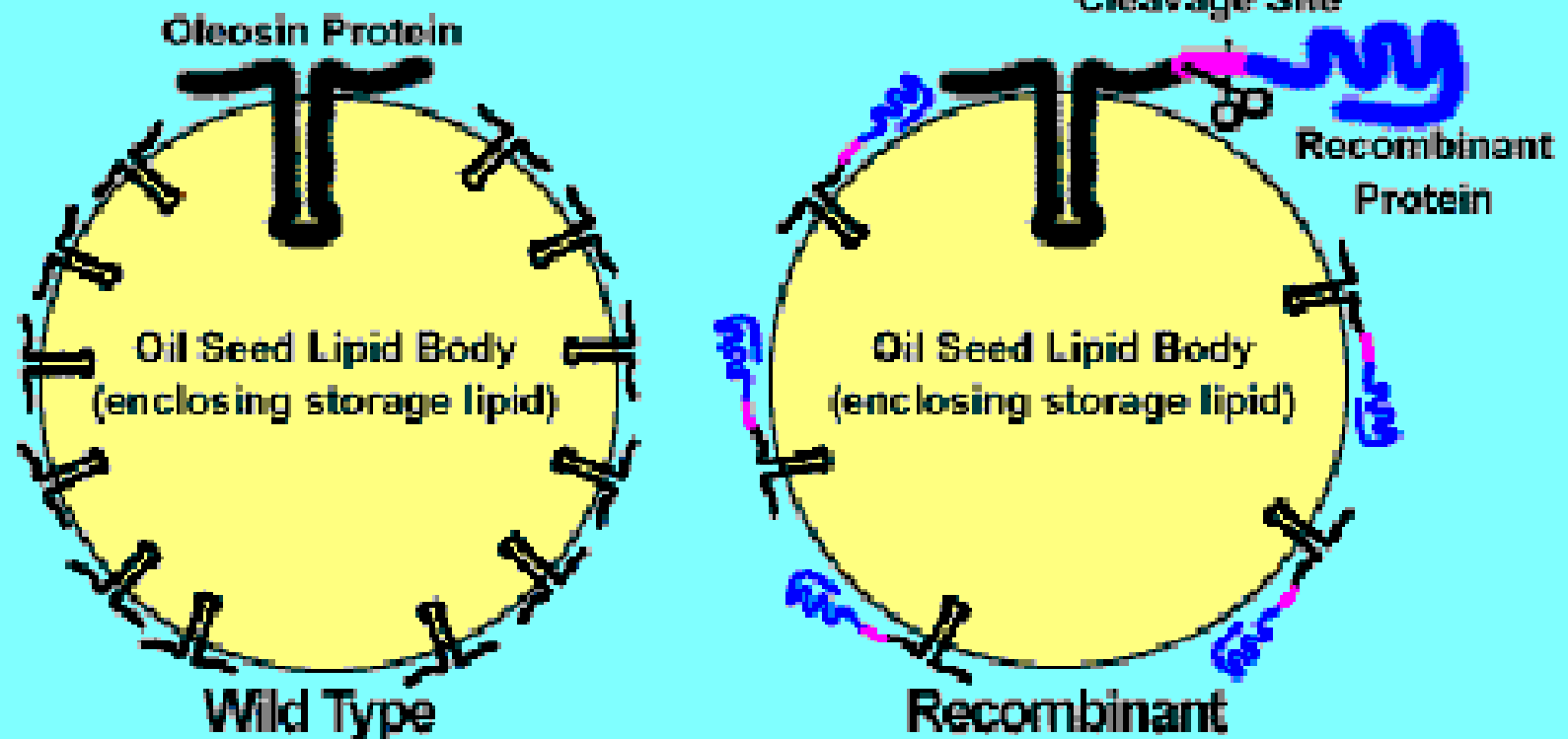
Oilbody

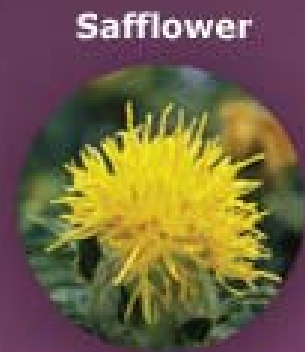
1 - 3  $\mu\text{m}$



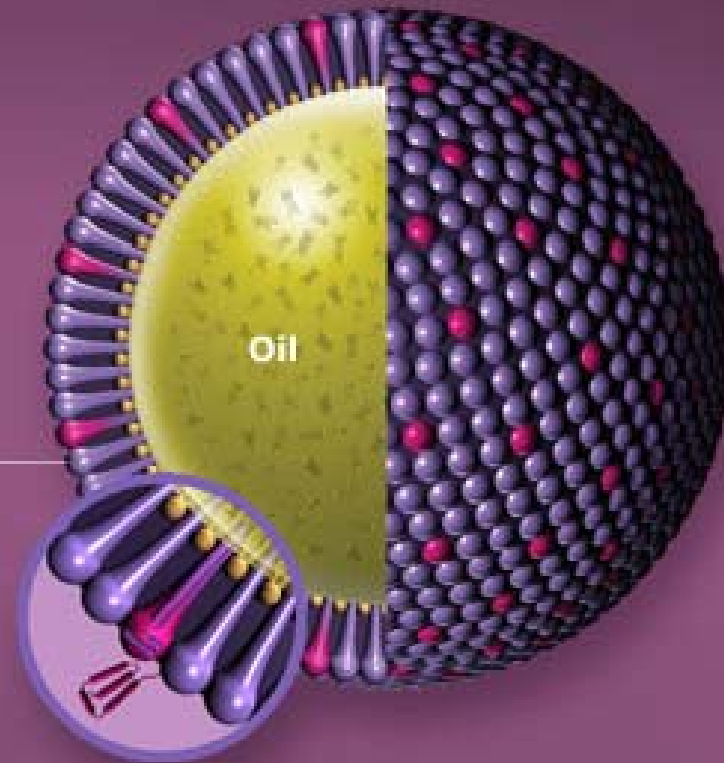


## Cytosol or Aqueous Extraction Media





**Oilbody**

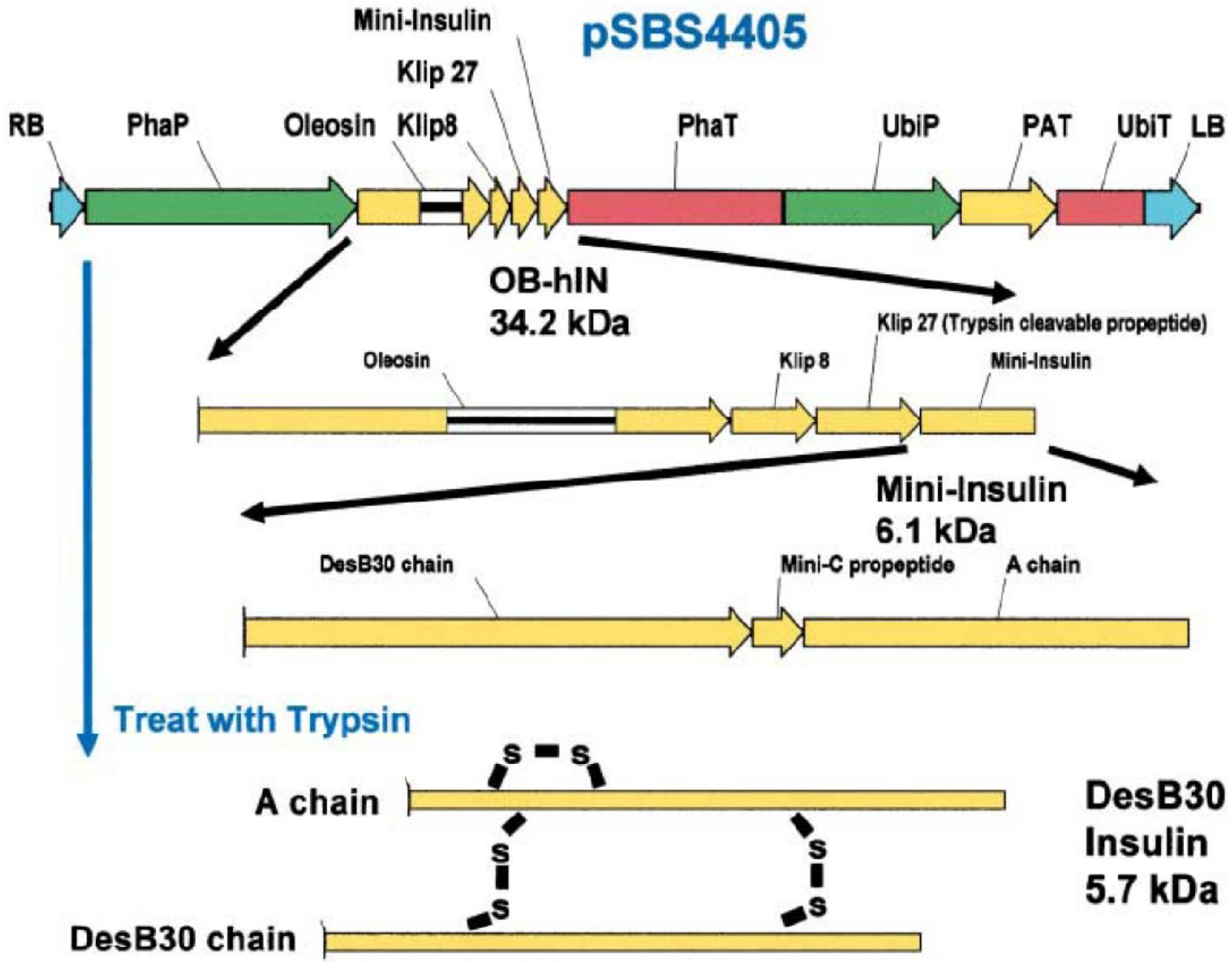


**Proteins**

**Oilbody:**

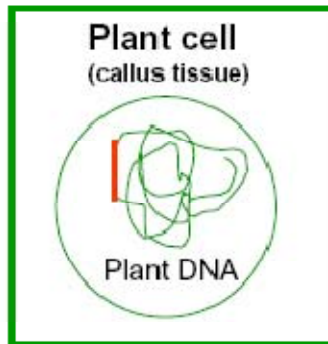
A seed structure with a protein coat that stores energy for germination in the form of oil.

Click to close



Human insulin from *Arabidopsis thaliana* seeds

# The LEX System from Gene to GMP Production



Protein gene sequence  
transferred to DNA of Lemna



Lemna  
regenerates



Separate and  
propagate lines

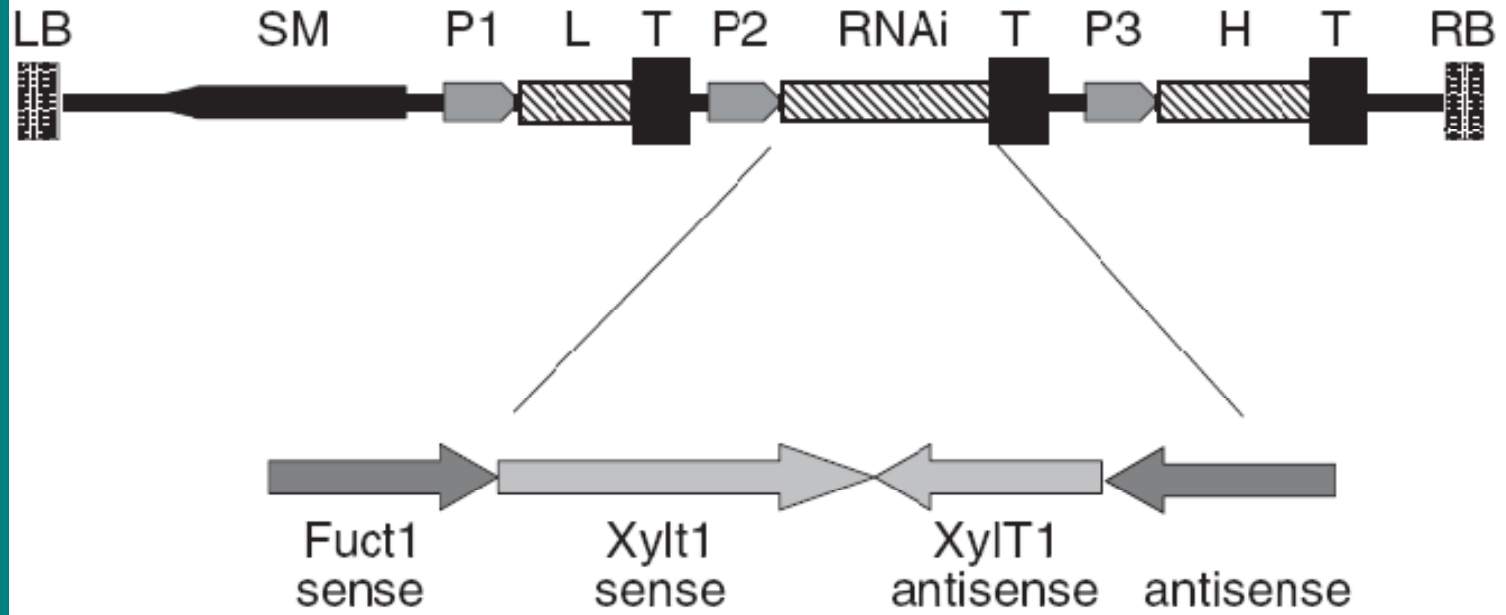











Line Screening:  
Analyze expression  
Select line for scale-up



Scale-up in GMP facilities

# MDXA04 expression vector



| N-glycan name <sup>a</sup>             | Proposed structure <sup>b</sup>   |
|--|---|
| <b>CHO</b>                             |   |
| GnGnF <sup>6</sup> -2AA                |    |
| Man <sup>5</sup> -2AA                  |    |
| GnA <sub>iso</sub> F <sup>6</sup> -2AA |    |
| AAF <sup>6</sup> -2AA                  |    |
| <b>LEX</b>                             |   |
| GnGn-2AA                               |    |
| GnGnX-2AA                              |    |
| GnGnXF <sup>3</sup> -2AA               |  |
| <b>LEX<sup>Opt</sup> (no. 52)</b>      |   |
| GnGn-2AA                               |  |
| <b>LEX<sup>Opt</sup> (no. 225)</b>     |   |
| GnGn-2AA                               |  |

# Βιομηχανικά Ένζυμα

Avidin/  $\beta$ -glucuronidase

trypsin

κυτταρινάσες

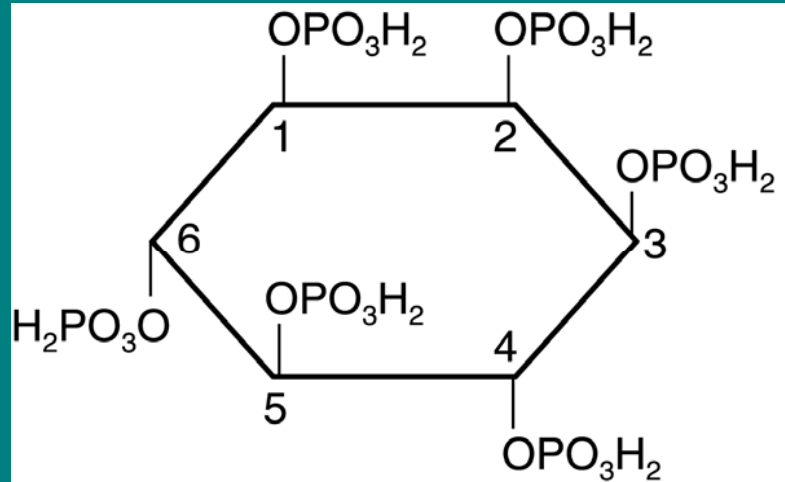
ξυλανάσες

υπεροξειδάση της λιγνίνης

$\alpha$ -αμυλάση

$\beta$ -γλουκανάση

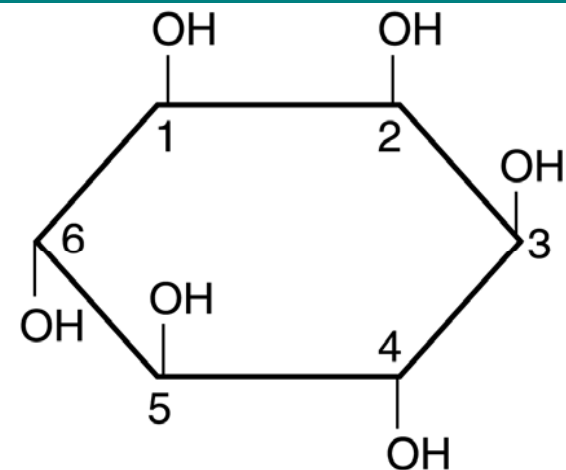
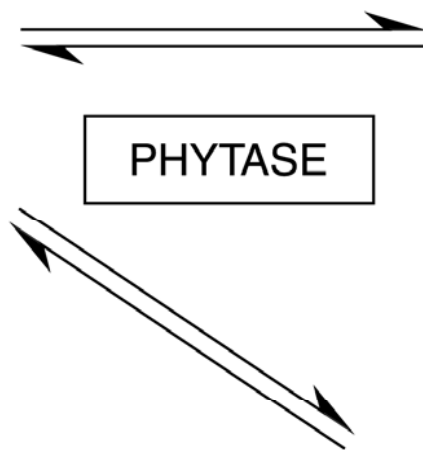
φυτάση



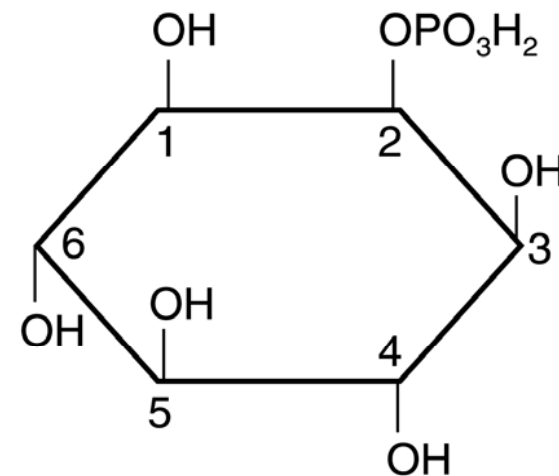
Phytate

myo-inositol 1,2,3,4,5,6-hexakis dihydrogen orthophosphate

εξαφωσφορική ινοσιτόλη



Inositol



Inositol monophosphate



# Εμβόλια- Αντισώματα- άλλα Φαρμακευτικά προϊόντα

## Εμβόλια

|                        | Ανασυνδρασμένη πρωτεΐνη | Φυτό               |
|------------------------|-------------------------|--------------------|
| Άνθρωπος               |                         |                    |
| <i>E. coli</i>         | enterotoxin B           | καπνός             |
| <i>Vibrio cholerae</i> | CtoxA / CtoxB           | πατάτα             |
| Hepatitis B            | envelope surface prot.  | πατάτα             |
| Norwalk virus          | capsid prot.            | πατάτα             |
| Rabies virus           | glycoprotein            | ντομάτα            |
| Ζώα                    |                         |                    |
| Foot and mouth virus   | VP1                     | μηδική             |
| Porcine coronavirus    | glycoprotein            | καλαμποκι          |
| Mink enteritis virus   | VP2                     | φασόλι             |
| Canine parvovirus      | VP2                     | <i>Arabidopsis</i> |

# Εμβόλια- Αντισώματα- άλλα Φαρμακευτικά προϊόντα

## Αντισώματα

|  | Φυτό                 | Αντίσωμα                        |
|--|----------------------|---------------------------------|
| <b>Ig</b>  |                      |                                 |
| <i>Streptococcus mutans</i><br>SA I/II (τερηδόνα)                                  | καπνός               | sIgA (hybrid)                   |
| <i>S.mutans</i> SA I/II ( <i>CaroRX</i> )<br>Surface antigen<br>(καρκίνος εντέρου) | καπνός               | IgG (guy's 13)                  |
| Herpes simplex virus   | καπνός<br>σόγια      | IgG Co17-1A<br>IgG (anti HSV-2) |
| <b>Single-chain Fv</b>   |                      |                                 |
| Lymphoma<br>Carcinoembryonic antigen   | καπνός<br>δημητριακά | scFv (38C13)<br>scFvT84.66      |

# Εμβόλια- Αντισώματα- άλλα Φαρμακευτικά προϊόντα

## Φαρμακευτικά προϊόντα

| Προέλευση                       | Ανασυνδυασμένη πρωτεΐνη   | Φυτό  | Εφαρμογή  |
|---------------------------------|---|---|---|
| Άνθρωπος                        | Protein C<br>β-interferon<br>serum albumin<br>haemoglobin α/β<br>hototrimeric<br>collagen<br>antitrypsin<br>apotrinin<br>lactoferrin<br>ACE<br>enkephalin | καπνός<br>ρύζι/ καπνός<br>καπνός<br>καπνός<br>καπνός<br>καπνός<br>ρύζι<br>καλαμπόκι<br>πατάτα<br>ντομάτα<br>Arabidopsis | anticoagulant<br>θεραπεία ηπατίτιδας<br><br>cystic fibrosis<br>μεταμοσχεύσεις<br>αντιμικροβιακή<br>hypertension<br>opiate |
| <i>Hirudo medicinalis</i>       | hirudin   | ελαιοκράμβη   | anticoagulant   |
| <i>Trichosanthes kirilowwii</i> | trichosanthin   | καπνός  | θεραπεία καρκίνου,<br>HIV   |

**Table 5. Examples of plant-based expression systems used for pharmaceutical protein production**

| System                                       |                 | Protein                | Expression     | Company <sup>a</sup>   |
|--|-----------------|------------------------|----------------|--|
| <b>Stable nuclear transformation systems</b> |                 |                        |                |  |
| Whole plant (cytosolic)                      |                 | HbsAg, vaccine [65]    | 0.007% TSP     | AltaGen Bioscience Inc. (potato)   |
|  |                 | collagen [66]          | 1 mg/g DW      | CropTech Corp. (tobacco)<br>Medicago Inc. (alfalfa)<br>Meristem Therapeutics (tobacco)   |
| Cellular compartment                         | Vacuole         | scFv, hepatitis B [67] | 0.032% TSP     | PlantGenix Inc. (not reported)   |
|  |                 | slgA/G [68]            | not reported   |  |
|  | ER              | scFv, cutinase [69]    | 1% TSP         | Novoplant GmbH (tobacco)   |
|  |                 | scFv, T84.66 [70]      | 29 µg/g FW     |  |
| Apoplast                                     |                 | scFv, ABA [71]         | 6.8% TSP       | EpicYTE Pharmaceutical Inc. (tobacco)  |
|  |                 | IgG1 [55]              | 1.3% TSP       |  |
|  |                 | IgA/G [72]             | 500 µg/g FW    |  |
| Tissue-specificity                           | Seed            | IgG1, Fab [73]         | 13% ISP        | ProdiGene Inc. (corn)<br>SemBioSys Genetics Inc. (canola)<br>Applied Phytologics Inc. (rice)<br>EpicYTE Pharmaceutical Inc. (corn)<br>IPT, Monsanto (corn)<br>Meristem Therapeutics (rape)<br>Meristem Therapeutics (potato) |
|  |                 | avidin [74]            | 6% TSP         |  |
|  |                 | hirudin [61]           | 1% FW          |  |
|  | Tuber           | scFv, oxalozone [75]   | 2% TSP         |  |
|  | Root            | IgM, RKN [76]          | 0.003% TSP     |  |
|  | Fruit           | RSV-F protein [77]     | not reported   |  |
|  | Exudate         | human SEAP [62]        | 20 µg/g DW/day |  |
|  | human SEAP [63] | 2.8% TEP               |                |  |
| <b>Stable plastid transformation system</b>  |                 |                        |                |  |
| Chloroplast                                  |                 | somatotropin [78]      | 7% TSP         |  |
| <b>Transient transformation system</b>       |                 |                        |                |  |
| Viral  |                 | α-trichosanthin [79]   | 2% TSP         | Large Scale Biology Corp. (tobacco)  |

Abbreviations: DW, dry weight; ER, endoplasmic reticulum; FW, fresh weight; ISP, intercellular soluble protein; TEP, total exuded protein; TSP, total soluble protein.

<sup>a</sup>Companies sharing a row with a protein and reference are sources of this information.

**Table 1** | Plant-derived pharmaceutical proteins that are closest to commercialization for the treatment of human diseases

| Product                                     | Class              | Indication                    | Company/Organization                                    | Crop                          | Status   |
|---|--------------------|-------------------------------|---|-------------------------------|----------|
| Various single-chain Fv anti-body fragments | Antibody           | Non-Hodgkin's lymphoma        | Large Scale Biology Corp                                | Viral vectors in tobacco      | Phase I  |
| CaroRx                                      | Antibody           | Dental caries                 | Planet Biotechnology Inc.                               | Transgenic tobacco            | Phase II |
| <i>E. coli</i> heat-labile toxin            | Vaccine            | Diarrhoea                     | Prodigene Inc.  | Transgenic maize              | Phase I  |
|   |                    |                               | Arntzen group (Tacket <i>et al</i> , 1998)              | Transgenic potato             | Phase I  |
| Gastric lipase                              | Therapeutic enzyme | Cystic fibrosis, pancreatitis | Meristem Therapeutics                                   | Transgenic maize              | Phase II |
| Hepatitis B virus surface antigen           | Vaccine            | Hepatitis B                   | Arntzen group (Richter <i>et al</i> , 2000)             | Transgenic potato             | Phase I  |
|   |                    |                               | Thomas Jefferson University/ Polish Academy of Sciences | Transgenic lettuce            | Phase I  |
| Human intrinsic factor                      | Dietary            | Vitamin B12 deficiency        | Cobento Biotech AS                                      | Transgenic <i>Arabidopsis</i> | Phase II |
| Lactoferrin                                 | Dietary            | Gastrointestinal infections   | Meristem Therapeutics                                   | Transgenic maize              | Phase I  |
| Norwalk virus capsid protein                | Vaccine            | Norwalk virus infection       | Arntzen group (Tacket <i>et al</i> , 2000)              | Transgenic potato             | Phase I  |
| Rabies glycoprotein                         | Vaccine            | Rabies                        | Yusibov <i>et al</i> (2002)                             | Viral vectors in spinach      | Phase I  |

**Table 2. European companies and organisations active in molecular farming<sup>a</sup>**

| Company or Organization                         | Plant host(s)  | Products or Indications  |
|---|--|--|
| Agrevec, Spain                                  | <i>Brassica</i> (viral expression)   | Contract manufacturing   |
| BASF, Germany                                   | <i>Brassica</i> , tobacco  | Polyunsaturated fatty acids  |
| Bayer Crop Science, BioScience, Germany         | Not specified  | Antibodies   |
| Cobento Biotech, Denmark                        | <i>Arabidopsis</i>   | Human intrinsic factor and transcobalamin protein  |
| CropDesign <sup>b</sup>                         | Maize, rice  | Contract manufacturing   |
| ERA Plantech, Spain                             | Protein bodies in most plant tissues and species   | Product-neutral productivity improvements  |
| Fraunhofer IME, Germany                         | Tobacco, corn, rice, wheat, tomato, plant suspension cells                                     | Antibodies, vaccines (injectable and oral administration), enzymes for oncology and infectious disease   |
| Greenovation Biotech GmbH, Germany <sup>c</sup> | Moss   | Monoclonal antibodies and other complex proteins   |
| Icon Genetics AG, Germany <sup>d</sup>          | Tobacco, <i>Nicotiana benthamiana</i> , spinach, red beets                                     | Interferon, somatotropin, restriction enzymes, single-chain antibodies, monoclonal antibodies, antigens, glucocerebrosidase, thaumatin, albumin, DNase, RNase inhibitor, insulin |
| LemnaGene S.A., France <sup>d</sup>             | <i>Lemna</i> sp.   | Not specified  |
| Maltagen Forschung GmbH, Germany                | Barley, malt   | Lactoferrin, lysozyme, human serum albumin, hepatitis vaccine, edible vaccines   |
| Meristem Therapeutics, France                   | Maize, tobacco   | Gastric lipase (MERISPASE <sup>®</sup> ), albumin, human collagen, human lactoferrin, human IgA (x4), dust mite allergens, murine IgM (monomeric) and human plasma proteins      |
| Novoplant GmbH, Germany                         | Tubers, rape seed, flax seed, peas   | Orally administered antibodies for animal health   |
| ORF Genetics, Iceland <sup>e</sup>              | Barley, lettuce  | Growth factors, proteases, antibodies and vaccines   |
| Phyton Biotech, Germany                         | Plant cells  | Includes growth hormone-receptor antagonist for treating acromegaly, cancer and diabetes   |
| Pharma-Planta Project, European Community       | Maize, tobacco (various plants)  | Antibodies and vaccines  |
| PlantBio Products, Spain                        | Chloroplast transformation   | Bioplastics  |
| Plantechno SRL, Italy                           | Rice, wheat, tomato, maize, poplar, <i>Agaricus</i> , barley                                   | Enzymes, phytoremediation  |
| Planton, Germany                                | Potato   | Contract manufacturing   |
| Plant Research International, The Netherlands   | Platform technologies applicable in all plant hosts (tobacco, potato, tomato, rice and others) | Antibodies as a model: vaccines for oral application and targeted delivery   |
| SunGene, Germany <sup>f</sup>                   | Rapeseed, potato, tagetes, <i>Arabidopsis</i> , tobacco and tomato                             | Secondary metabolites, for example, carotenoids and vitamins for food, feed and health   |
| Syngenta, Switzerland                           | Safflower  | Biopharmaceuticals for a range of indications, including antibodies, enzymes and other protein therapeutics  |
| UniCrop Ltd, Finland                            | <i>Camelina</i> sprouts  | Model proteins: monoclonal antibodies, immunoglobulin fusion protein, human serum albumin, enzymes   |

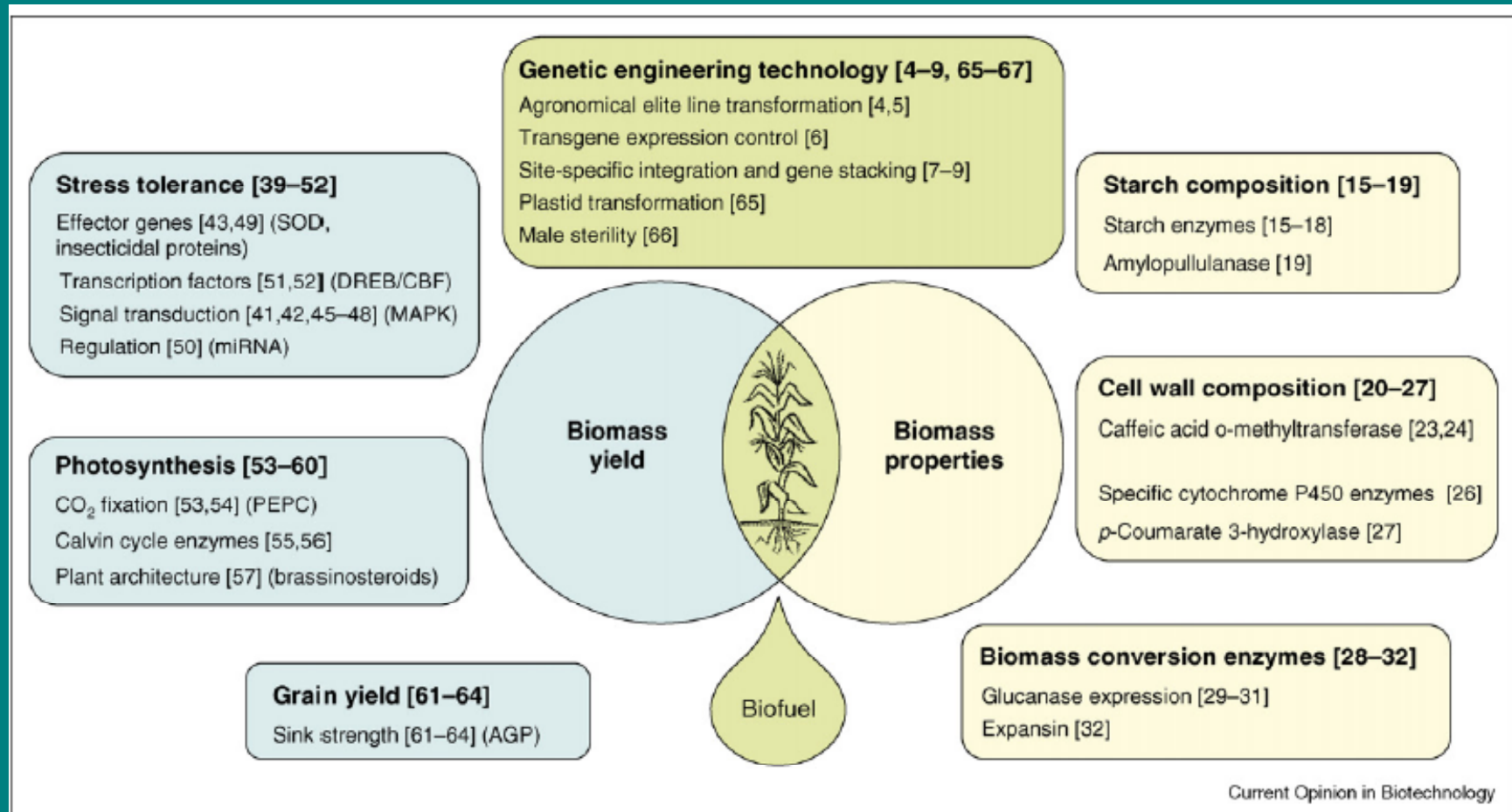
<sup>a</sup>Sources: [1,4] company websites (Box 2); <sup>b</sup>this company recently became a fully owned subsidiary of BASF; <sup>c</sup>licence agreement with Bayer; <sup>d</sup>this company recently became a fully owned subsidiary of Bayer; <sup>e</sup>recently acquired by the US company Biolex Therapeutics; <sup>f</sup>Iceland is not a member of the EU but belongs to the European Economic Area; <sup>g</sup>joint venture of BASF Plant Science, the Institute of Plant Genetics and Crop Plant Research.

## Box 2. Useful links

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Agrenvec: <http://www.agrenvec.es>  
Arizona State University: <http://www.asu.edu/>  
BASF: <http://www.corporate.basf.com/en/produkte/biotech/plantscience/pflanzenalsfabrik>  
Bayer Crop Science: <http://www.bayercropscience.com>  
Biolex Therapeutics: <http://www.biolex.com>  
Biotechnology Industry Organization: <http://www.bio.org>  
Canadian Food Inspection Agency (CFIA): <http://www.inspection.gc.ca>  
Cobento Biotech AS: <http://www.cobento.dk>  
CropDesign: <http://www.cropdesign.com>  
Dow Agro Sciences: <http://www.dowagro.com/newsroom/corporatenews/2006/20060131b.htm>  
Environment Protection Agency (EPA): <http://www.epa.gov/>  
ERA Plantech: <http://www.erabiotech.com>  
EuropaBio: <http://www.europabio.org>  
European Food Safety Authority: <http://www.efsa.eu.int>  
European Plant Science Organisation: <http://www.epsoweb.org>  
Fraunhofer Gesellschaft: <http://www.fraunhofer.de/fhg/EN/>  
Fraunhofer IME: <http://www.ime.fraunhofer.de>  
German Parliament: <http://www.bundestag.de>  
Greenovation Biotech GmbH: <http://www.greenovation.com>  
Icon Genetics AG: <http://www.icongenetics.com>  
Institute for Prospective Technology Studies: <http://www.jrc.es>  
International Alliance of Patients' Organizations: <http://www.patientsorganizations.org/>  
Large Scale Biology Company: <http://www.lsb.com>  
LemnaGene S.A.: <http://www.lemnagene.com>  
Maltagen Forschung GmbH: <http://www.maltagen.de>  
Meristem Therapeutics: <http://www.meristem-therapeutics.com>  
National Corn Growers Association: <http://www.ncga.com/>  
Novoplant GmbH: <http://www.novoplant.de>  
Office of Technology Assessment at the German Parliament: [http://www.tab.fzk.de/home\\_en.htm](http://www.tab.fzk.de/home_en.htm)  
ORF Genetics: <http://www.orfgenetics.com>  
Pharma-Planta Project: <http://www.pharma-planta.org>  
Phyton Biotech: <http://www.phytonbiotech.com>  
Planet Biotechnology: <http://www.planetbiotechnology.com>  
Plant Research International: <http://www.pri.wur.nl>  
PlantBio Products: <http://www.plantbioproducts.es>  
Planton: <http://www.planton.de>  
SemBioSys Genetics Inc.: <http://www.sembiosys.ca>  
Sigma-Aldrich: <http://www.sigmaaldrich.com>  
SunGene: <http://www.sungene.de>  
Syngenta: <http://www.syngenta.com>  
UniCrop Ltd: <http://www.unicrop.fi>  
United States Department of Agriculture (USDA): <http://www.usda.gov>  
Ventria: <http://www.ventria.com>

# Βιοκαύσιμα





# Βιοκαύσιμα-Βιοντιζελ



Παραγωγή βιοντίζελ από ελαιοκομικά φυτά  
(σόγια, ελαιοκράμβη, άλγες)

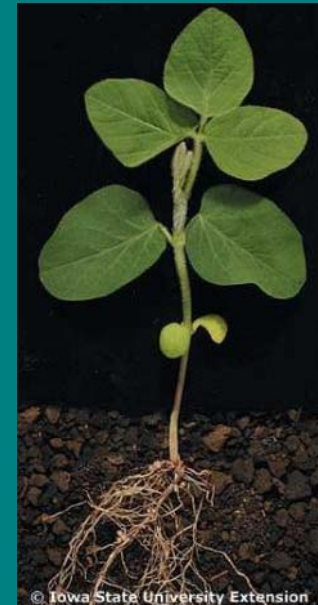


Image sources: [Tilo Hauke](#), University of Minnesota, Iowa State University Extension.



Τα «ενεργειακά» φυτά διαφέρουν ως προς το περιεχόμενό τους σε χρήσιμες πρώτες ύλες για παραγωγή βιοκαυσίμων

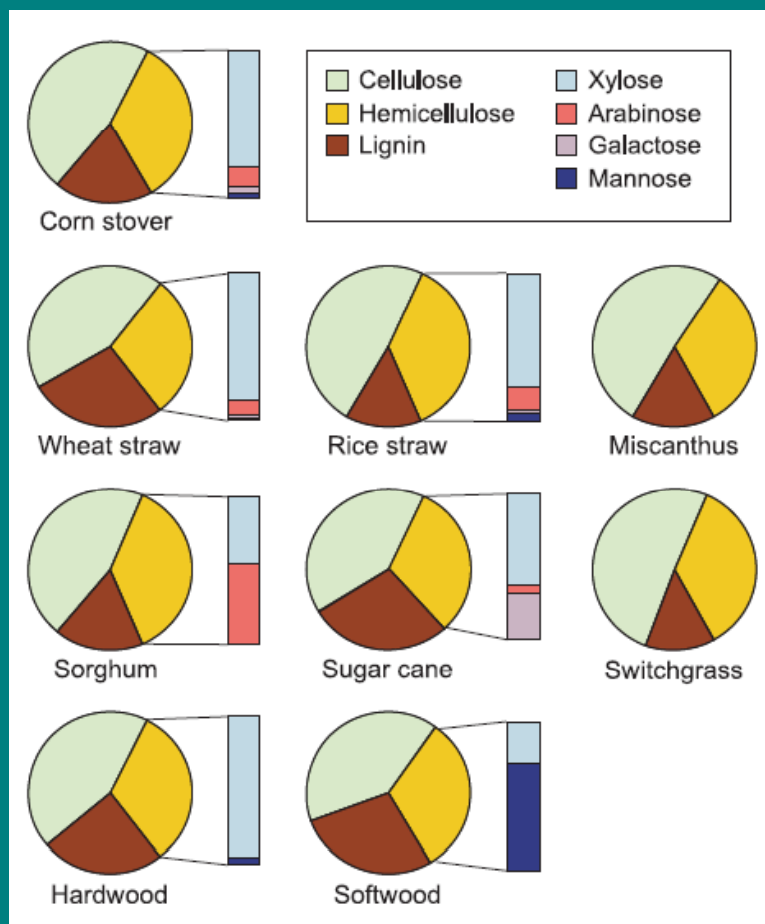




Photo Illustration courtesy S. Long Lab, University of Illinois, 2006

*Miscanthus giganteus*:  
ένα ενεργειακό φυτό που  
αναπτύσσεται ταχύτατα  
και καλλιεργείται σε  
εδάφη ακατάλληλα για  
φυτά-παραγωγείς τροφής






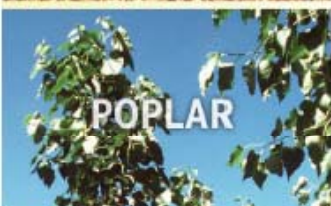
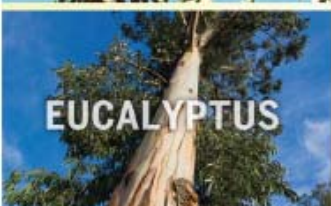

Από την παραγωγή βιοκαυσίμων μπορούν να παραχθούν και πολλά άλλα  
προϊόντα αυξημένης προστιθέμενης αξίας  
(με την περίσσεια της βιομάζας πχ αξιοποίηση λιγνίνης)



Primary Product

'Value Added' Products



| Plant resource  | % Hemicellulose | % Cellulose | % Lignin* |
|---|-----------------|-------------|-----------|
|  <b>MISCANTHUS</b>   | 24-33           | 45-52       | 9-13      |
|  <b>SWITCHGRASS</b>  | 26-33           | 37-32       | 17-18     |
|  <b>CORN STOVER</b>  | 31              | 37          | 18        |
|  <b>POPLAR</b>      | 16-22           | 42-48       | 21-27     |
|  <b>EUCALYPTUS</b> | 24-28           | 39-46       | 29-32     |
|  <b>PINE</b>       | 23              | 46          | 28        |

\*Typical aromatic polymer containing:

**Syringyl**

Cc1cc(C)cc(OC)c1

**Guaiacyl**

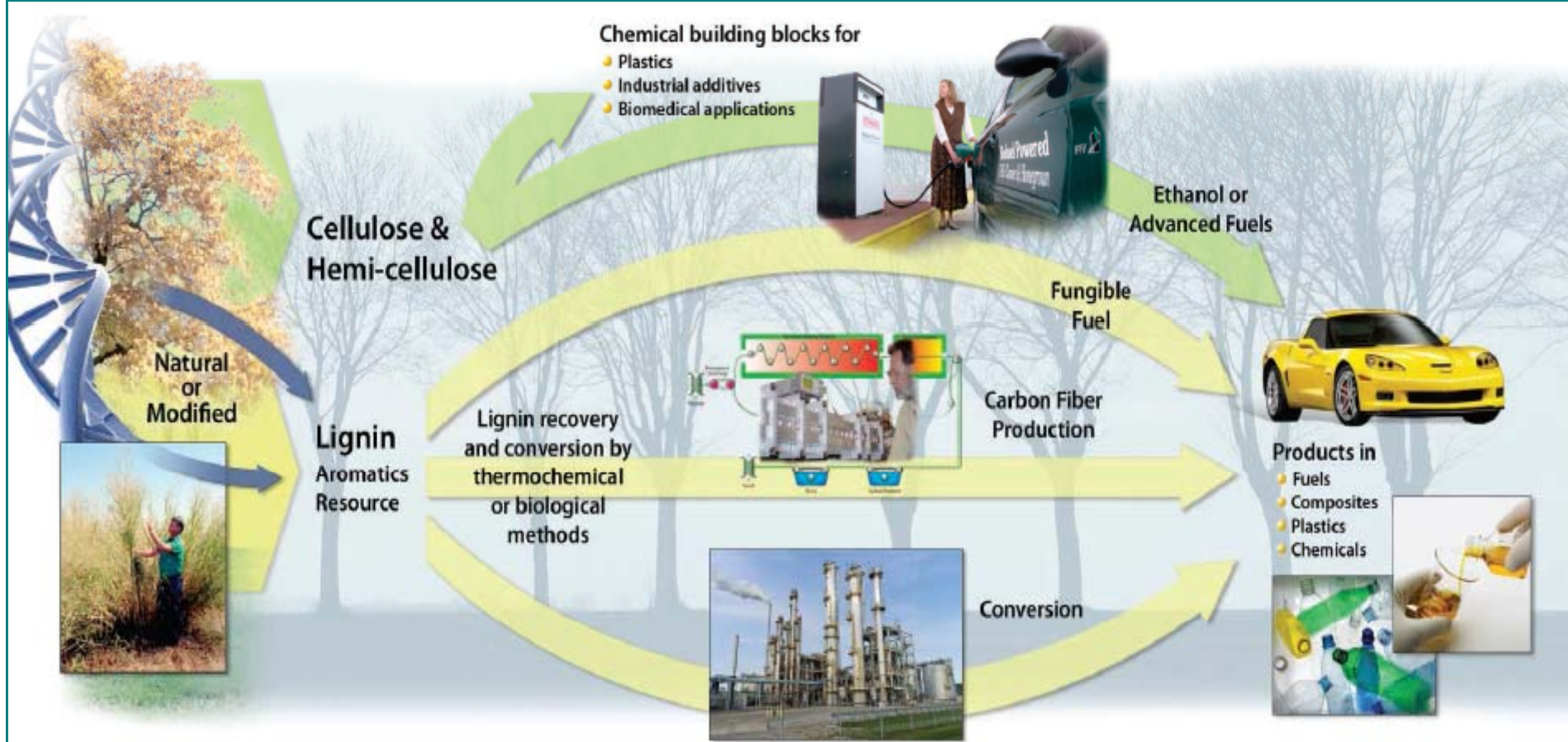
Cc1cc(C)ccc1OC

**Hydroxyphenyl**

Oc1ccccc1

Depending on the bioresource and isolation methodology, molecular weights for native lignin have been reported from 78,400 [in spruce (118)] to 8300 [in Miscanthus (119)] g mol<sup>-1</sup>, which are derived from C9 monolignols as described in Fig. 2.



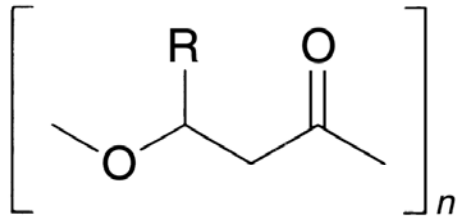


Ragauskas et al, 2014

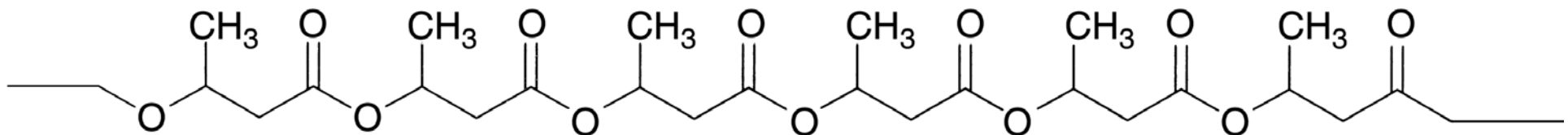
Πανεπιστήμιο Θεσσαλίας



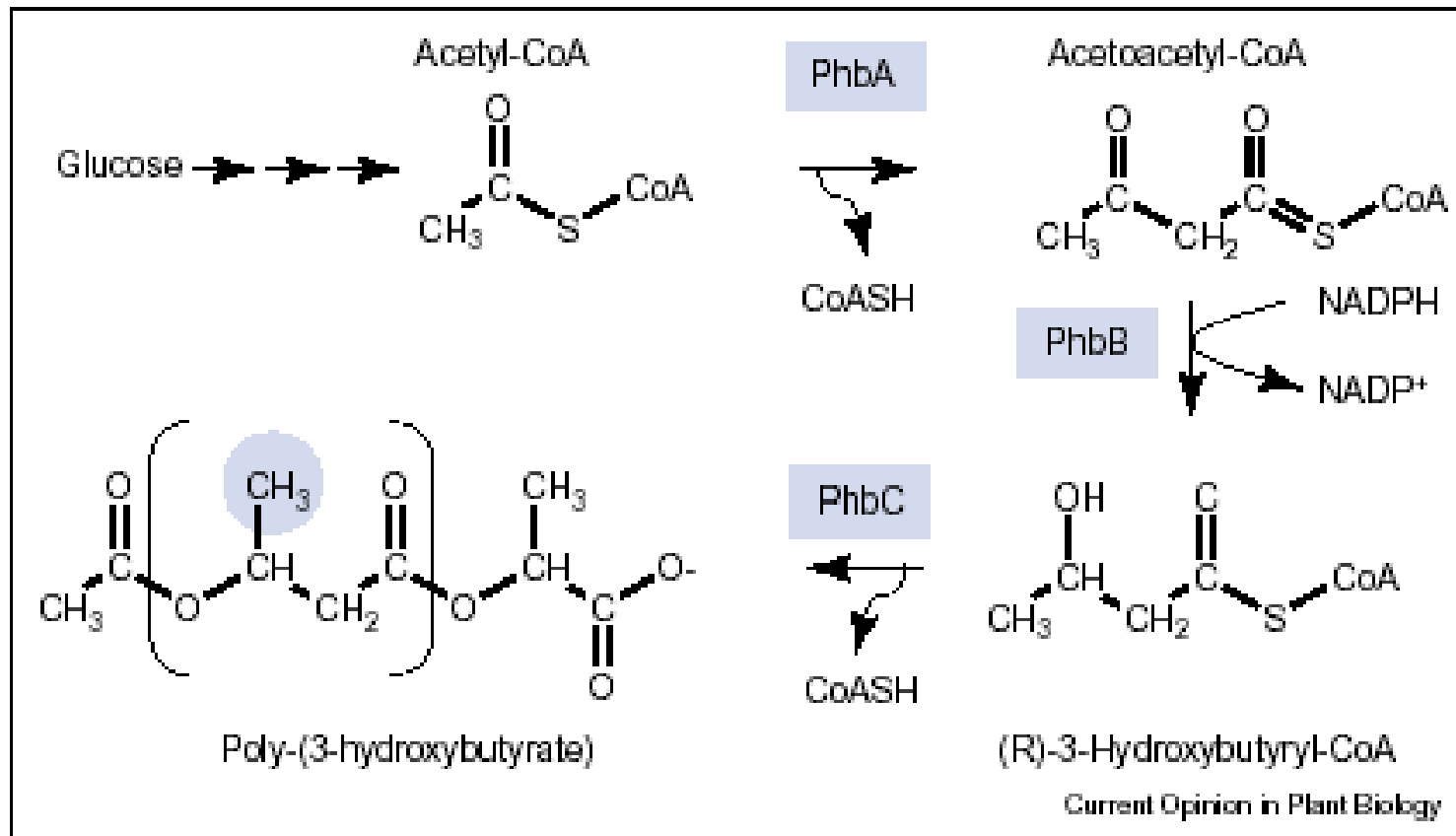
# Βιοπλαστικά



Πολυ υδροξυ αλκανικά οξέα



Πολυ υδροξυ-βουτυρικό οξύ



### *phaA, phaB, phaC*

- από *Alcaligenes eutrophus*

σε *Arabidopsis* (χλωροπλάστες) Υπό *CaMV*

σε *Gossypium* (ίνες) Υπό εξειδικευμένο προαγωγέα

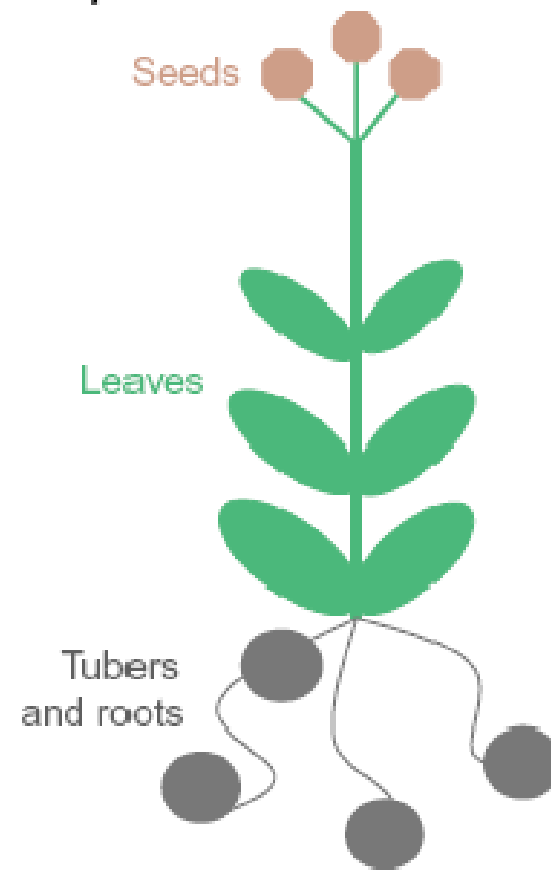
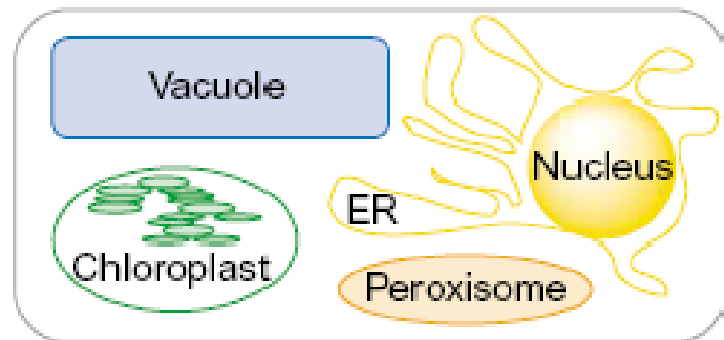
- από *Ralstonia eutropha*

σε *Brassica* (λευκοπλάστες) Υπό 12-υδροξυλάση ολεϊκού



## Expression systems for the production of biopolymers in plants:

- Ubiquitous expression and expression of transgenic proteins in storage organs (e.g. tubers, seeds)
- Accumulation in 'optimal' compartments (e.g. ER, chloroplast)
- Production of plastic-like biomaterials in chloroplasts and peroxisomes



Current Opinion in Plant Biology

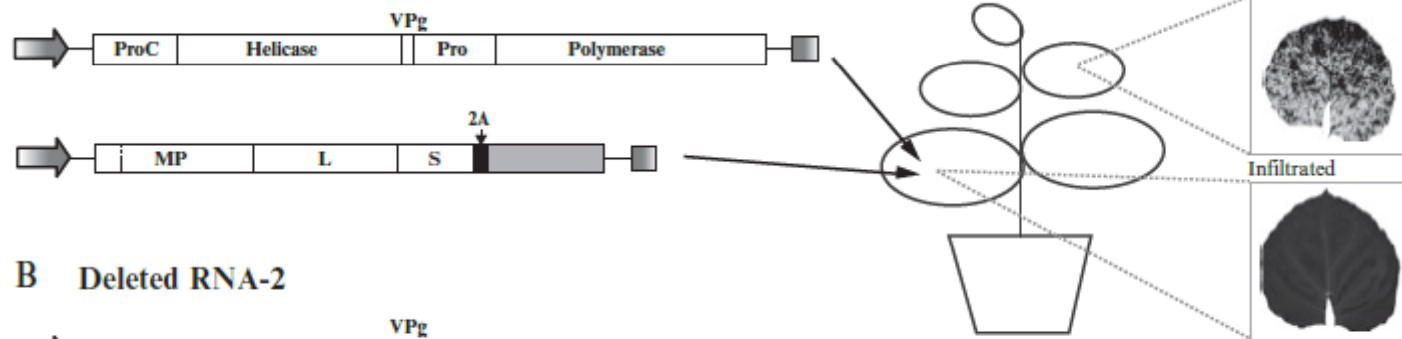
## Απορρύπανση

- ✓ Βιοαποδόμηση  
οργανικών διαλυτών / φυτοφαρμάκων/ πετρελαϊκών προϊόντων
- ✓ Απομάκρυνση βαρέων μετάλλων (Ni, Zn, Cd, As, Se)

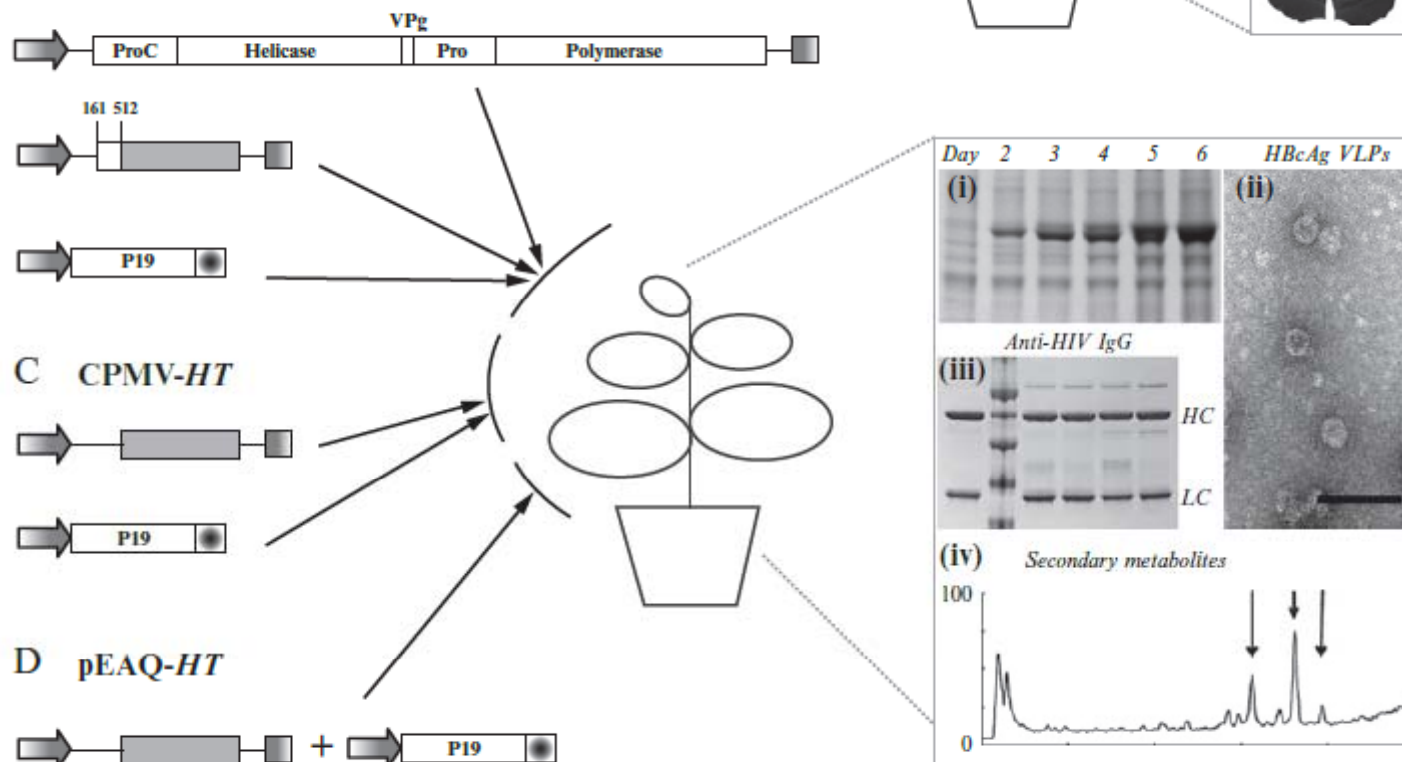


Αυξημένη αντοχή και συσσώρευση  
είτε με υπερπαραγωγή χηλικών μορίων (κιτρικού,  
φυτοχηλίνες, μεταλλοθειονίνες, φυτοσιδηροφόρα,  
φυτοφερριτίνη)  
είτε με υπερέκφραση μεταφορέων μετάλλων (π.χ.  
υδράργυρος)

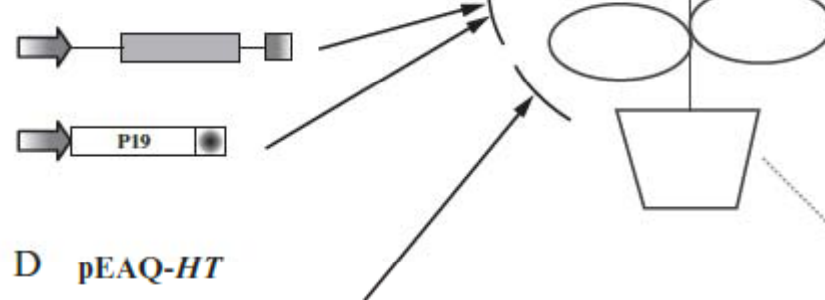
### A Full-length RNA-2



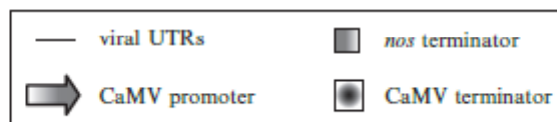
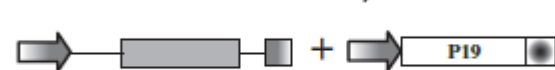
### B Deleted RNA-2



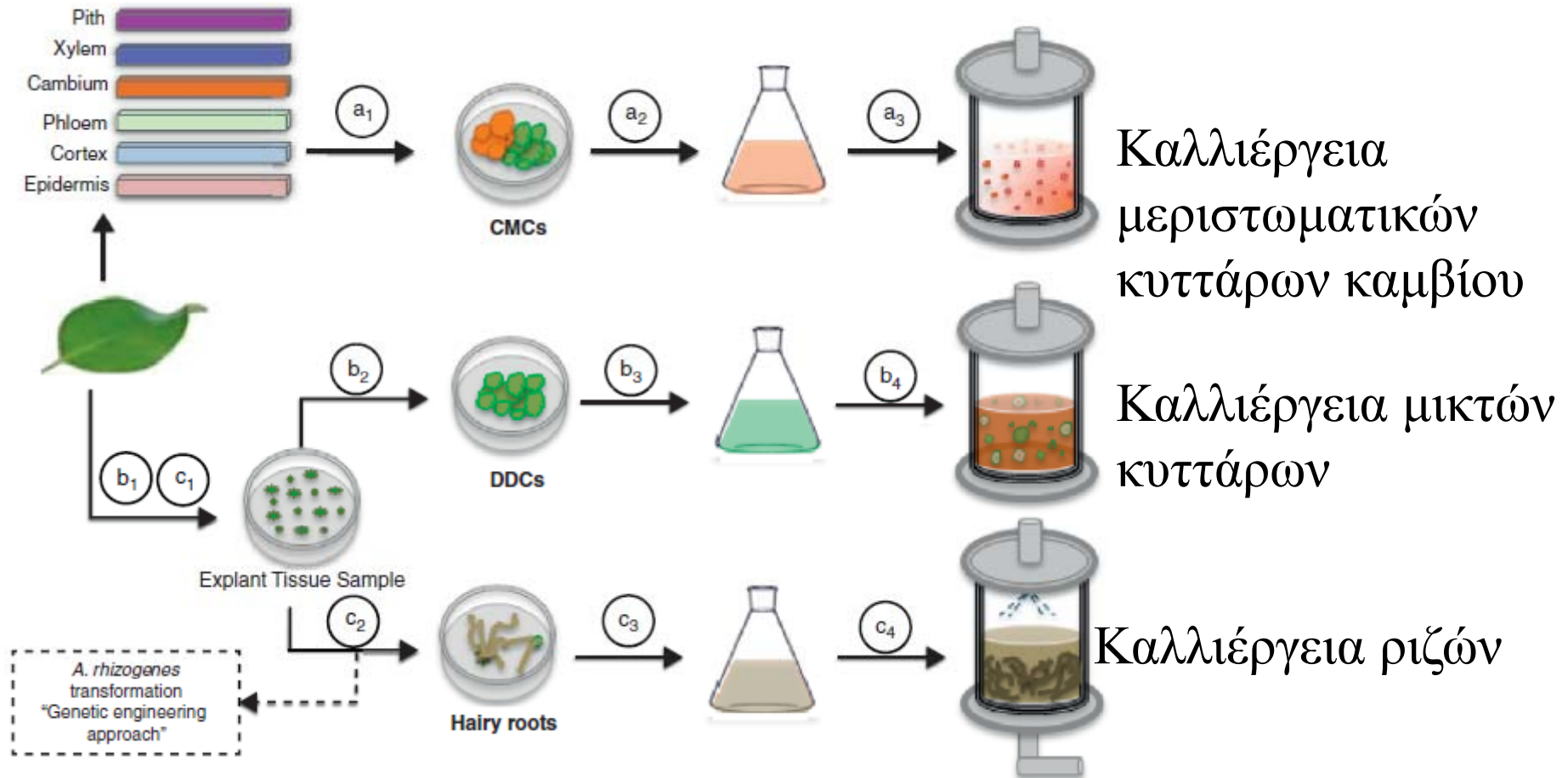
### C CPMV-HT



### D pEAQ-HT



# Διάφορα συστήματα καλλιέργειας φυτικών κυττάρων



# Protalix Biotherapeutics



<http://www.elelyso.com/how-elelyso-is-made>

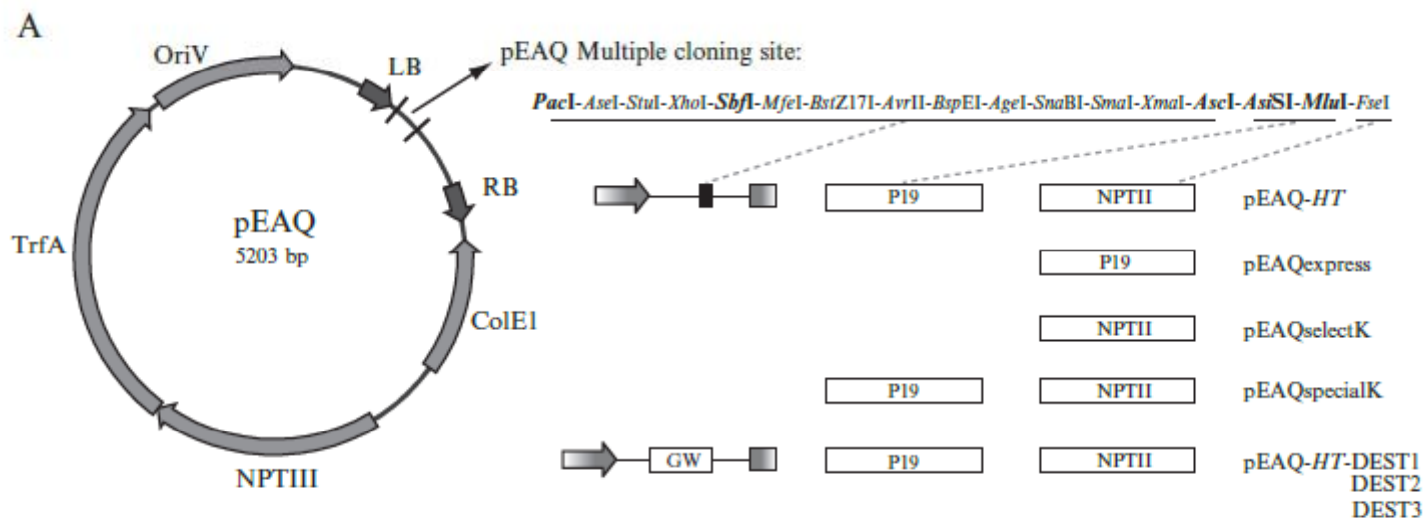
*ELELYSO™ (taliglucerase alfa):*

*FDA 2012, Pfizer*

*Γλυκοσερεβροσιδάση για θεραπεία  
υποκατάστασης ενζύμου σε νόσο Gaucher*

Πανεπιστήμιο Θεσσαλίας





**pEAQ-HT polylinker:** *AgeI/NruI* - 6xHis - *XmaI/SmaI* - 6xHis - *XhoI/StuI*

