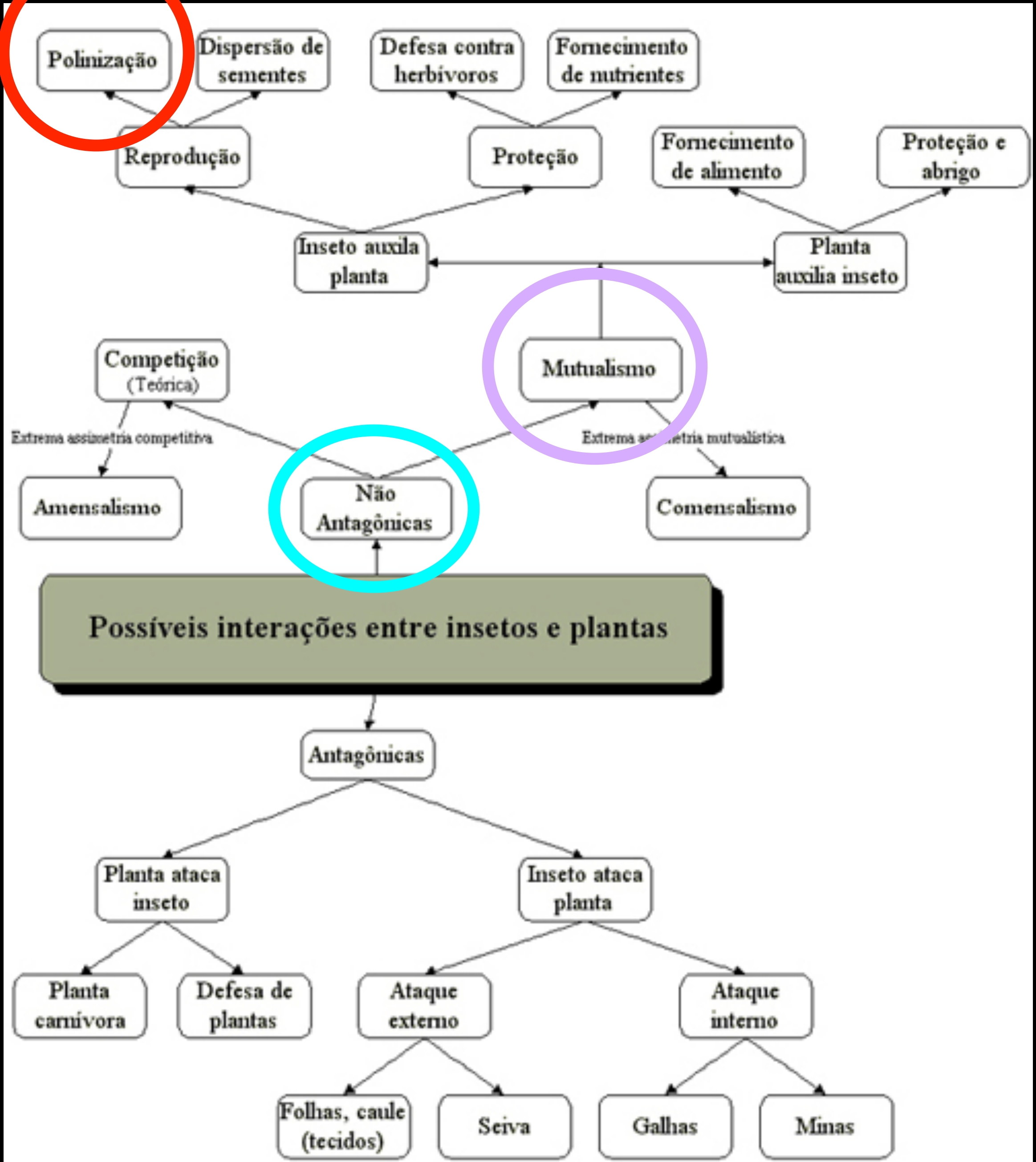
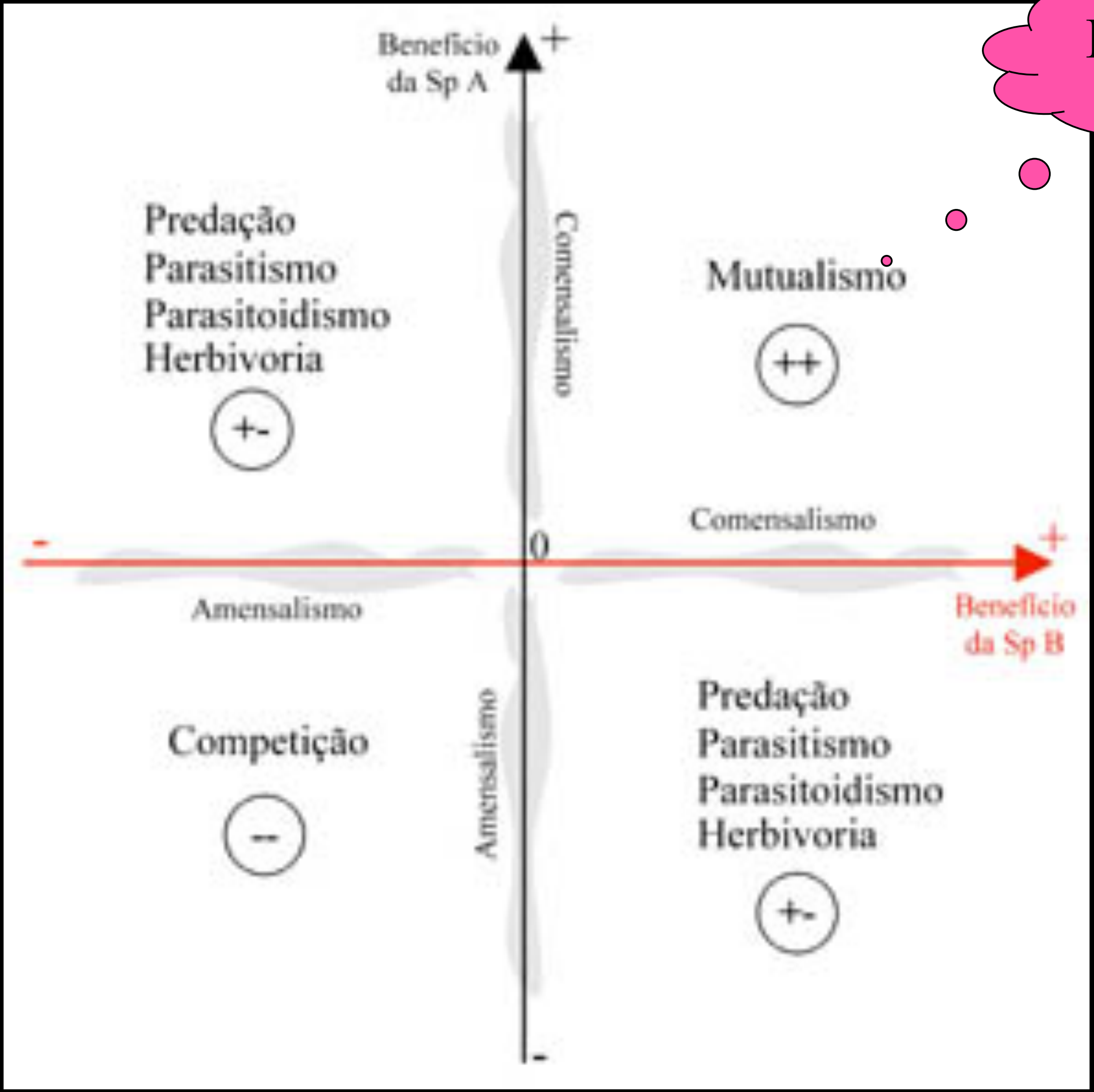
“Biologia da Polinização e Problemas Reprodutivos”

Kayna Agostini (Unicamp)
E-mail: kaynaagostini@gmail.com

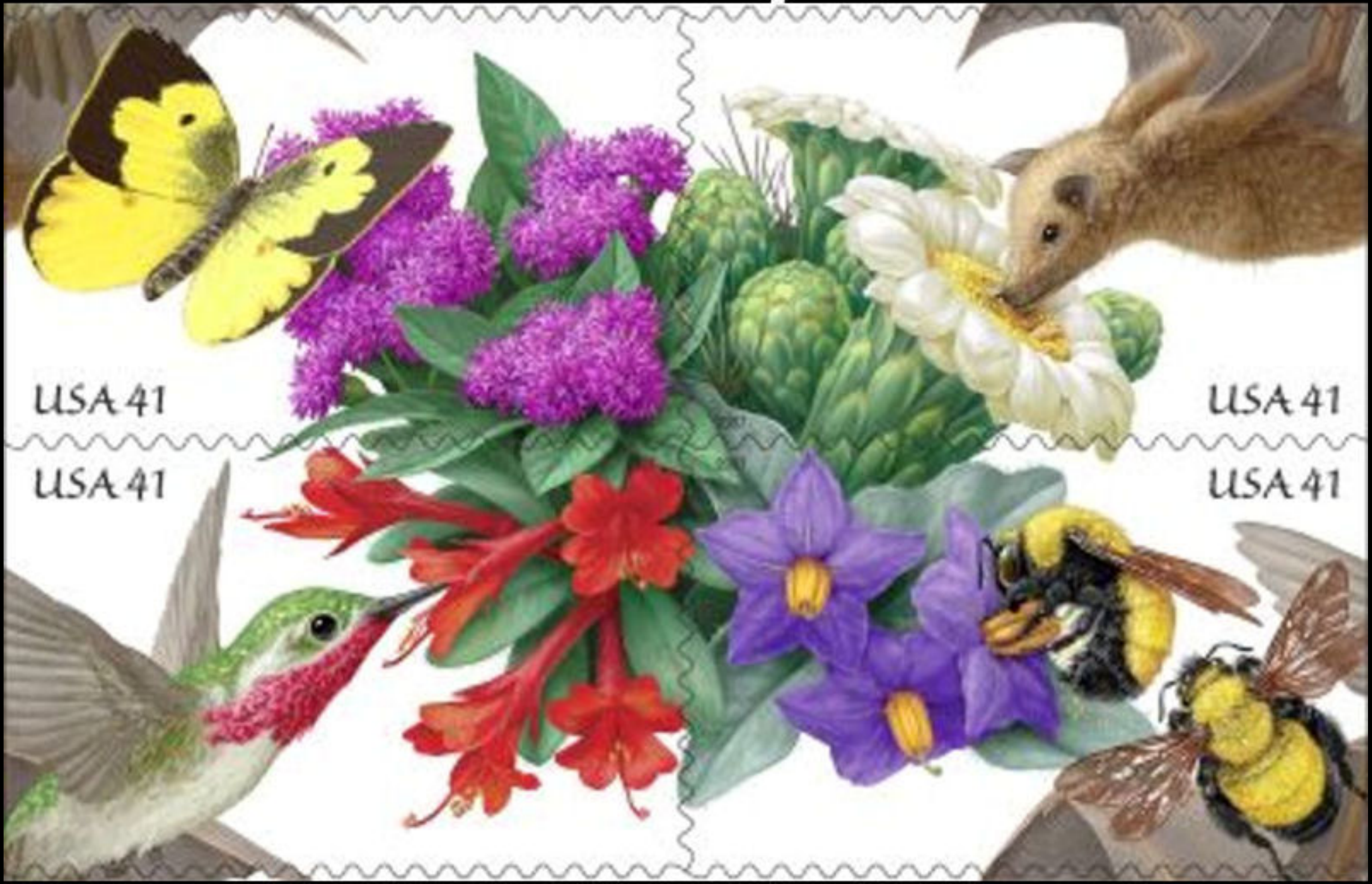

Polinização
Dispersão de sementes
Defesa contra herbívoros
Fornecimento de nutrientes
Reprodução
Proteção
Fornecimento de alimento
Proteção e abrigo
Inseto auxila planta
Planta auxilia inseto
Competição (Teórica)
Mutualismo
Extrema assimetria competitiva
Extrema assimetria mutualística
Amensalismo
Não Antagônicas
Comensalismo
Possíveis interações entre insetos e plantas
Antagônicas
Planta ataca inseto
Inseto ataca planta
Planta carnívora
Defesa de plantas
Ataque externo
Ataque interno
Folhas, caule (tecidos)
Seiva
Galhas
Minas

Polinização


Benefício
da Sp A
+
Predação
Parasitismo
Parasitoidismo
Herbivoria
+-
Comensalismo
Mutualismo
++
Comensalismo
-
0
+
Amensalismo
Benefício
da Sp B
Competição
--
Amensalismo
Predação
Parasitismo
Parasitoidismo
Herbivoria
+-
-

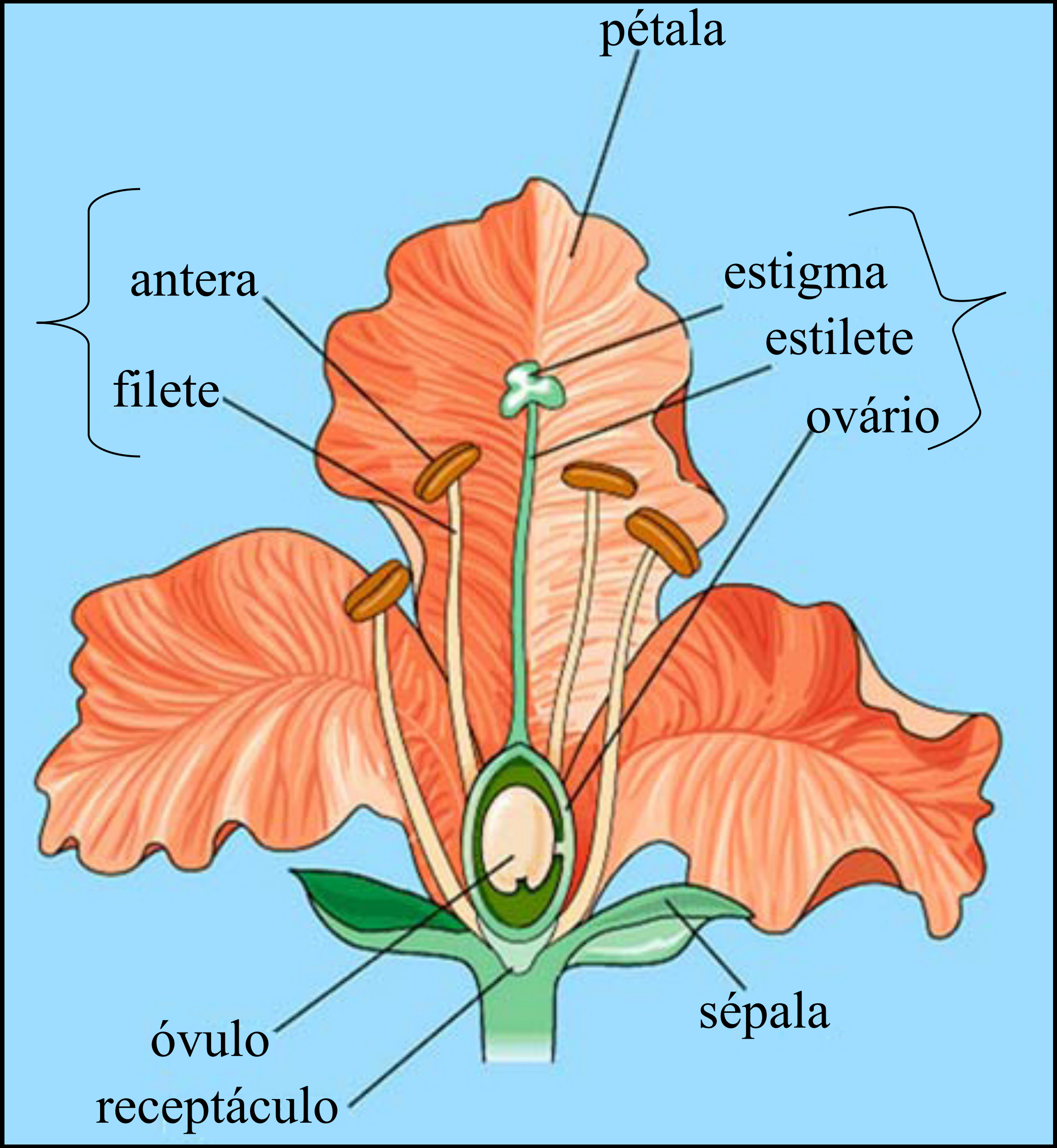
Popularização devido a beleza dos estudos de caso

The Virtual Stamp Club

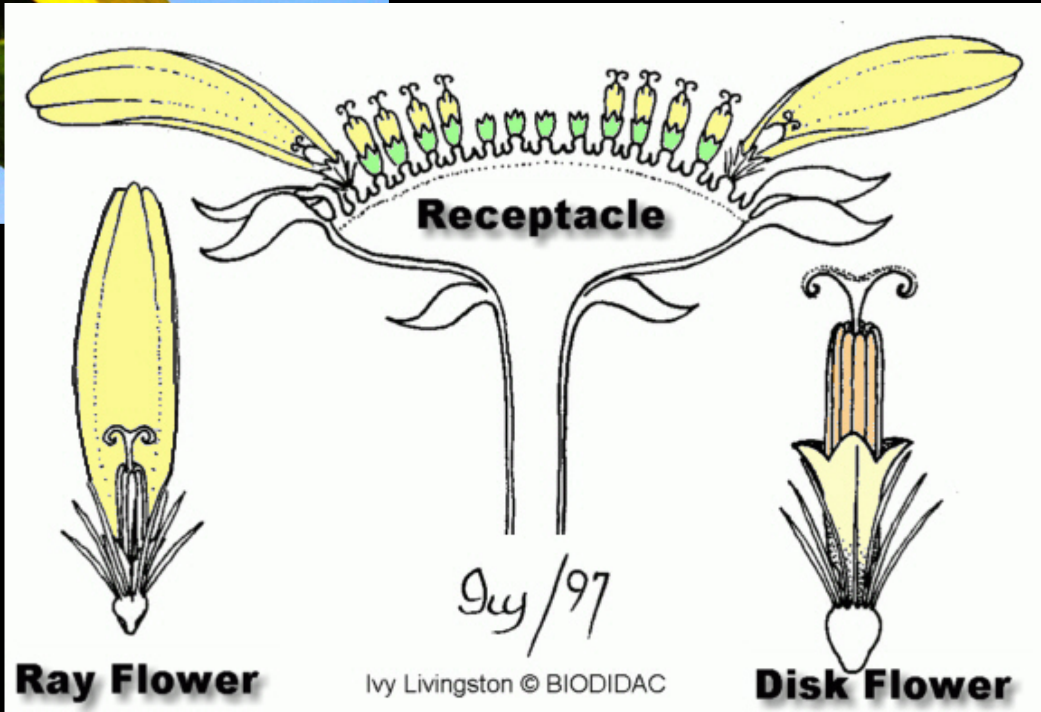

USA 41
USA 41
USA 41
USA 41

©2006 USPS. Used with permission. All rights reserved.

Unidade básica da polinização: flor

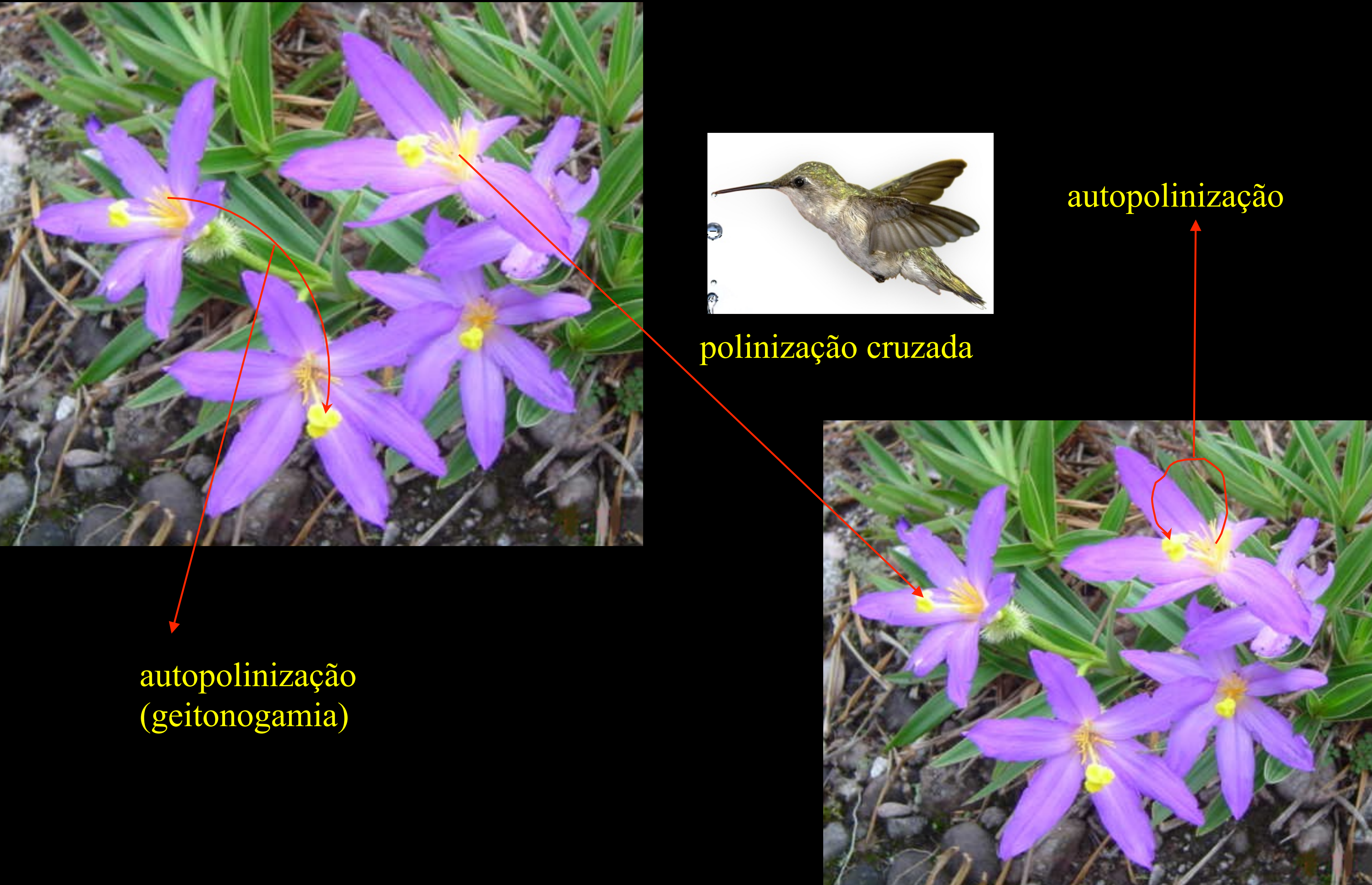

pétala
antera
estigma
estilete
filete
ovário
óvulo
receptáculo
sépala

Unidade básica de polinização pode ser a inflorescência


Receptacle
Ray Flower
Ivy/97
Disk Flower

Ivy Livingston © BIODIDAC

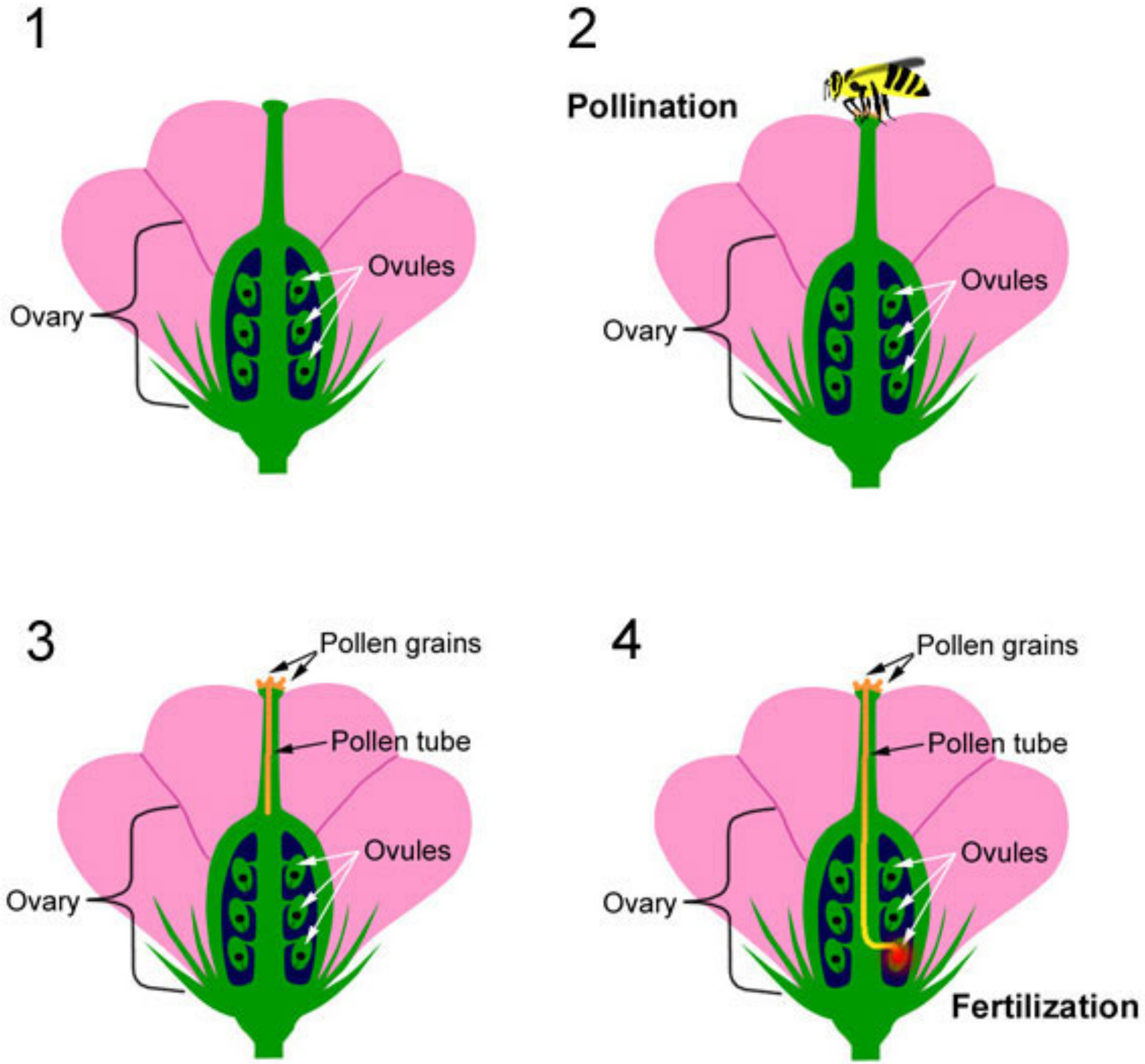
O que é Polinização???



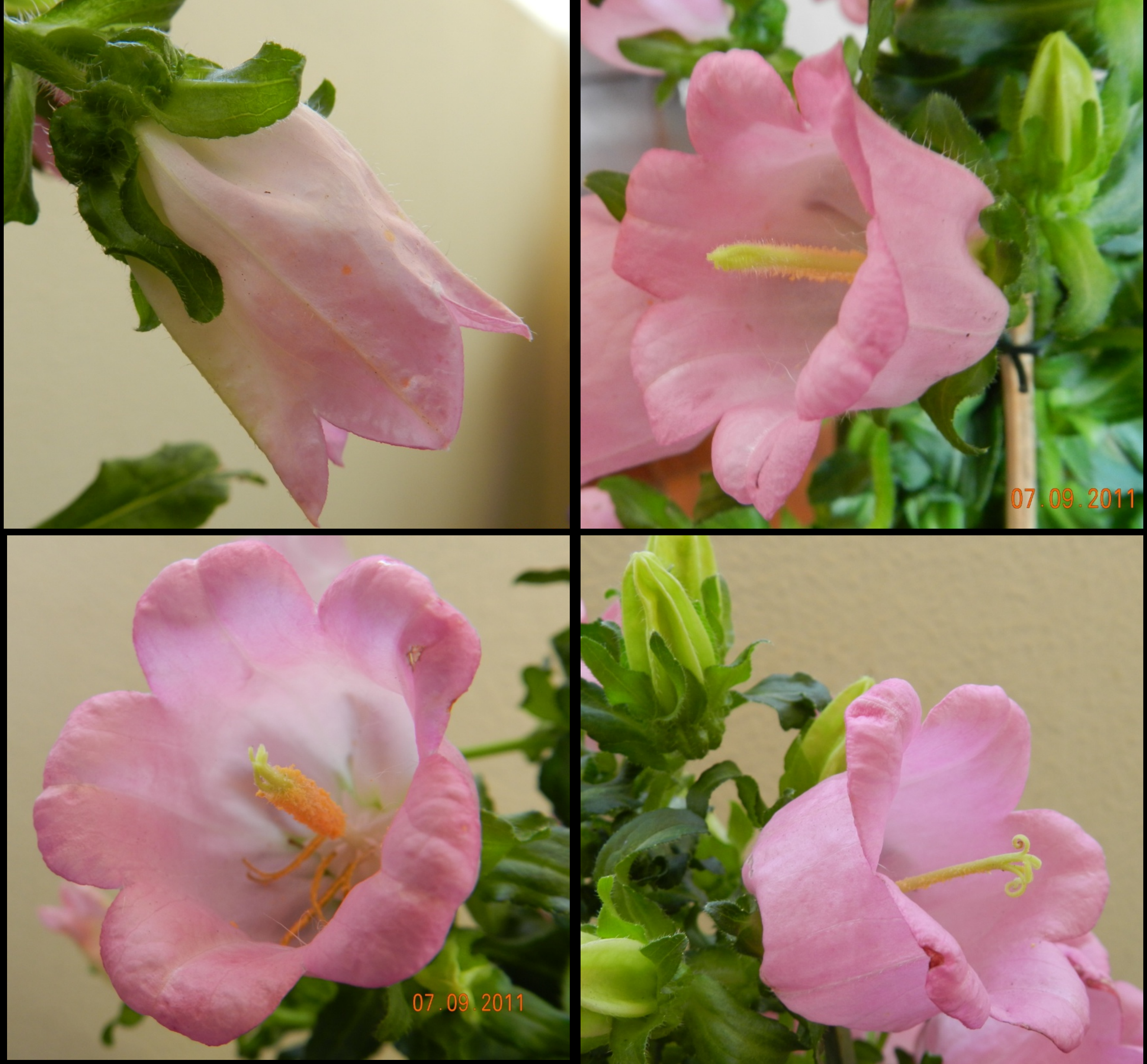
autopolinização

polinização cruzada

autopolinização
(geitonogamia)


1
Ovules
Ovary
2
Pollination
Ovules
Ovary
3
Pollen grains
Pollen tube
Ovules
Ovary
4
Pollen grains
Pollen tube
Ovules
Ovary
Fertilization

ANTESE



07.09.2011

07.09.2011

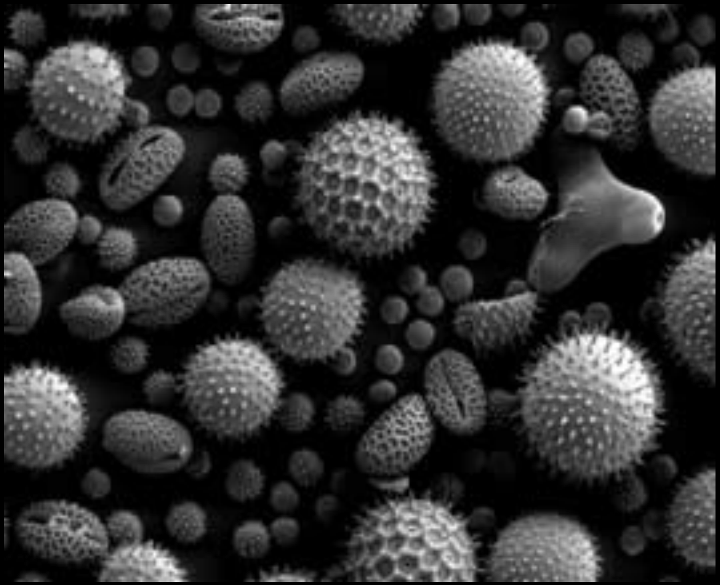
10.09.2011

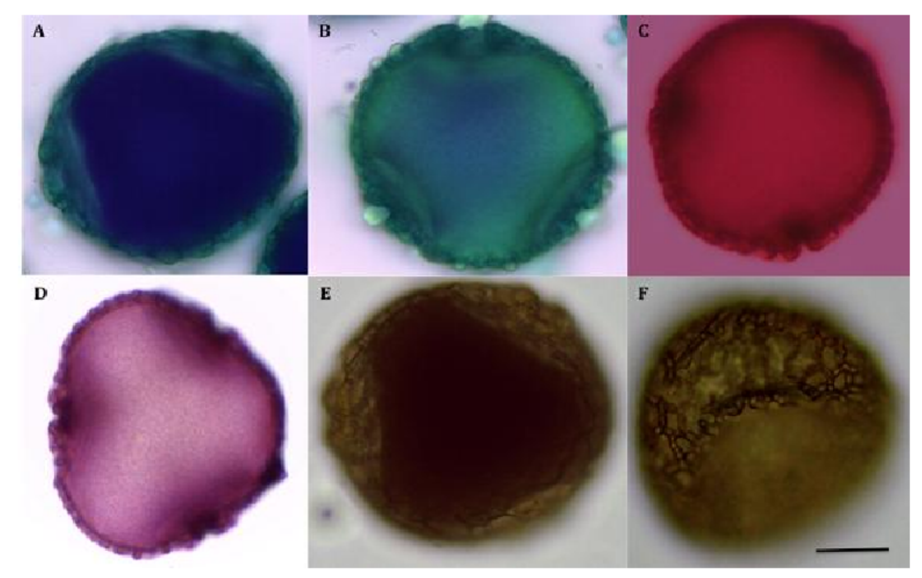
10.09.2011

Recursos florais

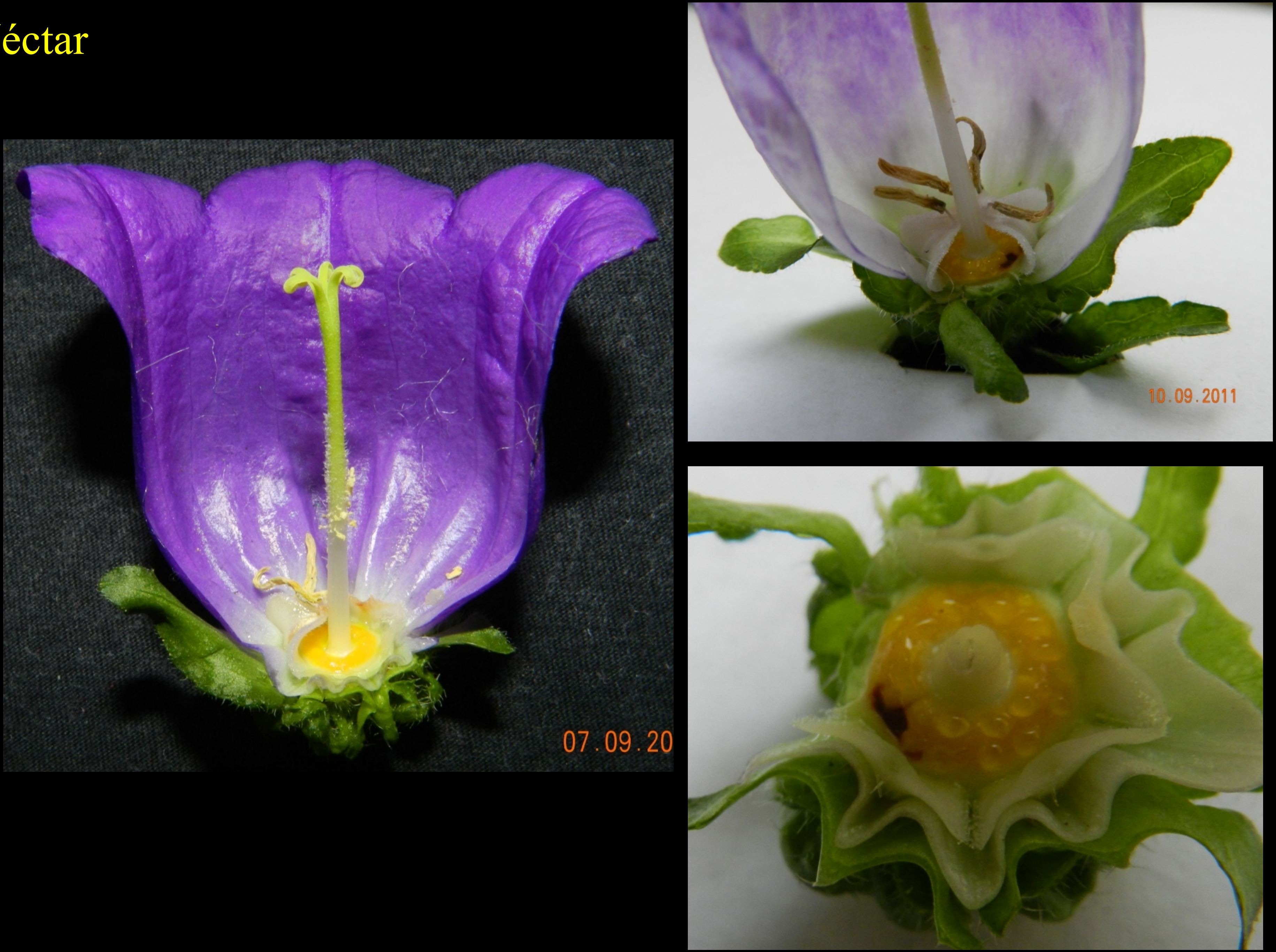
- Pólen = fonte de proteínas
- Néctar = fonte energética (açúcares)
- Óleo = construção de ninhos
- Substâncias odoríferas = atração para cópula
- Resina = construção de ninhos

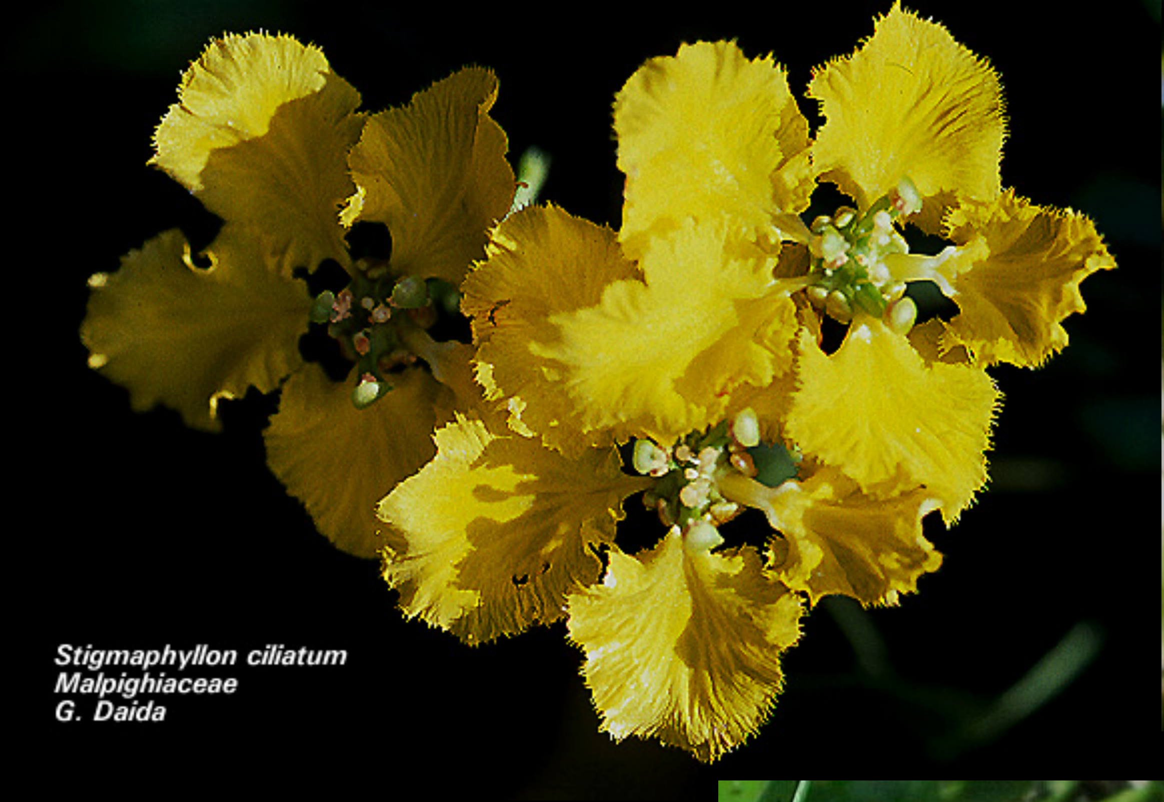
Pólen

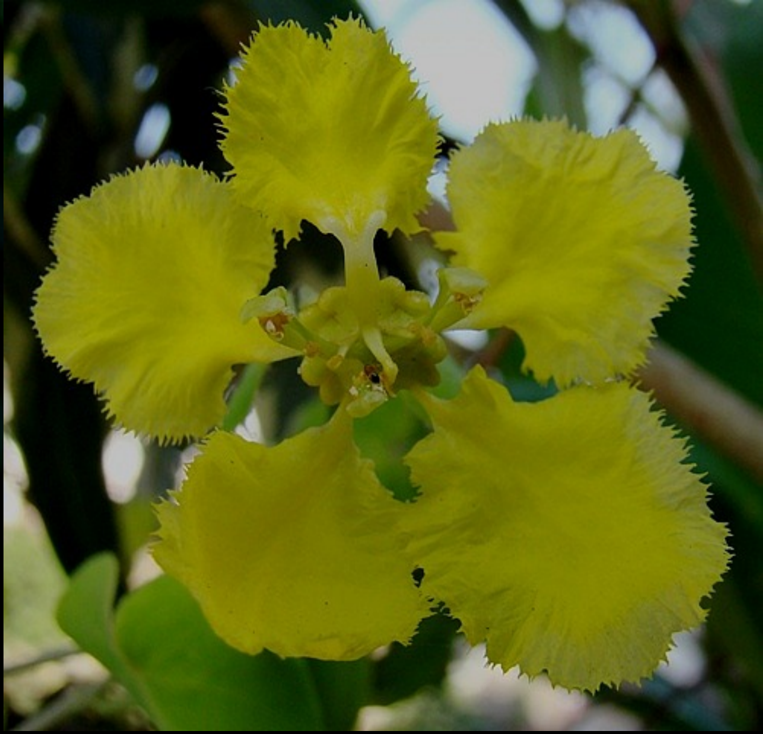


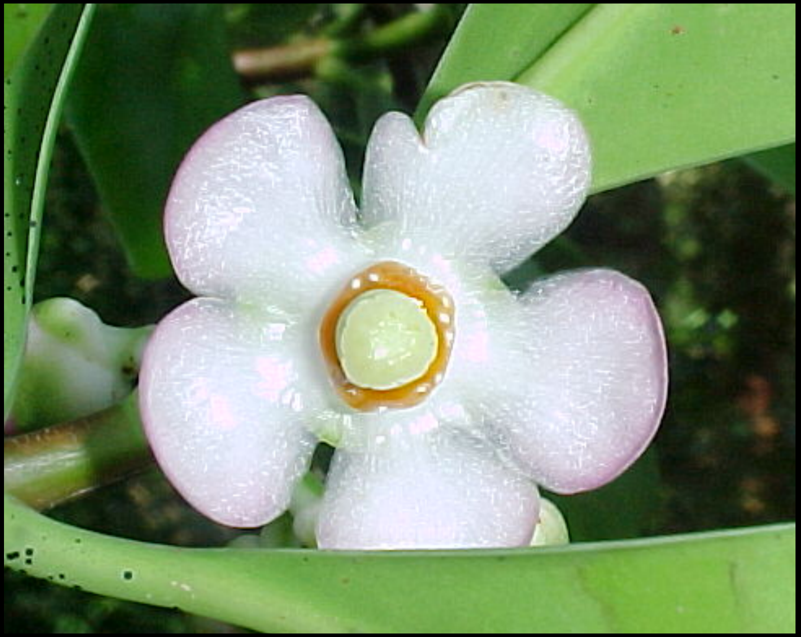


Néctar


07.09.20
10.09.2011

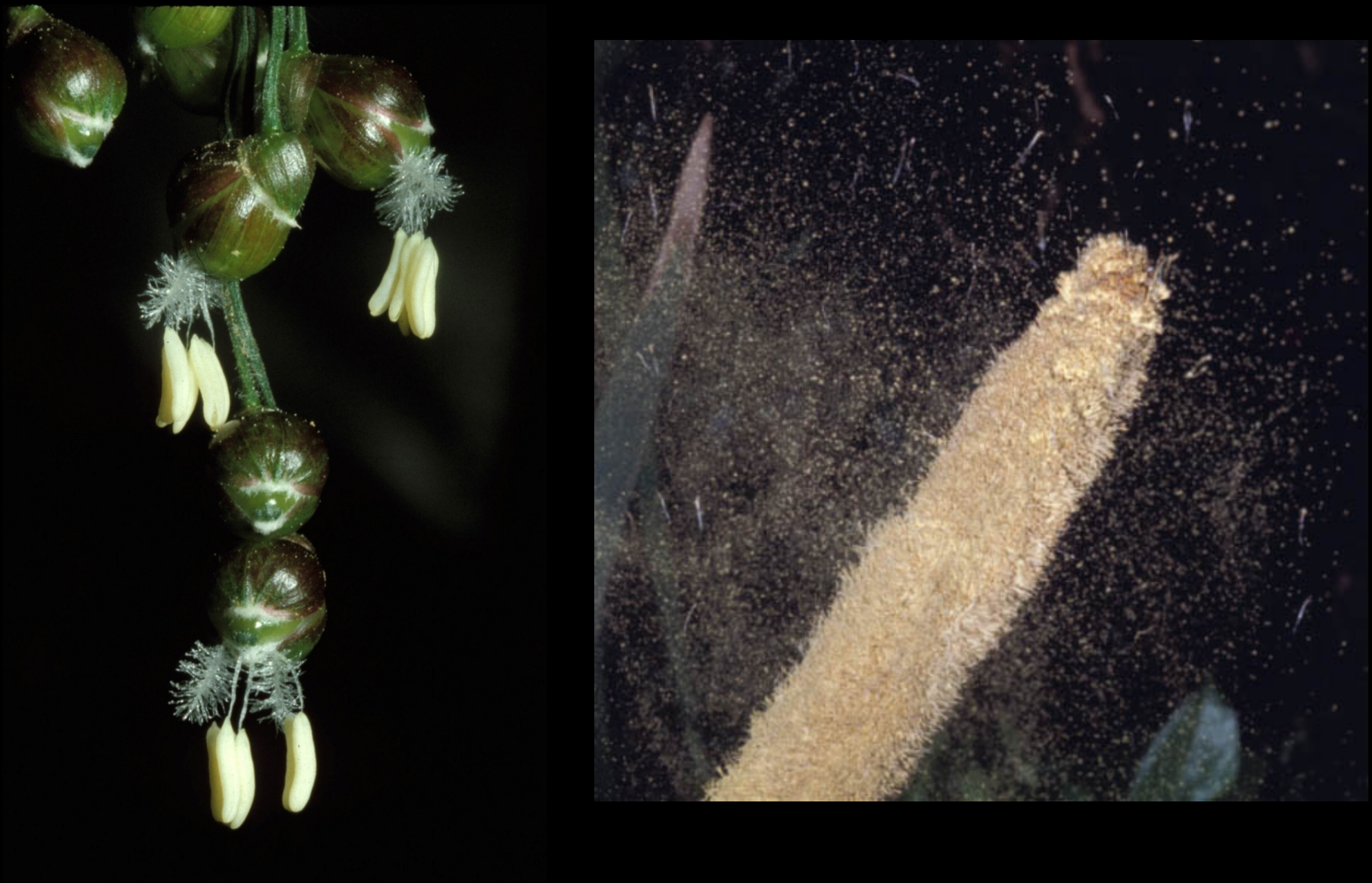

Stigmaphyllon ciliatum
Malpighiaceae
G. Daida



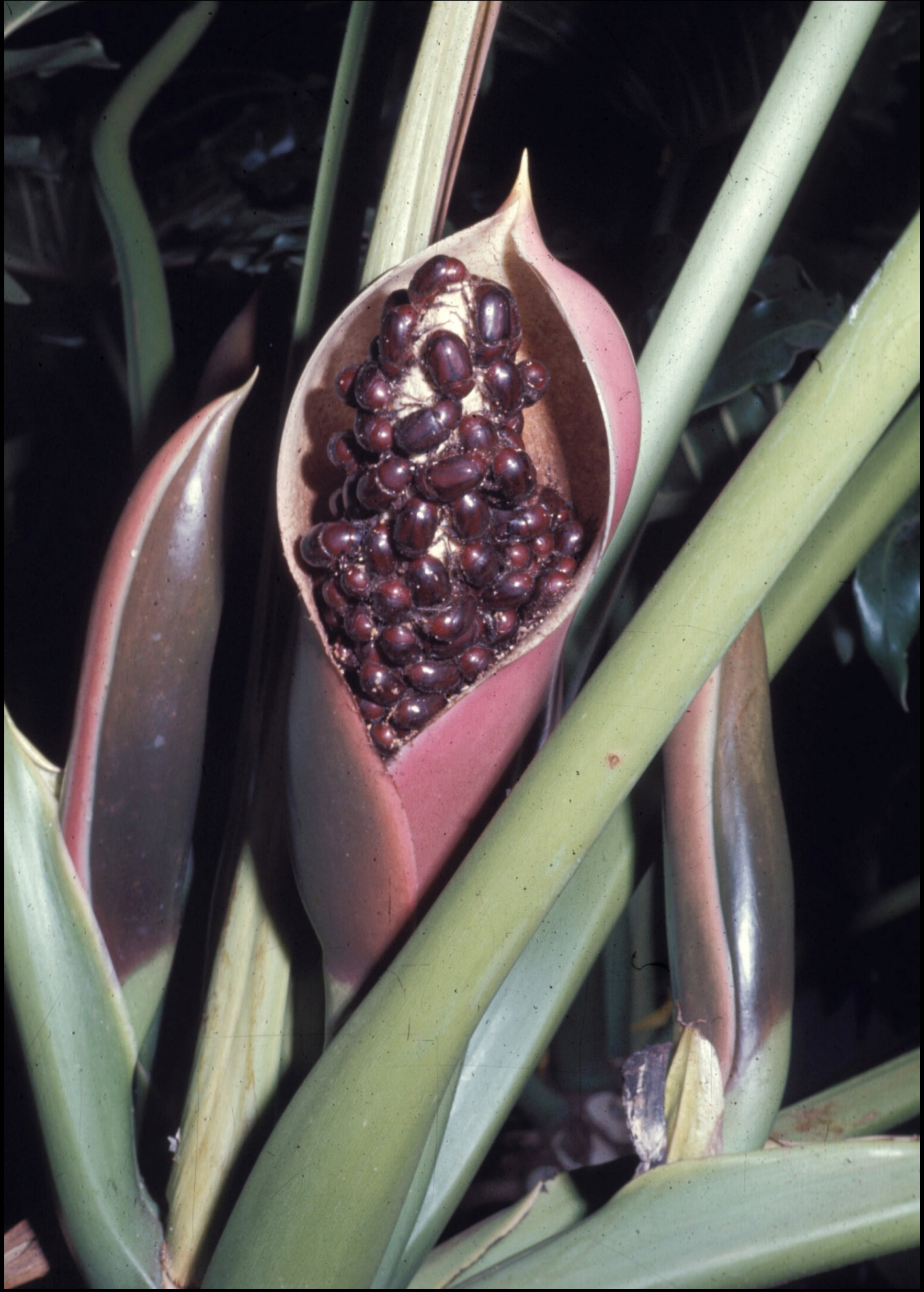


SISTEMAS DE POLINIZAÇÃO

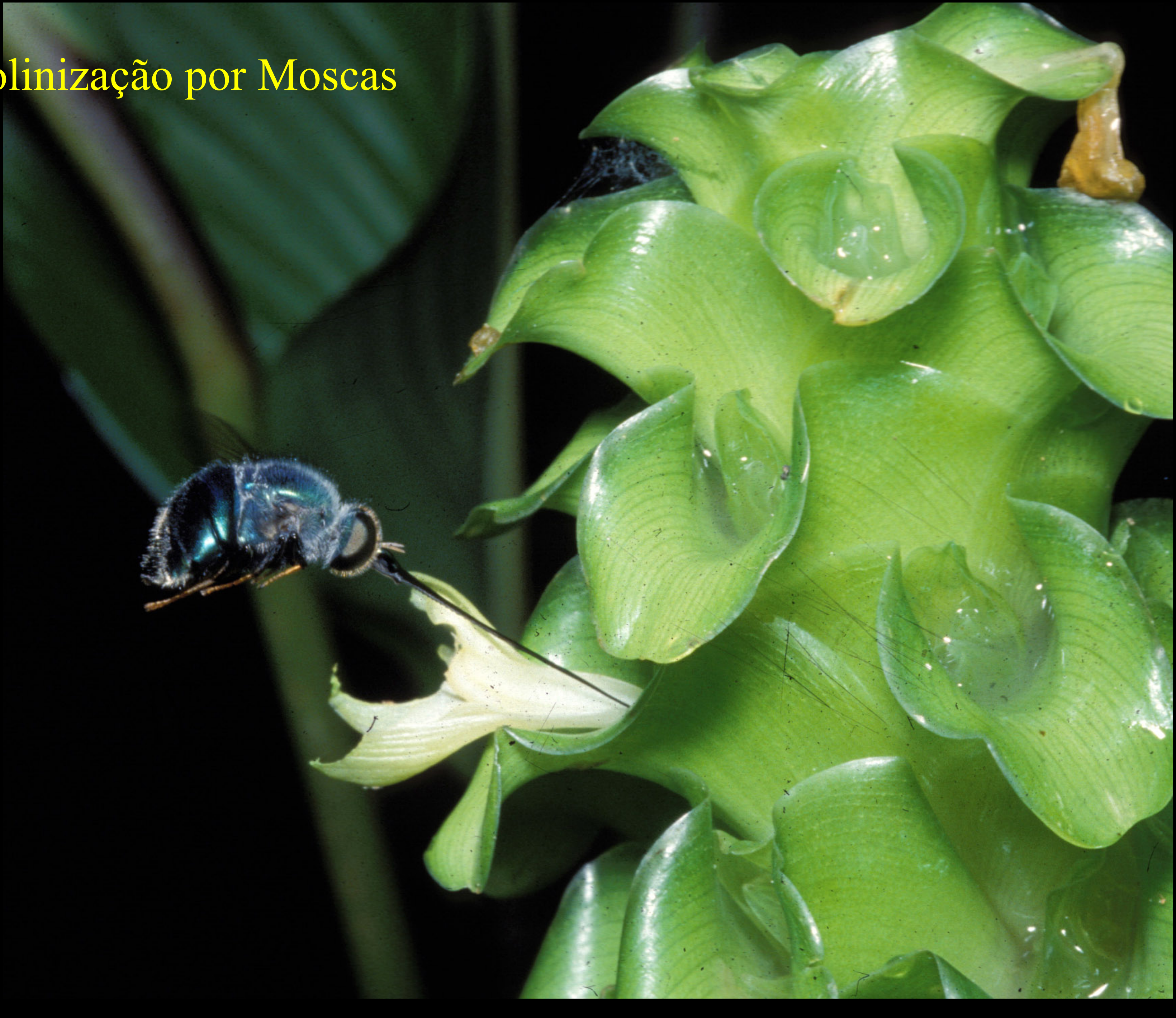
Polinização pelo Vento



Polinização por Besouros



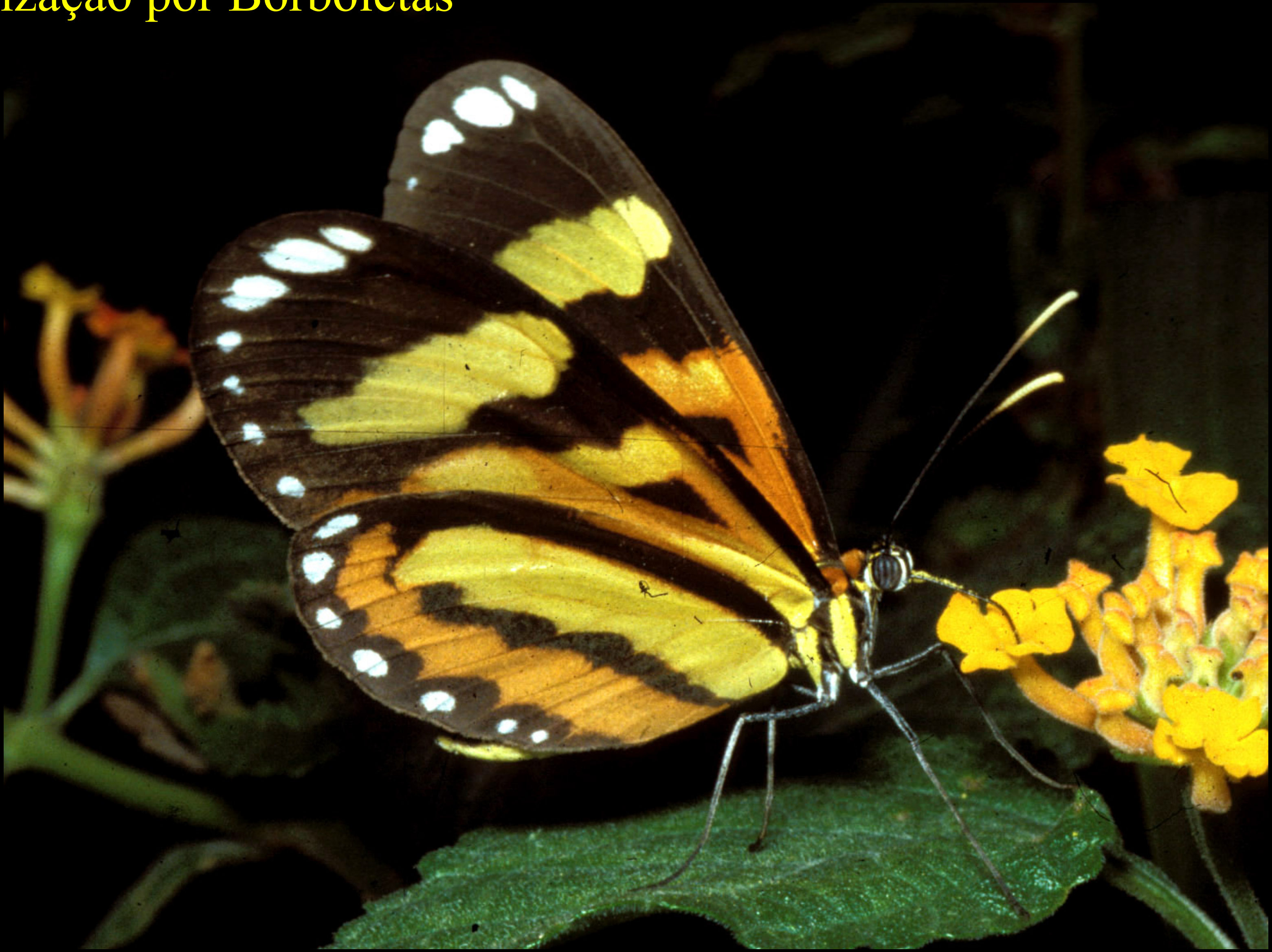
Polinização por Moscas



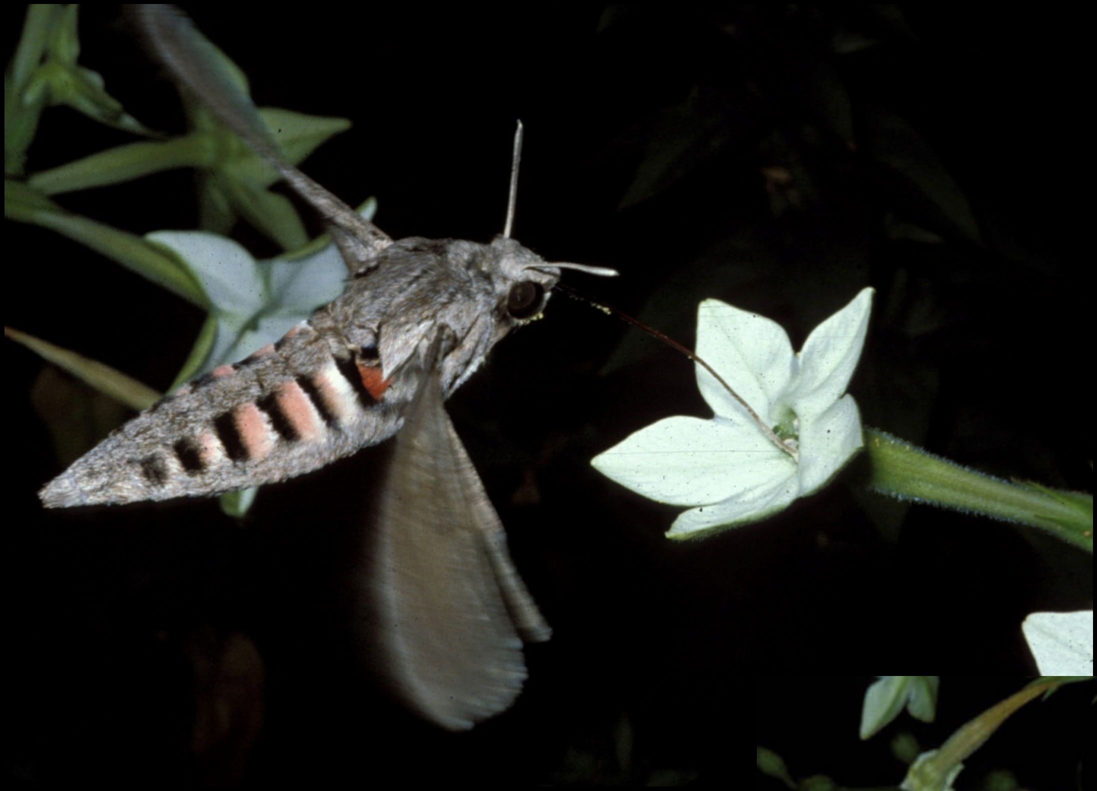
© Martin Heigan

© Martin Heiga

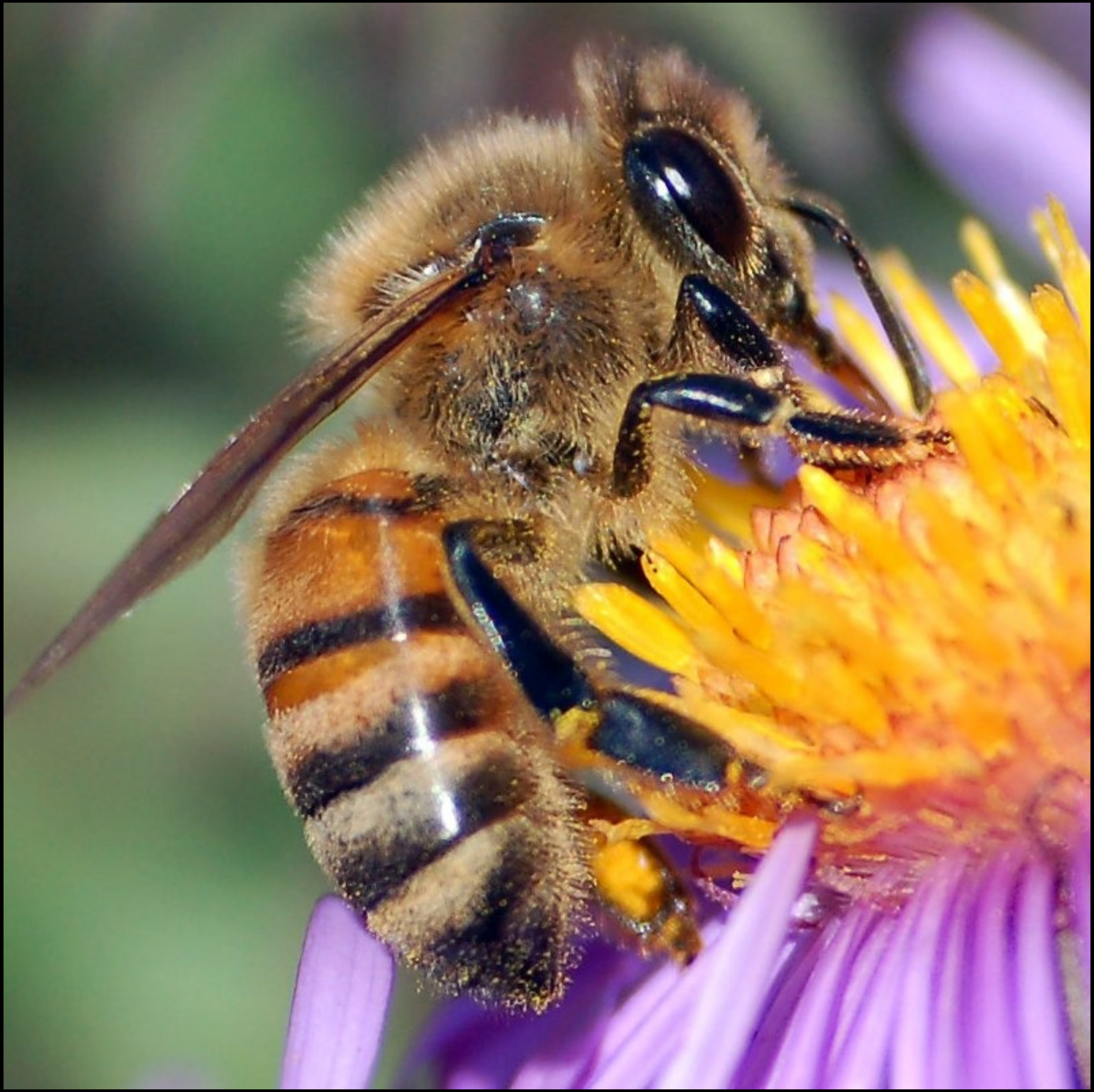
Polinização por Borboletas

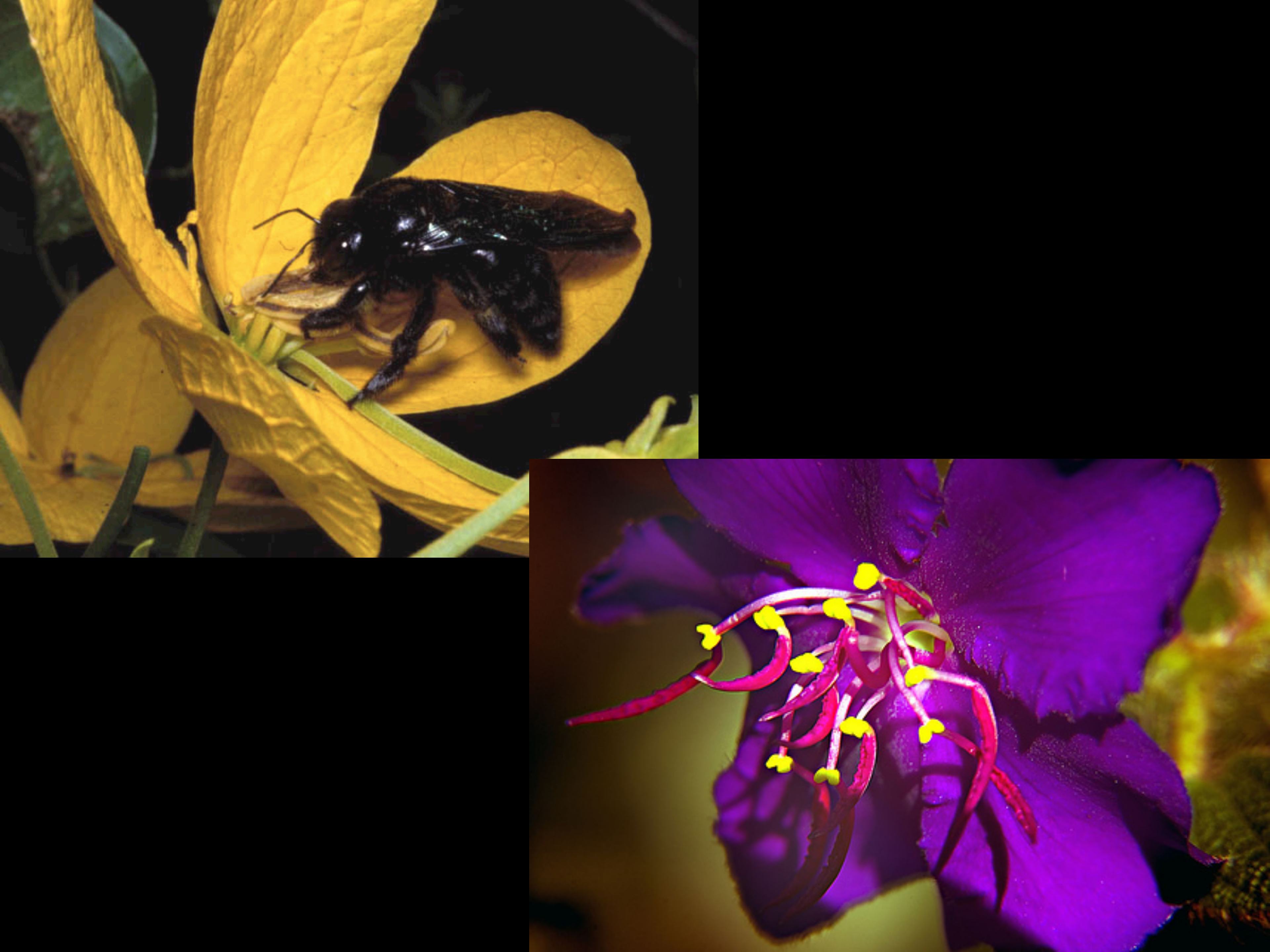


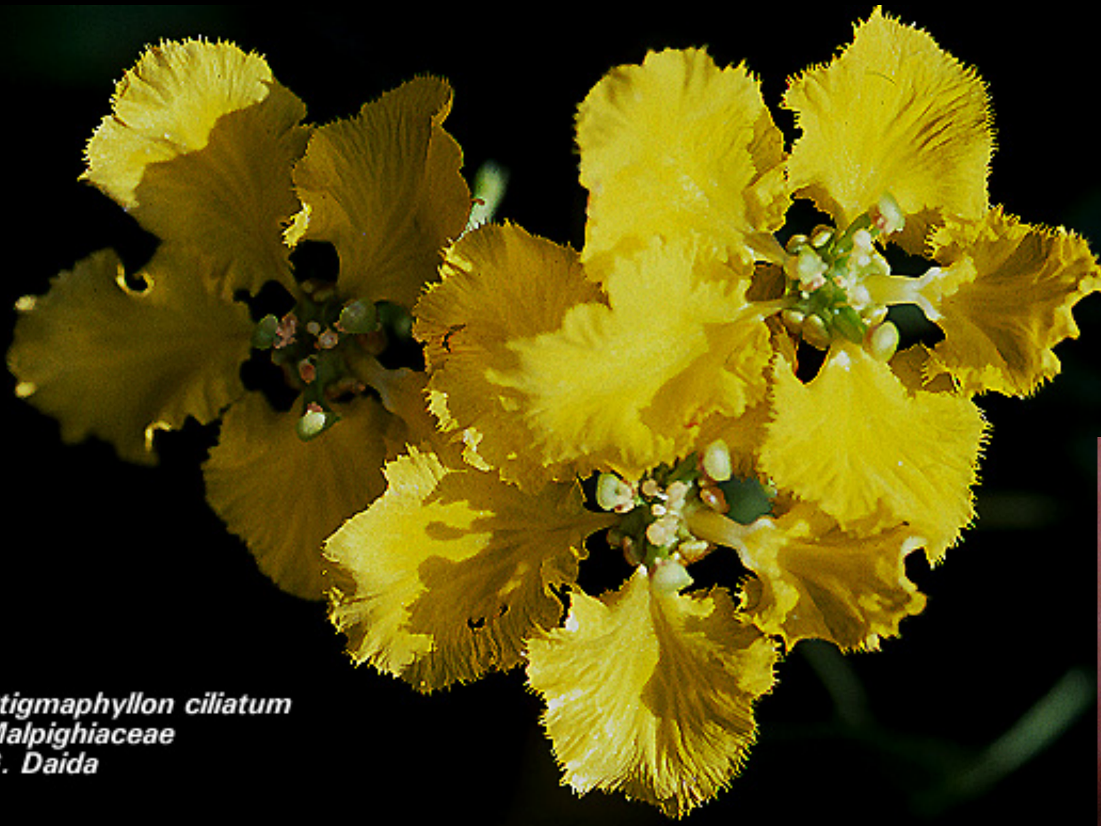
Polinização por Mariposas



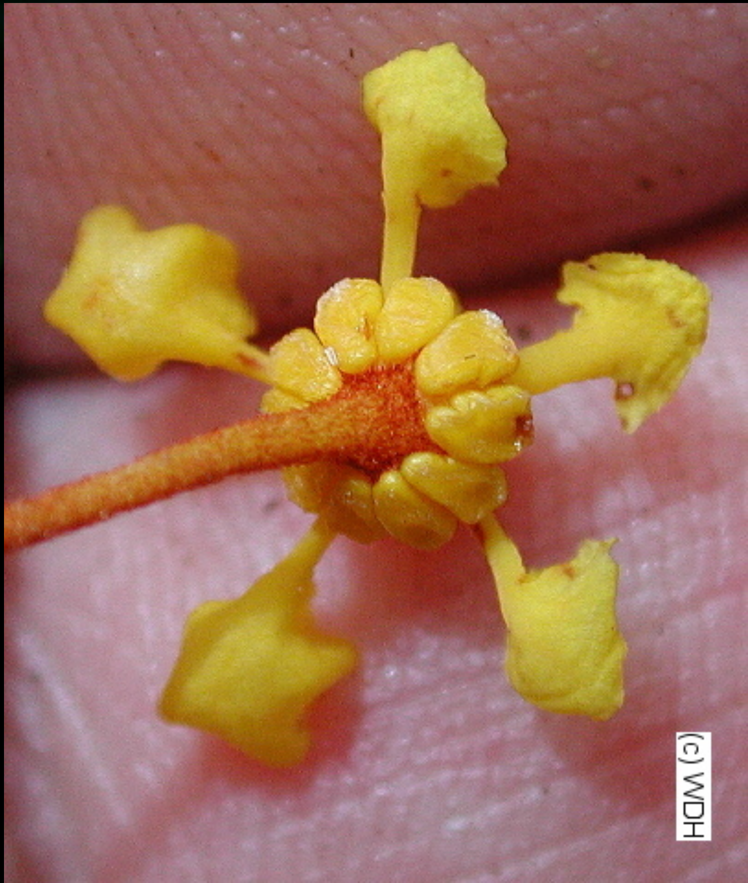
Polinização por Abelhas



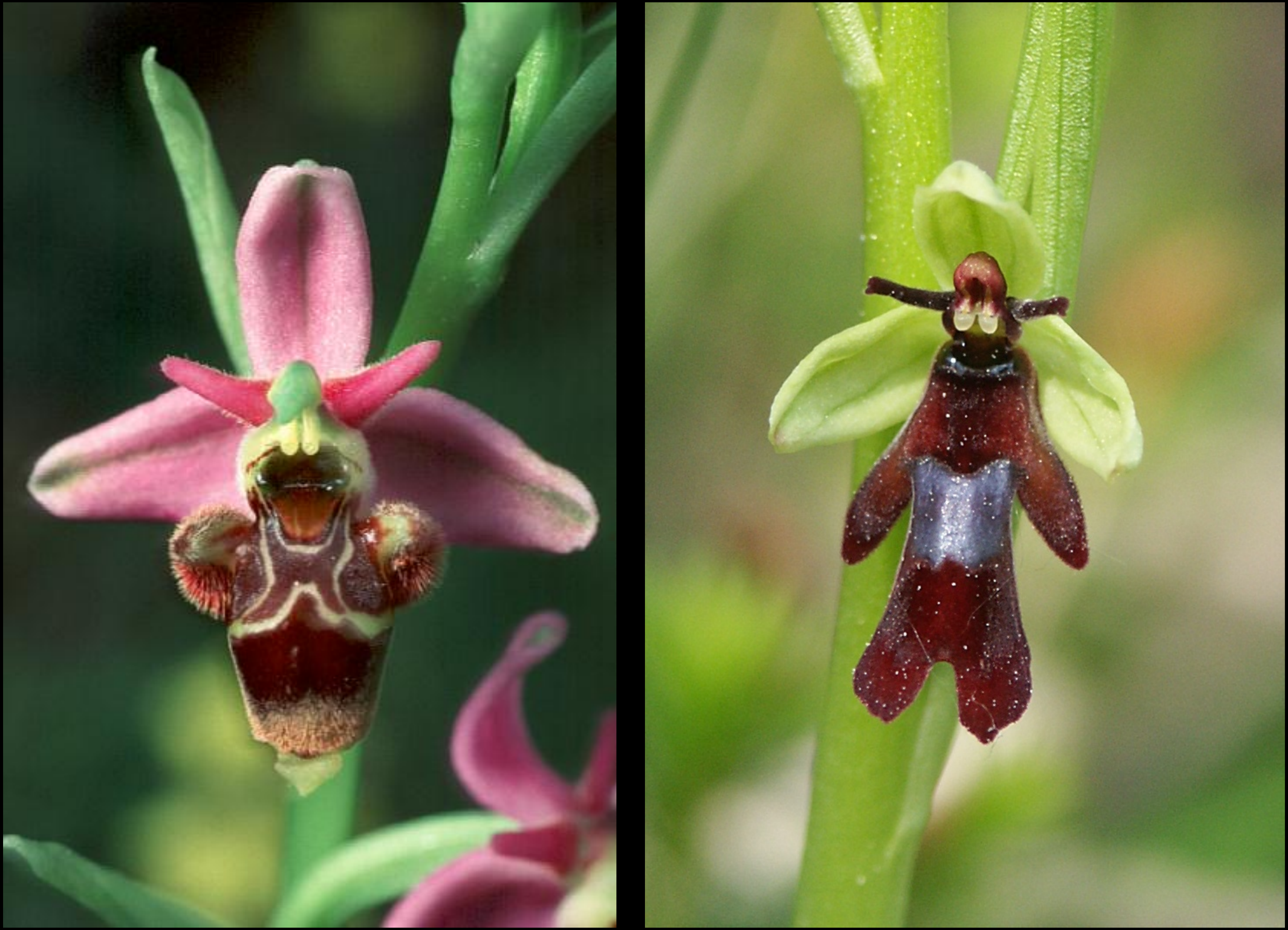




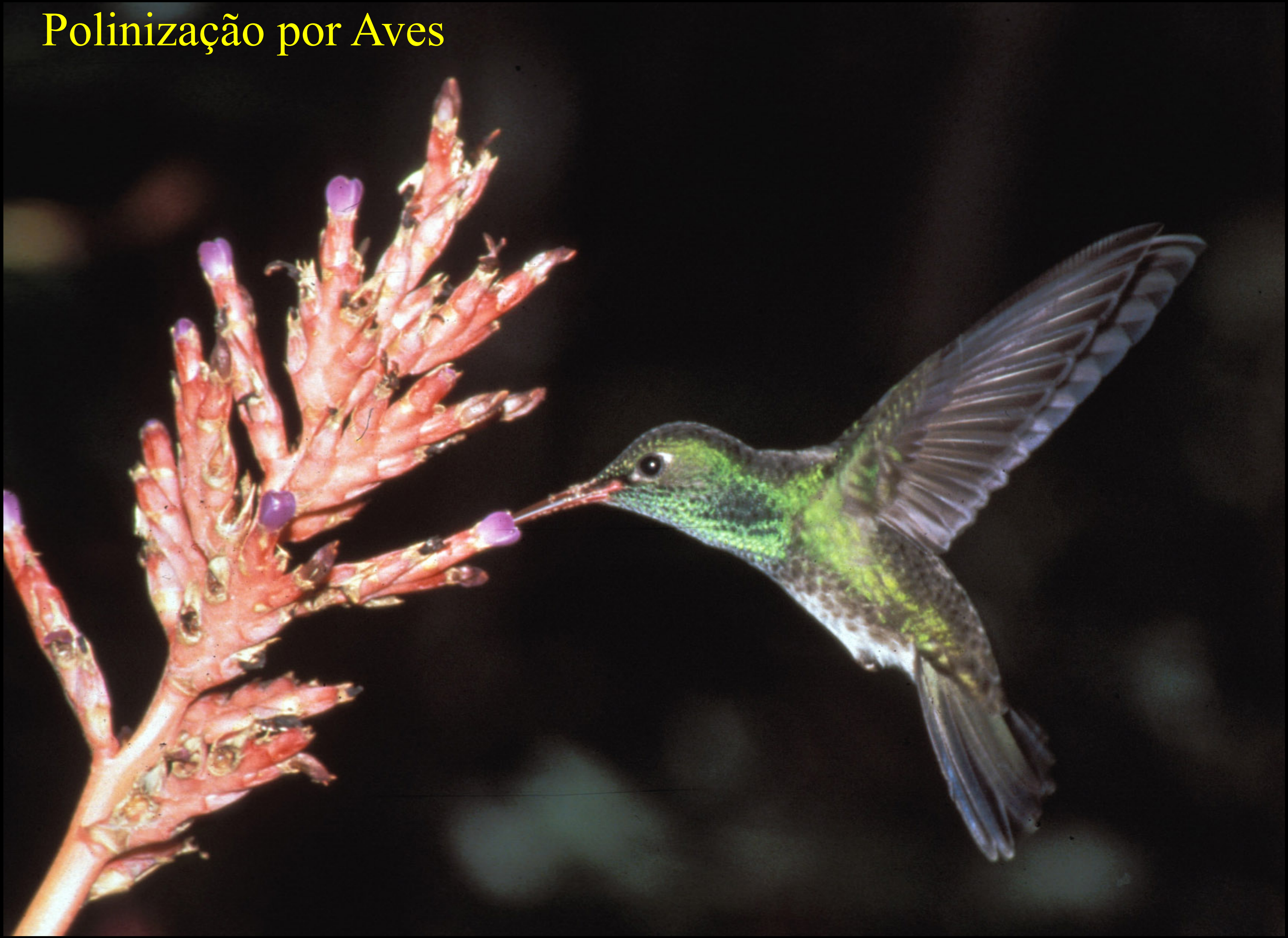
Stigmaphyllon ciliatum
Malpighiaceae
G. Daida

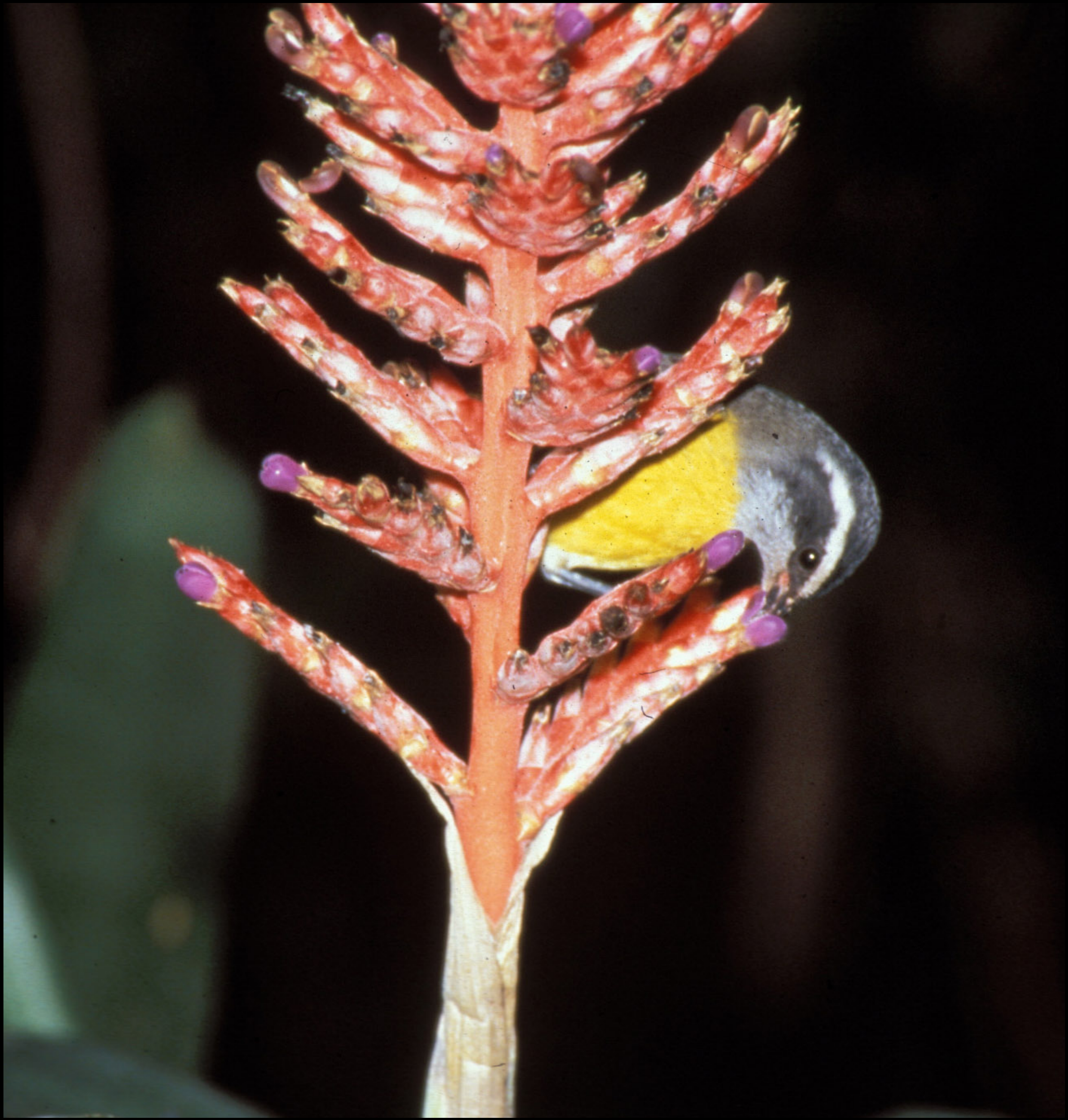


Polinização por Vespas

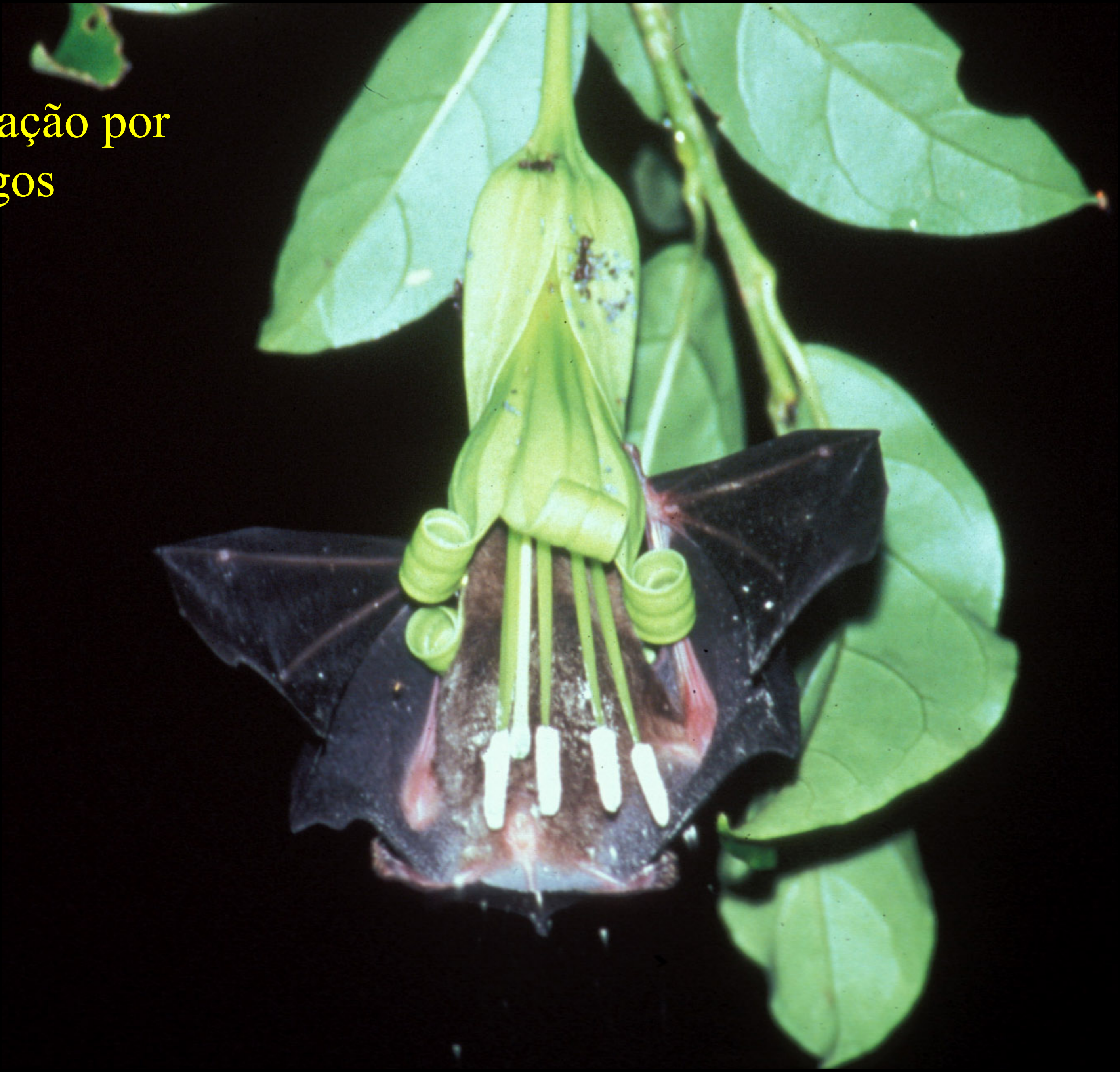


Polinização por Aves

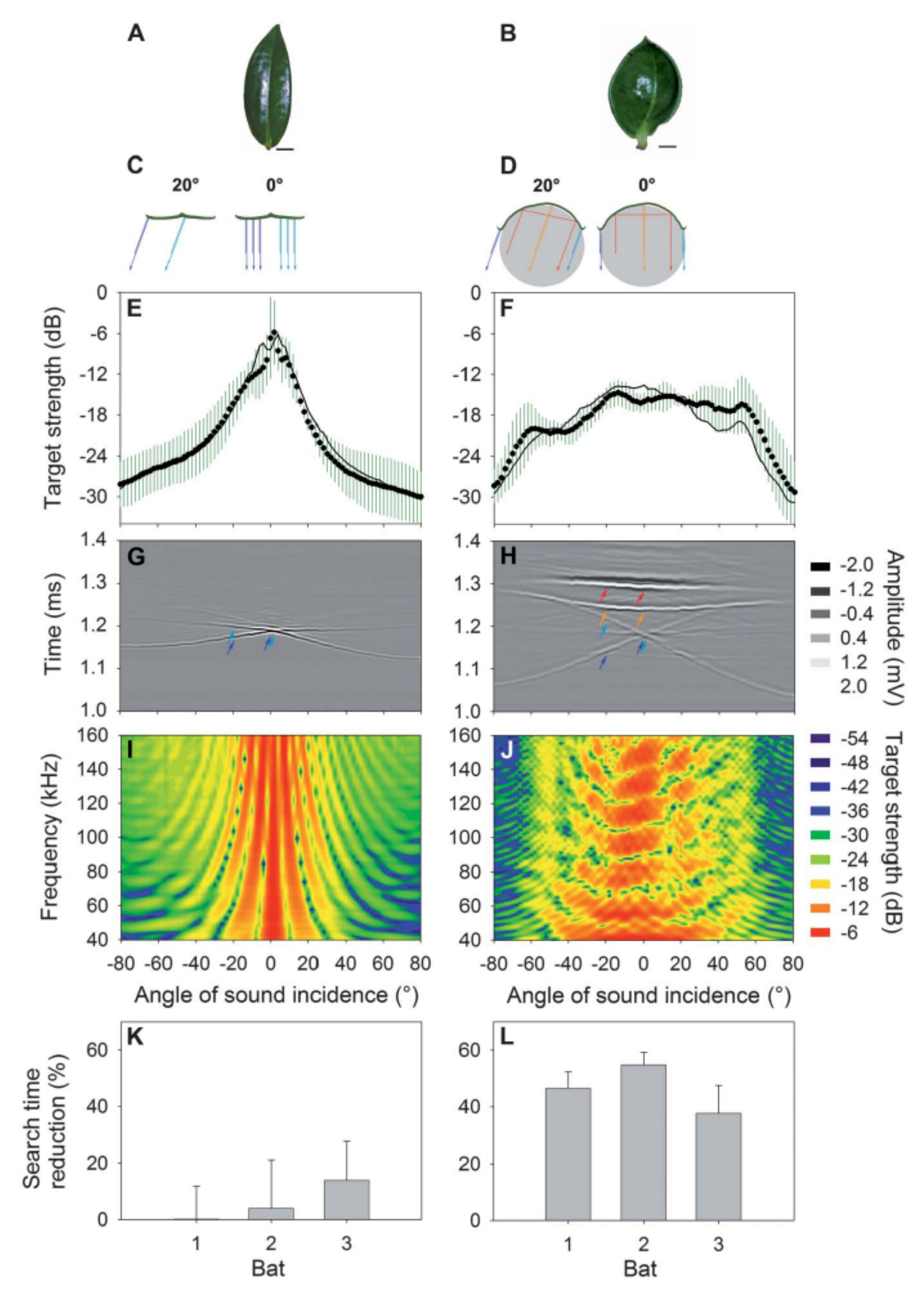




Polinização por Morcegos



Ami Pate/NPS


A
B
C
20°
0°
D
20°
0°
E
F
Target strength (dB)
0
-6
-12
-18
-24
-30
G
H
Time (ms)
1.4
1.3
1.2
1.1
1.0
-2.0
-1.2
-0.4
0.4
1.2
2.0
Amplitude (mV)
I
J
Frequency (kHz)
160
140
120
100
80
60
40
-54
-48
-42
-36
-30
-24
-18
-12
-6
Target strength (dB)
-80 -60 -40 -20 0 20 40 60 80
Angle of sound incidence (°)
K
L
Search time reduction (%)
60
40
20
0
1
2
3
Bat

Néctar: Principal recurso floral para os polinizadores

Composição do néctar

- -Glicose (monossacarídeo)
- -Frutose (monossacarídeo)
- -Sacarose (dissacarídeo)

A proporção de cada tipo de açúcar no néctar pode variar de acordo com cada grupo de polinizadores

(BAKER & BAKER 1983)

A variabilidade do néctar é determinada por um conjunto de fatores intrínsecos e extrínsecos dependendo da espécie de planta, isto é:

Fatores intrínsecos

-volume

-concentração

-taxa de produção

-composição química

-efeitos de remoção

-reabsorção

-idade da flor

Fatores extrínsecos

-temperatura,

-umidade,

-presença de outros visitantes florais que roubam néctar

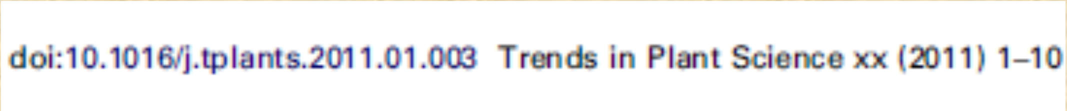
Review

Cell PRESS

Nectar: generation, regulation and ecological functions

Martin Heil

Departamento de Ingeniería Genética, CINVESTAV – Irapuato, Km. 9.6 Libramiento Norte, CP 36821, Irapuato, Guanajuato, México



doi:10.1016/j.tplants.2011.01.003 Trends in Plant Science xx (2011) 1–10

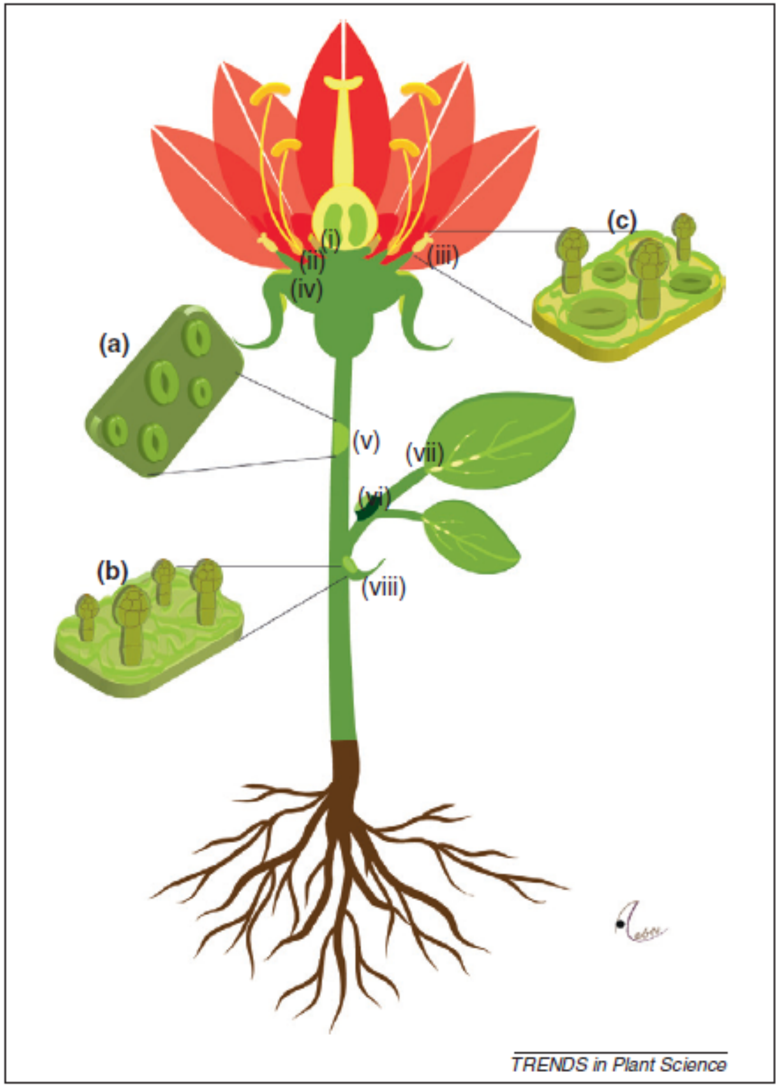
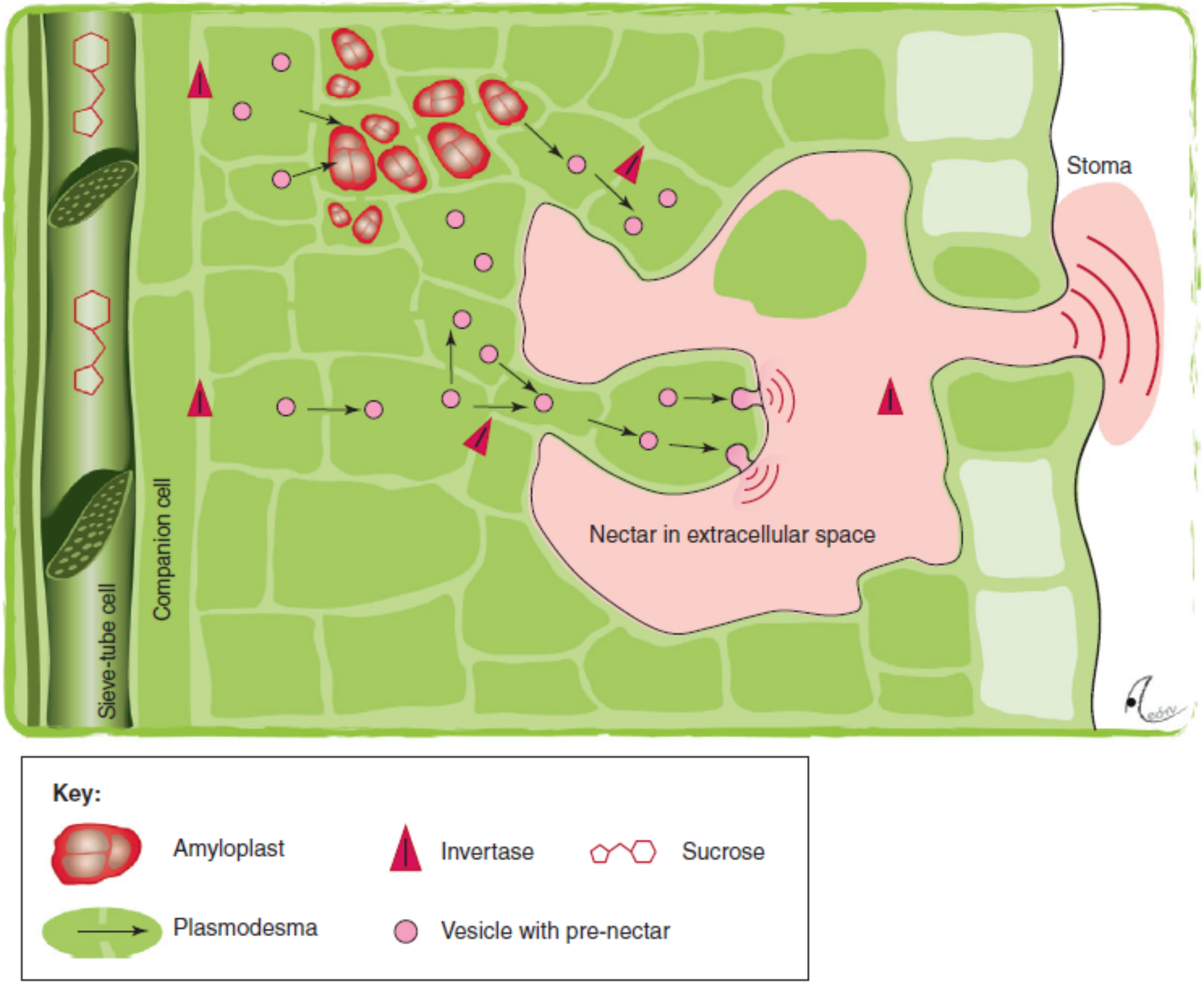
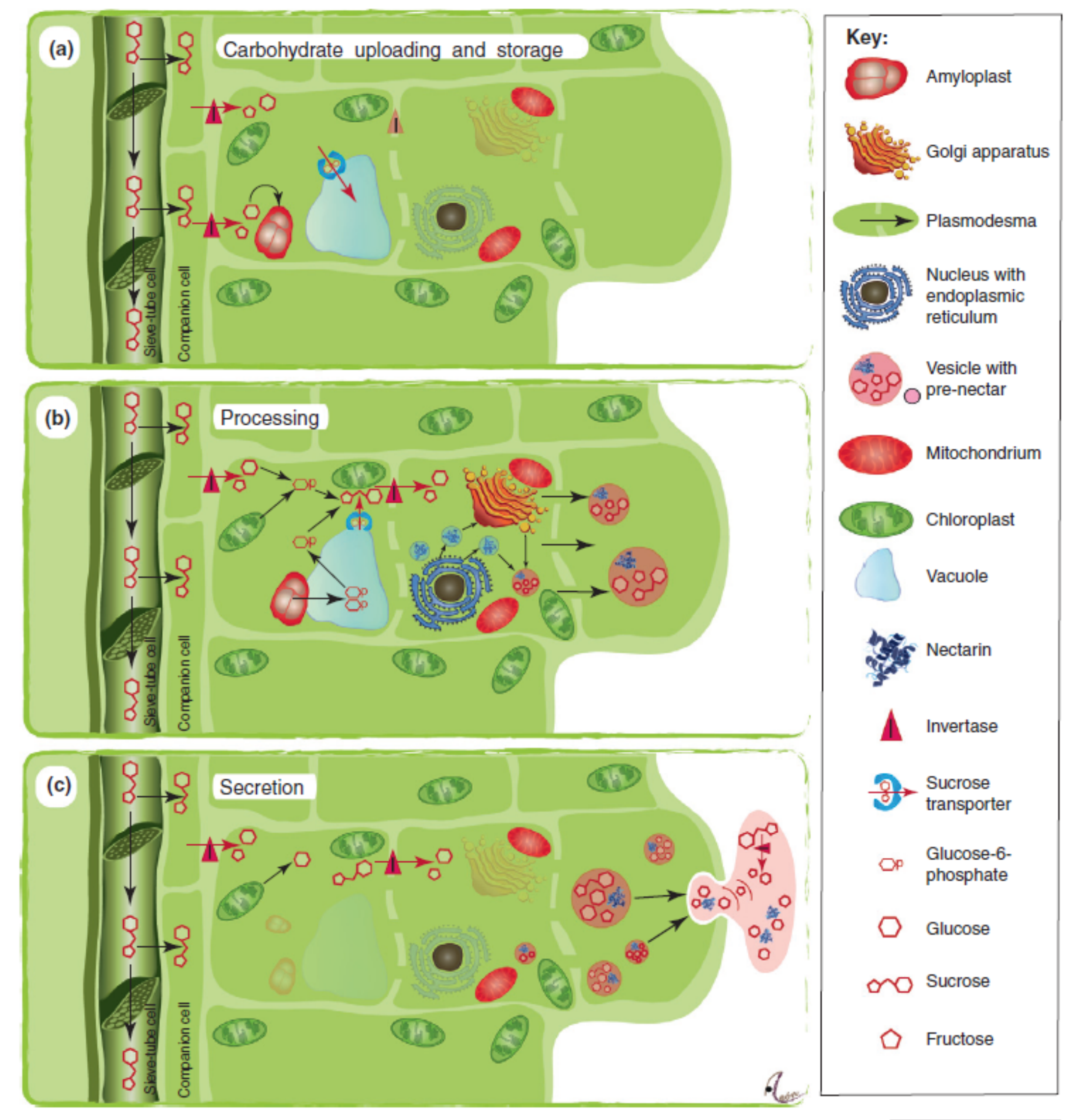


Figure 1. The distribution of nectaries within a plant. Floral nectaries can be located at the base of the ovary **(i)**, the filaments **(ii)** or the petals **(iii)**, whereas extrafloral nectaries can be located on the inner or outer surfaces of the sepals **(iv)**, on the shoot **(v)**, leaf stalks **(vi)**, leaf blades **(vii)** or stipules **(viii)**. The most common types of nectaries secrete via constantly open stomata **(a)**, secretory trichomes **(b)** or a combination of both **(c)**.


Stoma
Nectar in extracellular space
Companion cell
Sieve-tube cell
Key:
Amyloplast
Invertase
Sucrose
Plasmodesma
Vesicle with pre-nectar

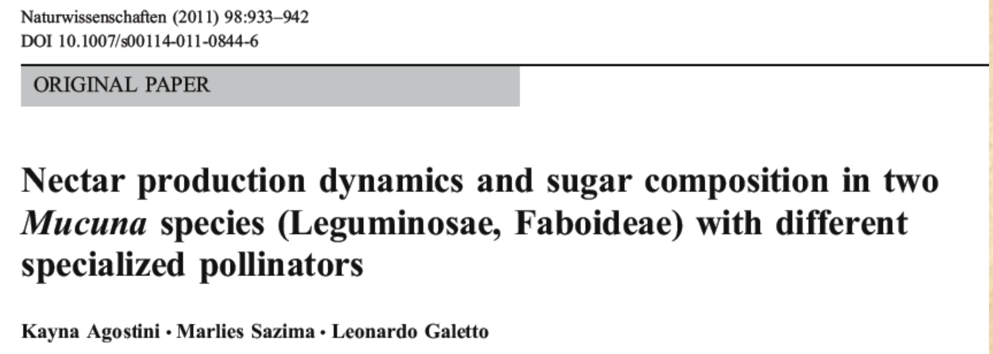
TRENDS in Plant Science

Figure I. The ultrastructure of nectar secretion. The hypothesis that prenectar is formed, metabolized and transported in vesicles within the nectariferous tissue is supported by the ultrastructural properties of this tissue [95]. The high density of plasmodesmata, which is common in the nectariferous tissue [37,110], allows vesicles to move rapidly among cells. In the case of floral nectaries, the prestorage of carbohydrates in amyloplasts can be involved (upper region), enabling floral nectaries to reach high peak sugar secretion rates owing to a combination of starch breakdown and the current uploading of sucrose from the phloem [99,103]. These peak rates are achieved when starch-containing plastids come into direct contact with the vacuole [35]. However, the prestorage of starch is not an essential prerequisite for nectar secretion (lower region) because it is not likely to occur in extrafloral nectaries.


(a)
Carbohydrate uploading and storage
Sieve-tube cell
Companion cell
(b)
Processing
Sieve-tube cell
Companion cell
(c)
Secretion
Sieve-tube cell
Companion cell
Key:
Amyloplast
Golgi apparatus
Plasmodesma
Nucleus with endoplasmic reticulum
Vesicle with pre-nectar
Mitochondrium
Chloroplast
Vacuole
Nectarin
Invertase
Sucrose transporter
Glucose-6-phosphate
Glucose
Sucrose
Fructose

TRENDS in Plant Science

Figure 2. Nectar formation and secretion. Nectar formation and secretion probably require three metabolically different phases (see online supplementary movie): **(a)** optional carbohydrate uploading and storage, **(b)** nectar processing and the synthesis of non-carbohydrate components and **(c)** secretion. Invertases seem to be involved in several steps: **(i)** the uploading of sucrose from the phloem into the nectariferous tissue [22]; **(ii)** the formation of the sink required for the secretion of sugars into the extracellular space [22,92,94,95,102]; and **(iii)** the formation of hexose-rich nectars. The last step can be catalyzed by invertases that are localized in the nectariferous tissue or in the secreted nectar itself [14,102]. *In situ* photosynthesis by chloroplasts in the nectariferous tissue might provide additional carbohydrates. Nectariferous tissues are usually characterized by a dense, rough endoplasmic reticulum, the presence of many dictyosomes and an active Golgi apparatus [109,110]. The presence of protein-rich inclusions [37] points towards the synthesis and storage of nectarins in the nectariferous tissue itself, and the generally high abundance of mitochondria [34,109,110] indicates high metabolic activity. Therefore, many of the non-carbohydrate components of the nectar are likely to be synthesized in the nectariferous tissue. It remains to be elucidated whether the vesicles stem from the Golgi apparatus or directly from the endoplasmic reticulum, and where carbohydrates and the other nectar components are combined to form the final nectar.



Naturwissenschaften (2011) 98:933–942
DOI 10.1007/s00114-011-0844-6

ORIGINAL PAPER

Nectar production dynamics and sugar composition in two *Mucuna* species (Leguminosae, Faboideae) with different specialized pollinators

Kayna Agostini • Marlies Sazima • Leonardo Galetto

1) Dinâmica de produção de néctar

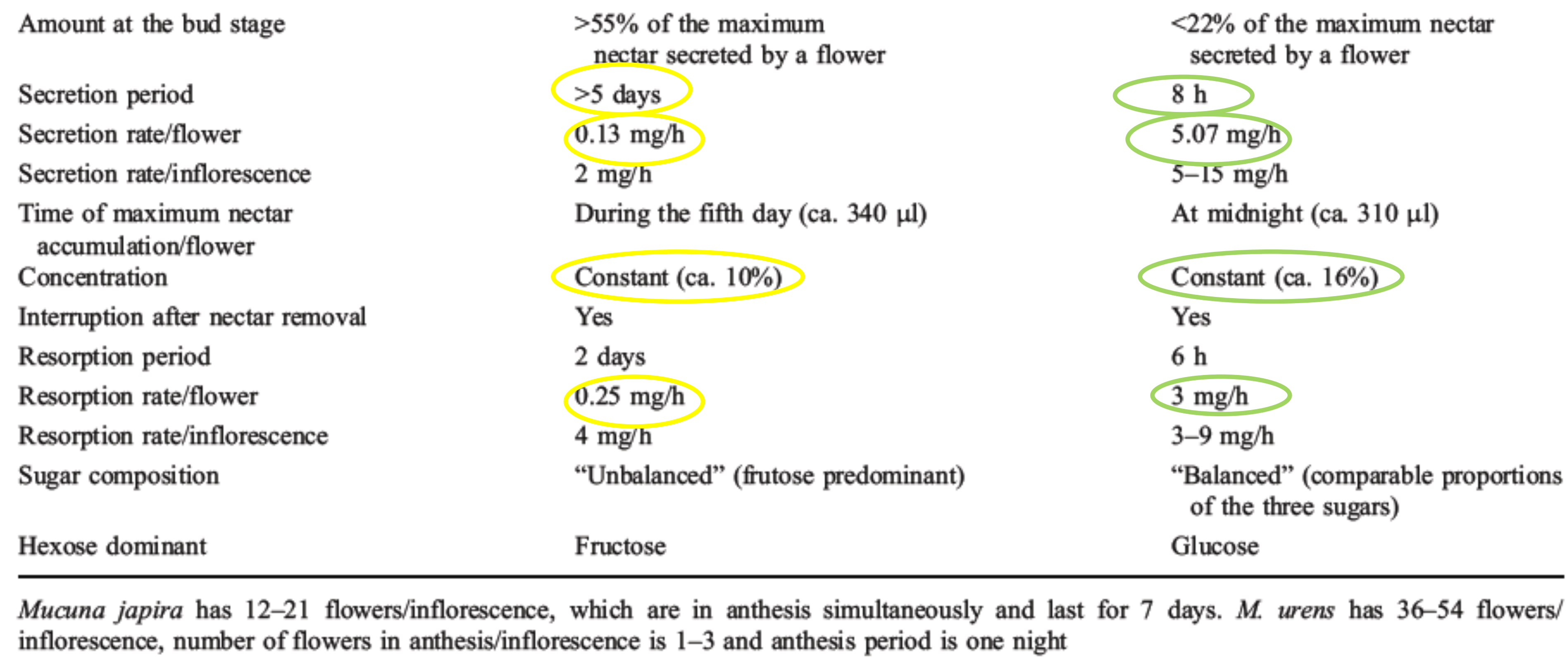


Table 1 Comparison of nectar traits between two species of *Mucuna*

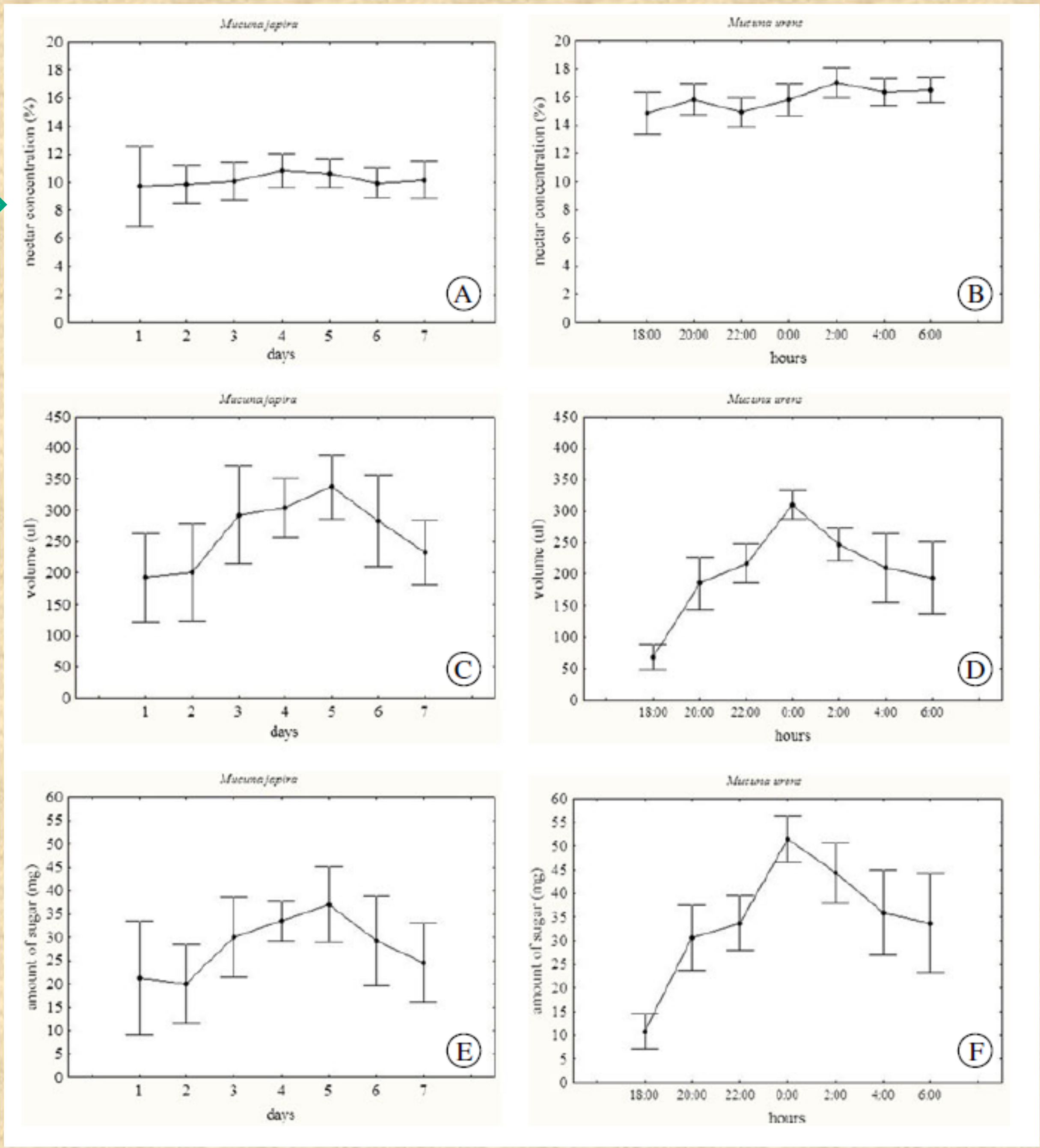
Nectar traits	*M. japira*	*M. urens*
Amount at the bud stage	>55% of the maximum nectar secreted by a flower	<22% of the maximum nectar secreted by a flower
Secretion period	>5 days	8 h
Secretion rate/flower	0.13 mg/h	5.07 mg/h
Secretion rate/inflorescence	2 mg/h	5–15 mg/h
Time of maximum nectar accumulation/flower	During the fifth day (ca. 340 µl)	At midnight (ca. 310 µl)
Concentration	Constant (ca. 10%)	Constant (ca. 16%)
Interruption after nectar removal	Yes	Yes
Resorption period	2 days	6 h
Resorption rate/flower	0.25 mg/h	3 mg/h
Resorption rate/inflorescence	4 mg/h	3–9 mg/h
Sugar composition	"Unbalanced" (frutose predominant)	"Balanced" (comparable proportions of the three sugars)
Hexose dominant	Fructose	Glucose

Mucuna japira has 12–21 flowers/inflorescence, which are in anthesis simultaneously and last for 7 days. *M. urens* has 36–54 flowers/inflorescence, number of flowers in anthesis/inflorescence is 1–3 and anthesis period is one night

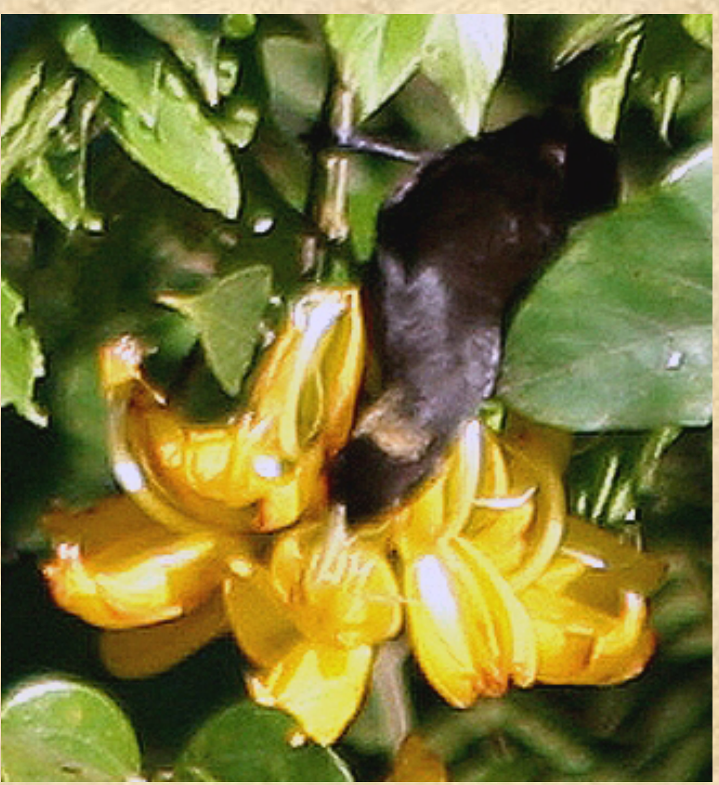
Concentração de açúcar no néctar

Volume

Taxa de açúcar no néctar



2) Composição de açúcares no néctar e 3) variação intra e interindividual



M. japira	Frutose	Glicose	Sacarose	S/(F+G)	G/F
Planta 1					
Flor 1	95.62	3.05	1.33	🟨 0.01	0.03
Flor 2	46.42	11.56	43.03	🟩 0.74	0.25
Flor 3	47.98	10.88	41.13	🟩 0.70	0.23
Flor 4	46.42	11.56	42.03	🟩 0.72	0.25
Planta 2					
Flor 1	74.25	6.86	18.89	🟥 0.23	0.09
Flor 2	61.36	18.05	20.59	🟥 0.26	0.29
Flor 3	83.05	4.89	12.06	🟥 0.13	0.06
Planta 3					
Flor 1	64.80	12.85	22.35	🟥 0.29	0.20
Flor 2	62.49	21.26	16.25	🟥 0.19	0.34
Flor 3	64.47	18.33	17.20	🟥 0.21	0.28
Planta 4					
Flor 1	78.32	4.86	16.82	🟥 0.20	0.06
Flor 2	65.07	17.55	17.37	🟥 0.21	0.27
Flor 3	79.86	4.71	15.43	🟥 0.18	0.06
Planta 5					
Flor 1	72.58	4.43	22.98	🟩 0.30	0.06
Flor 2	74.12	18.08	7.79	🟨 0.08	0.24
Flor 3	70.42	13.16	16.42	🟩 0.20	0.18

passeriformes ← 🟨 Néctar hexose-dominante

morcegos ← 🟥 Néctar hexose-rico

abelhas ← 🟩 Néctar sacarose-rico

M. urens	Frutose	Glicose	Sacarose	S/(F+G)	G/F
Planta 1					
Flor 1	29.75	33.76	36.49	🟩 0.58	1.13
Flor 2	55.57	33.48	10.95	🟥 0.12	0.60
Flor 3	34.72	45.20	20.08	🟥 0.25	1.30
Flor 4	29.67	34.79	35.54	🟩 0.55	1.17
Planta 2					
Flor 1	39.42	34.31	26.27	🟥 0.36	0.87
Flor 2	42.46	42.74	14.89	🟥 0.17	1.00
Flor 3	29.56	34.03	36.41	🟩 0.57	1.15
Flor 4	37.04	45.51	17.45	🟥 0.21	1.23
Planta 3					
Flor 1	47.15	40.12	12.73	🟥 0.15	0.85
Flor 2	37.94	34.39	27.67	🟥 0.38	0.91
Flor 3	37.20	44.46	18.34	🟥 0.22	1.19
Flor 4	40.42	38.49	31.77	🟥 0.21	1.12
Planta 4					
Flor 1	30.36	25.77	43.86	🟩 0.78	0.85
Flor 2	30.39	31.97	37.64	🟩 0.60	1.05
Flor 3	29.74	38.49	31.77	🟥 0.47	1.29
Flor 4	25.31	28.89	45.81	🟩 0.84	1.14
Planta 5					
Flor 1	37.74	37.19	25.08	🟥 0.33	0.99
Flor 2	43.30	45.25	11.45	🟥 0.13	1.04
Flor 3	33.76	41.69	24.55	🟥 0.32	1.23

passeriformes ← 🟨 Néctar hexose-dominante

morcegos ← 🟥 Néctar hexose-rico

abelhas ← 🟩 Néctar sacarose-rico

4) Influência da reabsorção do néctar na reprodução das espécies

Tratamentos	*M. japira*	*M. urens*
Polinização cruzada manual (sem remoção de néctar)	36,4% (20/55)	73,5% (25/34)
Polinização natural (com remoção de néctar pelos visitantes florais)	2,7% (27/997)	11,0% (59/536)

Maior reabsorção de néctar

Para que a formação de sementes e frutos seja bem sucedida, vários obstáculos devem ser vencidos, entre eles:

- Formação do Grão de Pólen e do Óvulo
- Mecanismos de compatibilidade
- Desenvolvimento do Embrião

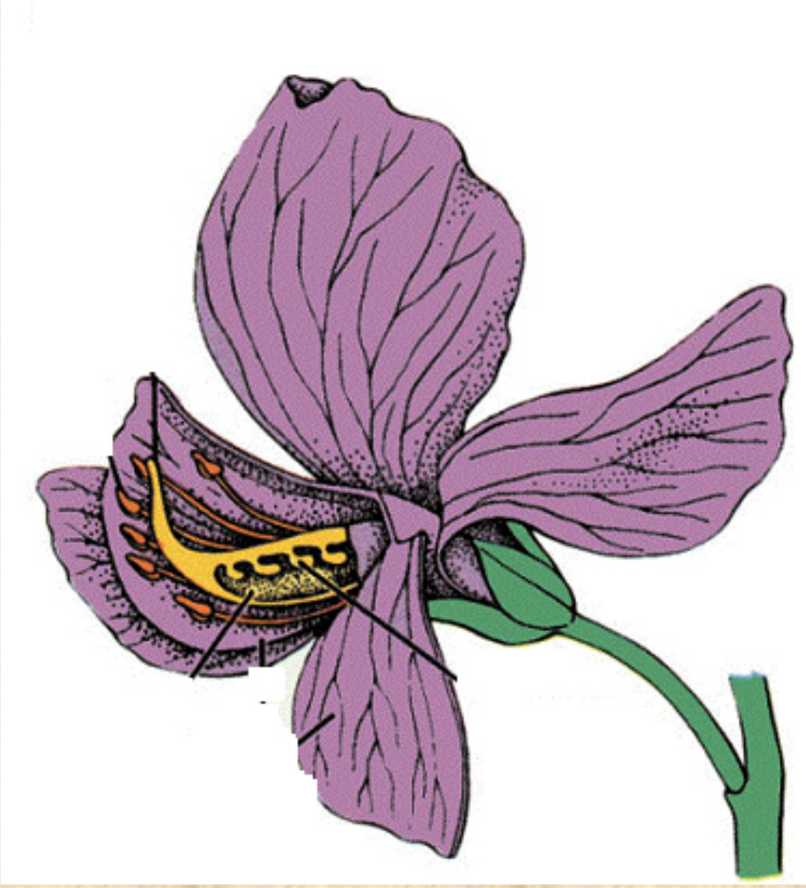
Desenvolvimento do grão de pólen

Verticilos estéreis = perianto ou perigônio (pétalas e sépalas)

Verticilos férteis

estames

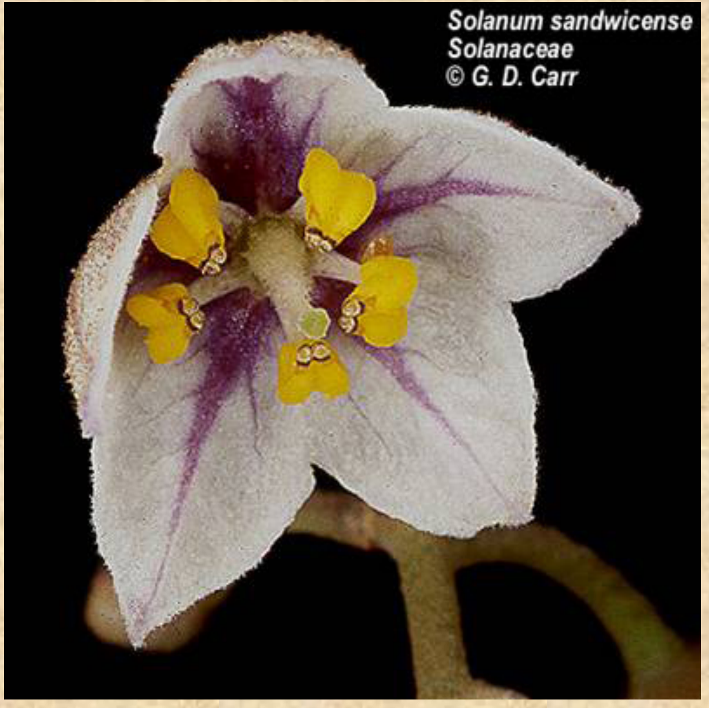
carpelos

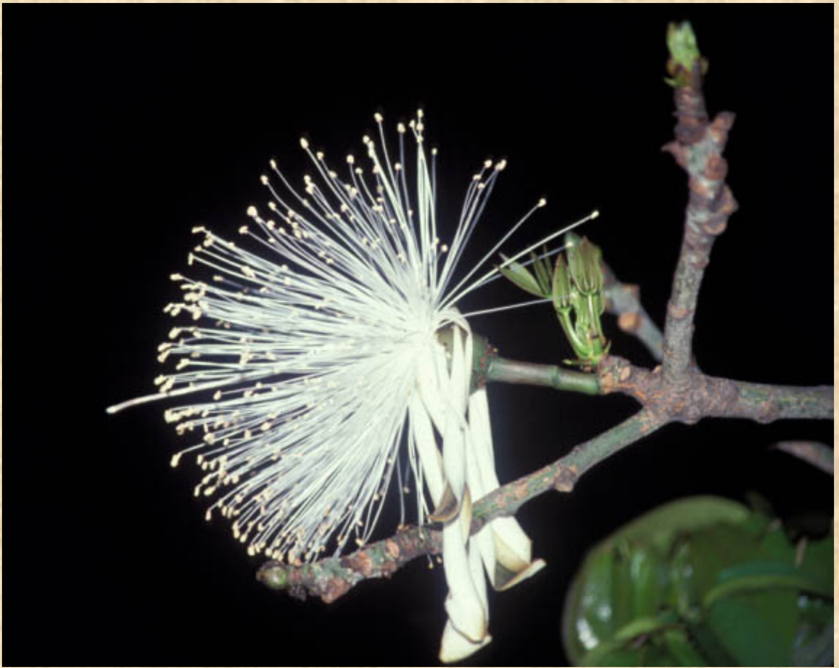


ANDROCEU

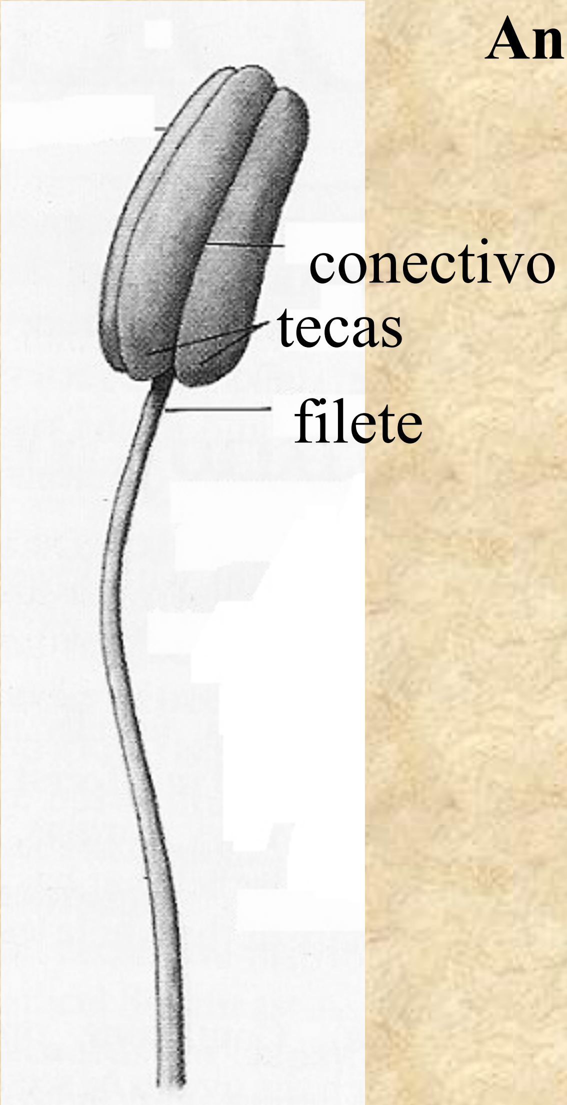
Androceu: verticilo fértil mais externo, composto de unidades chamadas de estames, arranjados em um ou vários círculos

–Estames: carregam os sacos polínicos


Solanum sandwicense
Solanaceae
© G. D. Carr

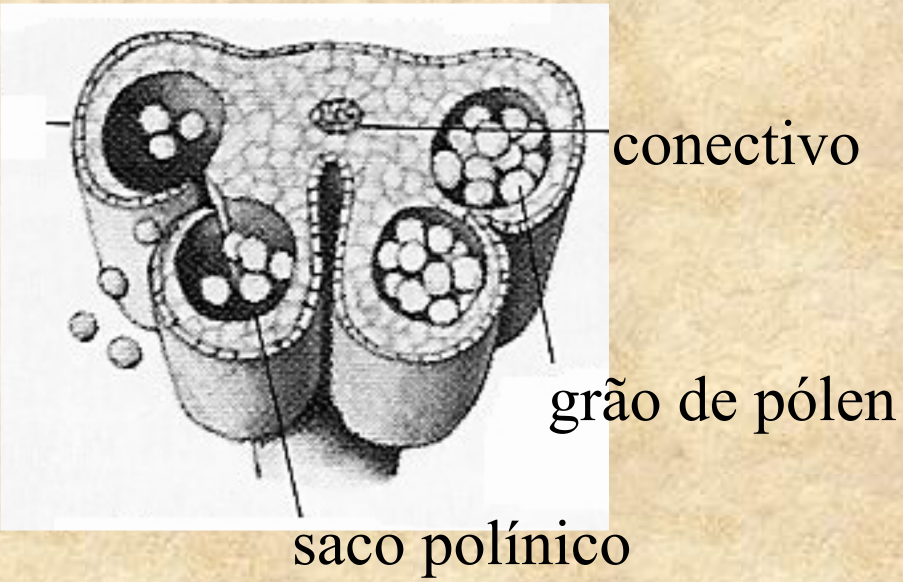


Androceu
Antera

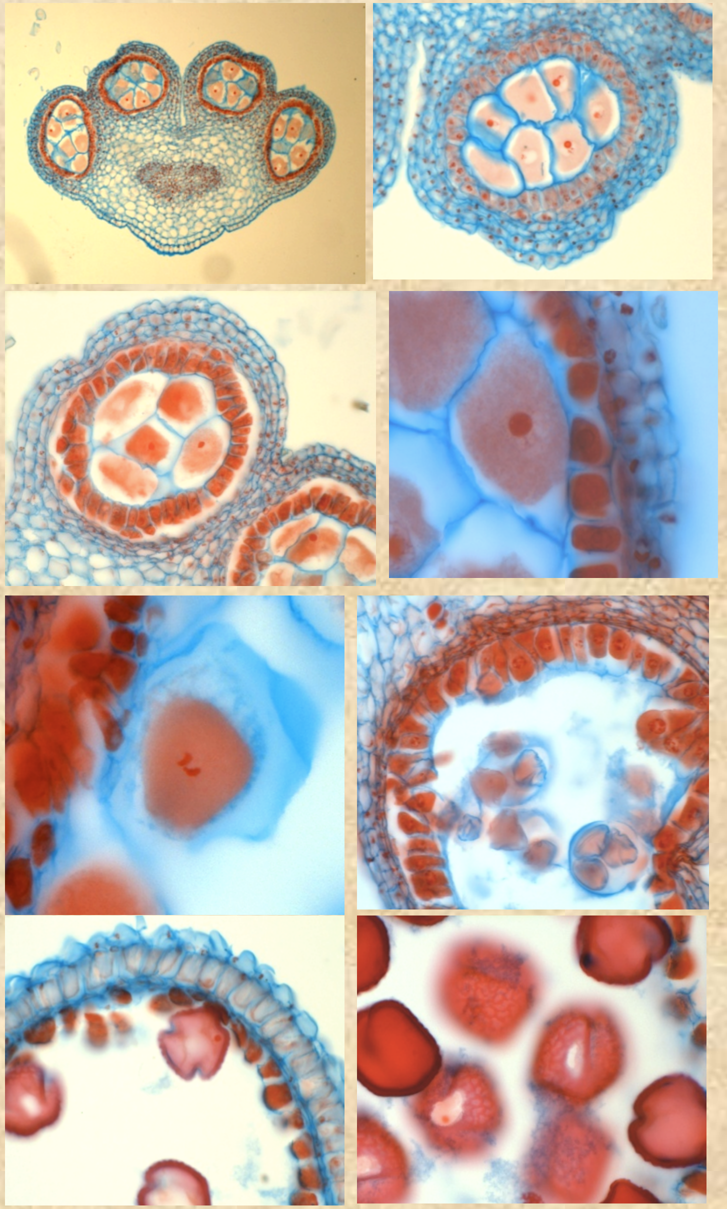

conectivo
tecas
filete

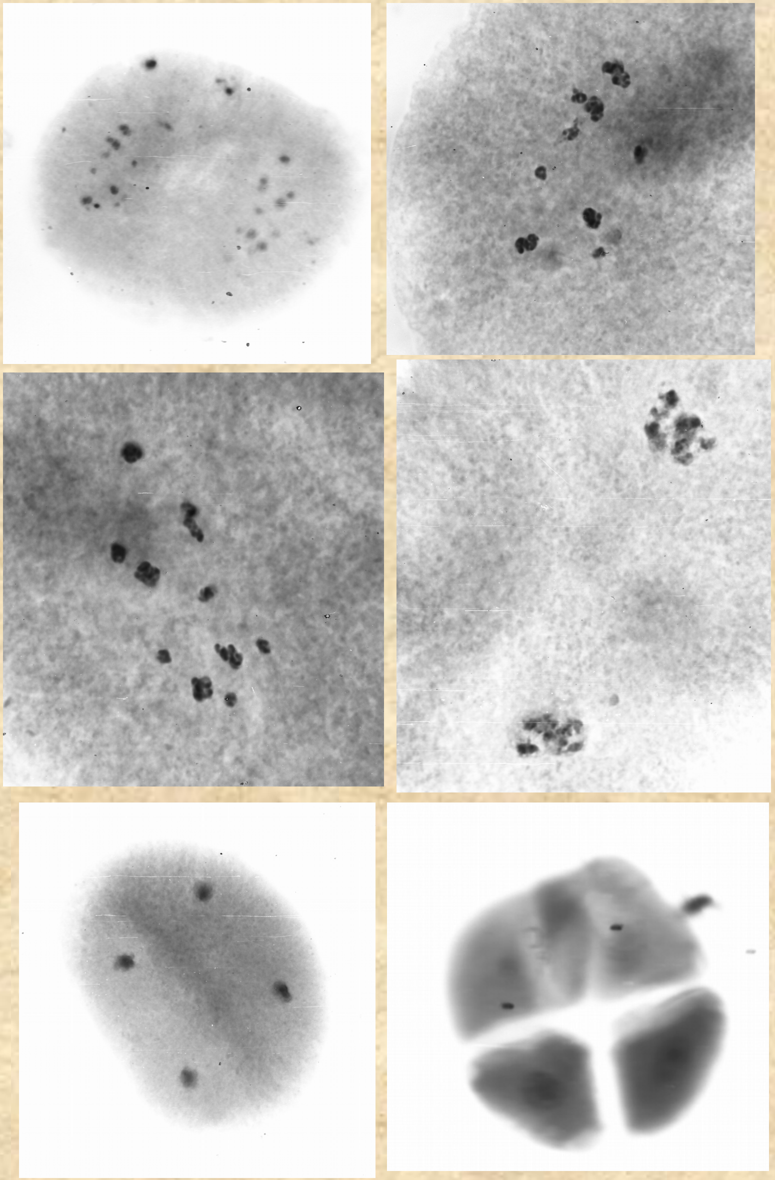
A antera geralmente é dividida em duas metades, as tecas, unidas entre si pelo conectivo. Cada teca carrega geralmente dois microesporângios ou sacos polínicos, onde são produzidos os (grãos de pólen)

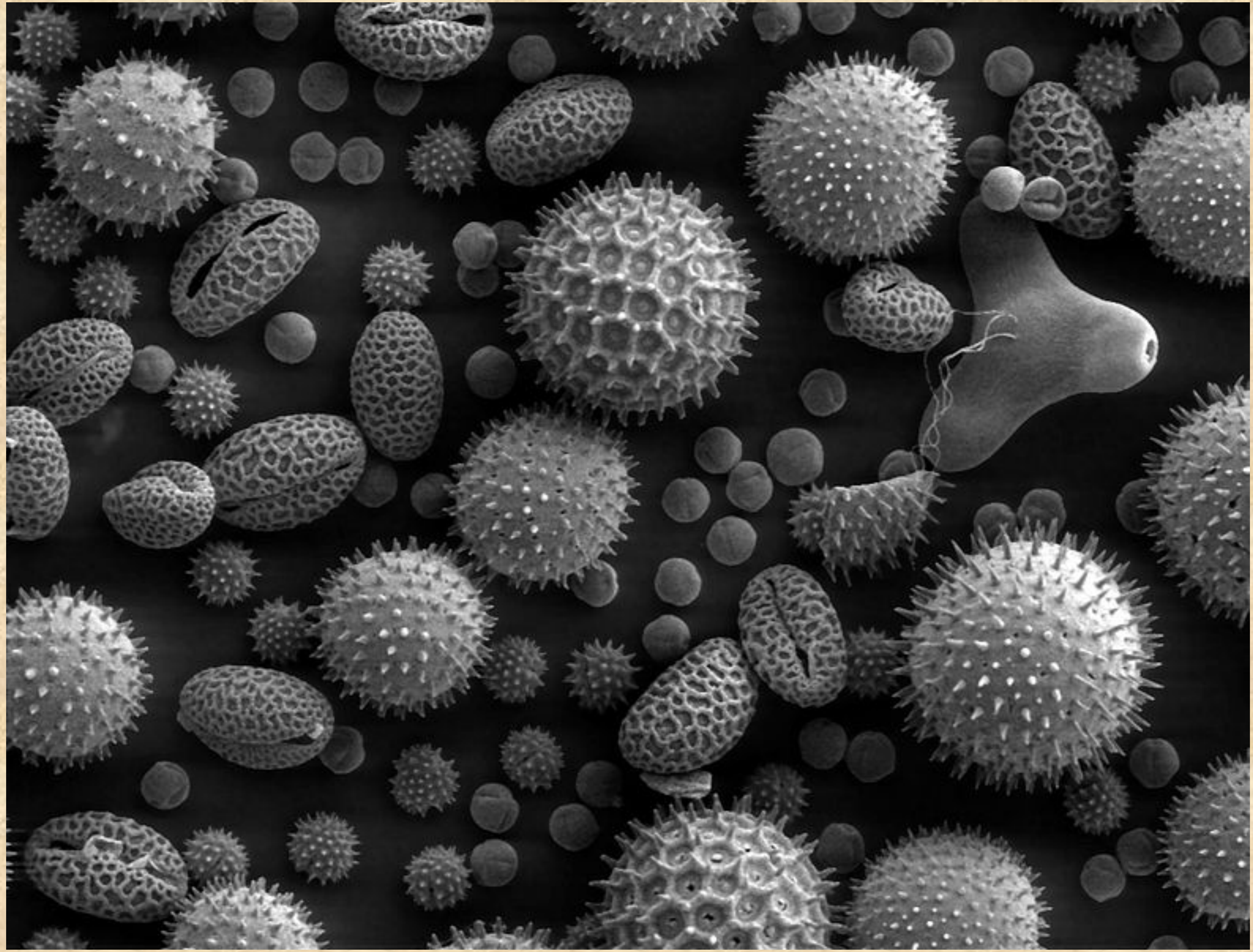
–A antera é revestida pela epiderme e pelo endotécio ou estrato fibroso, o interior dos sacos polínicos é revestido pelas células do tapetum, que nutrem as células-mãe dos grãos de pólen


conectivo
grão de pólen
saco polínico

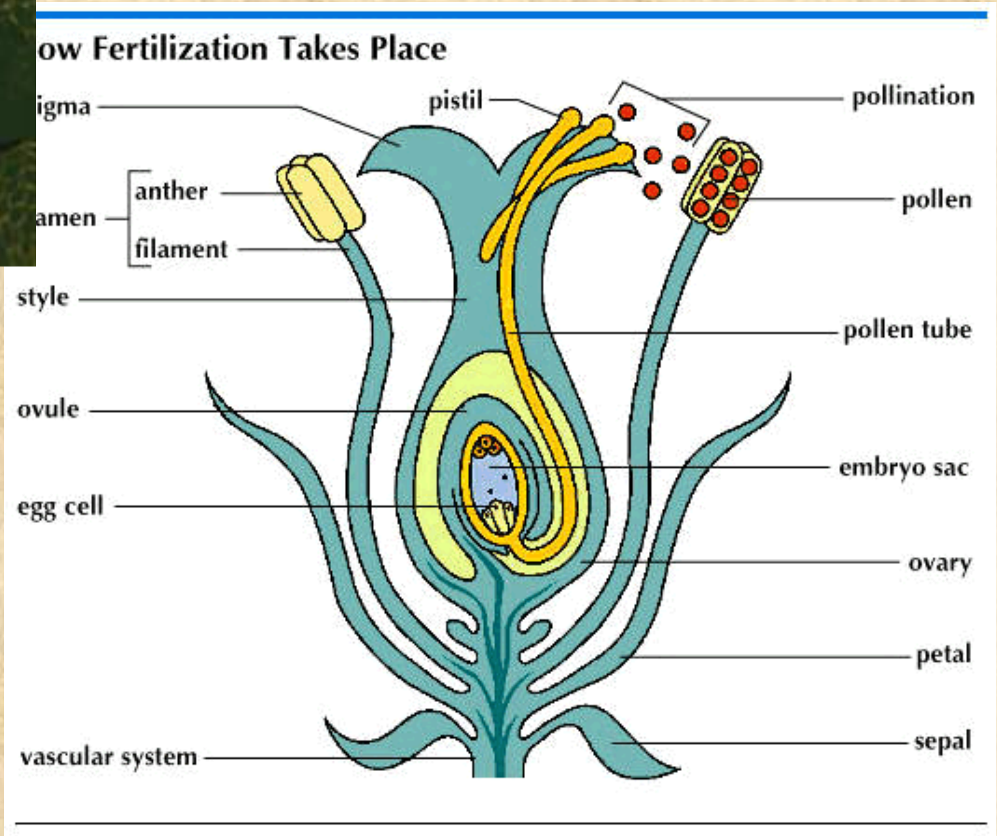
Processo de desenvolvimento do grão de pólen





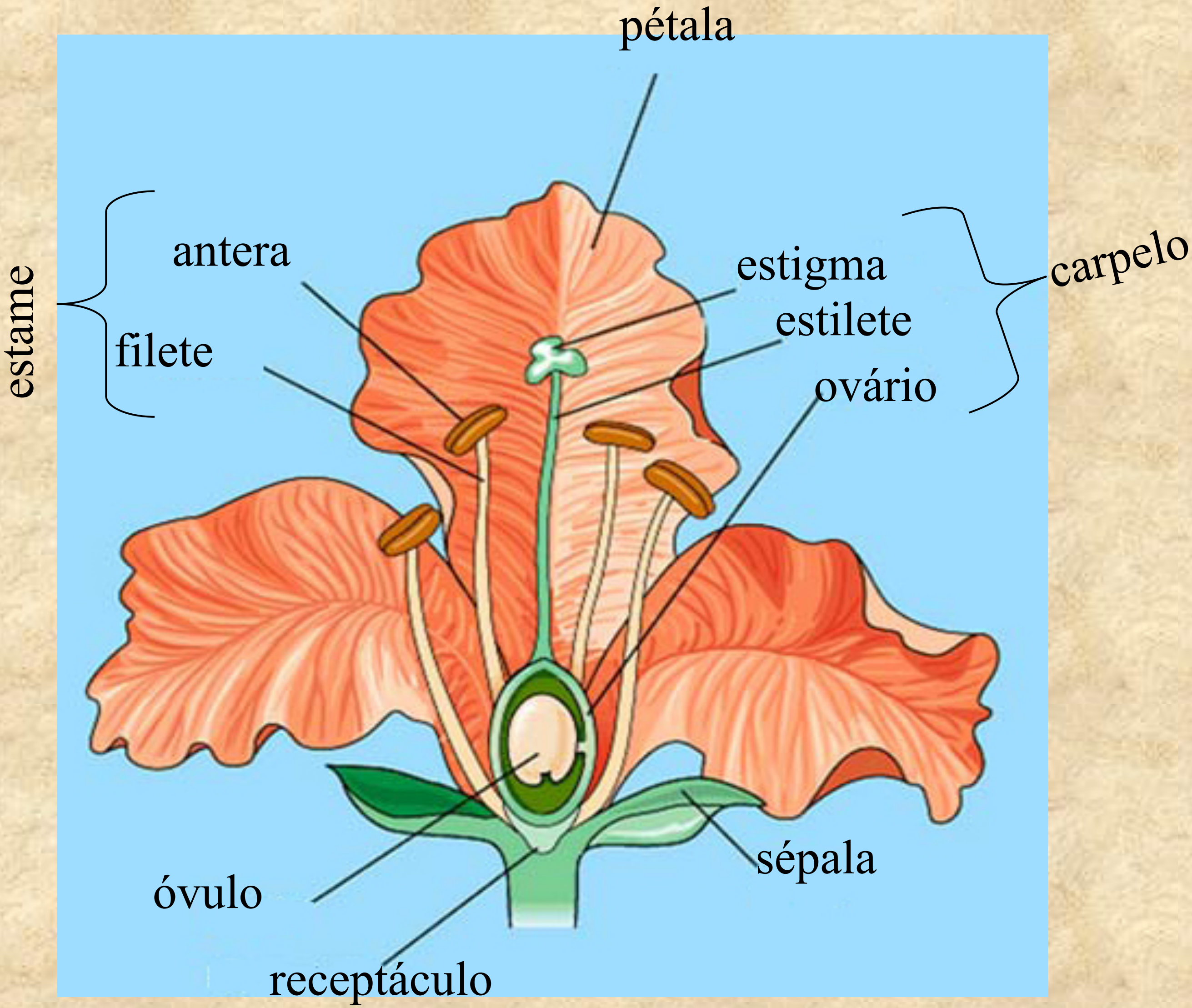


Papel do grão de pólen no processo de fertilização


ow Fertilization Takes Place
igma
pistil
pollination
anther
amen
filament
pollen
style
pollen tube
ovule
embryo sac
egg cell
ovary
petal
sepal
vascular system

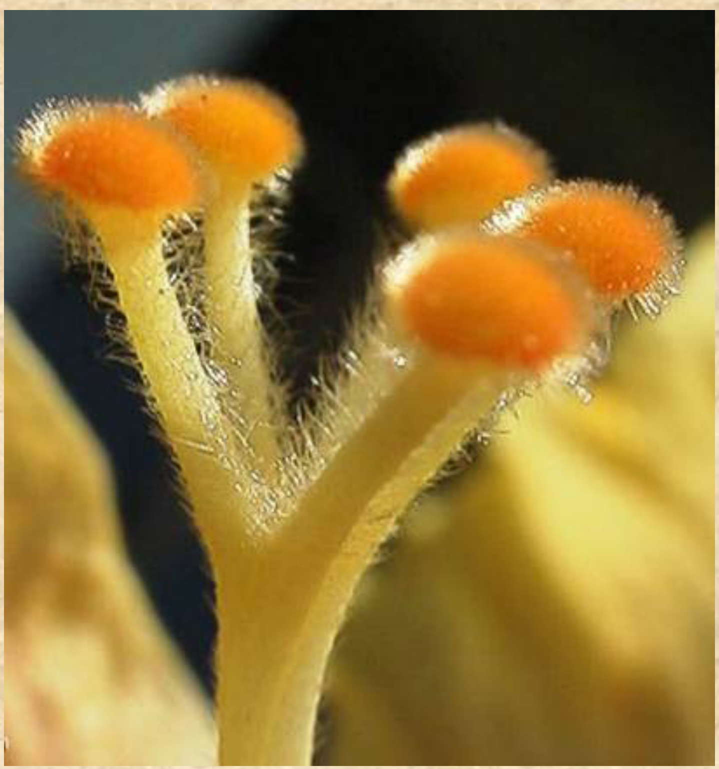
Desenvolvimento do óvulo

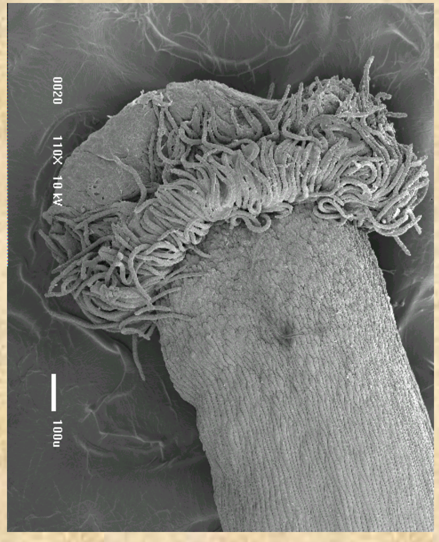
Partes da flor

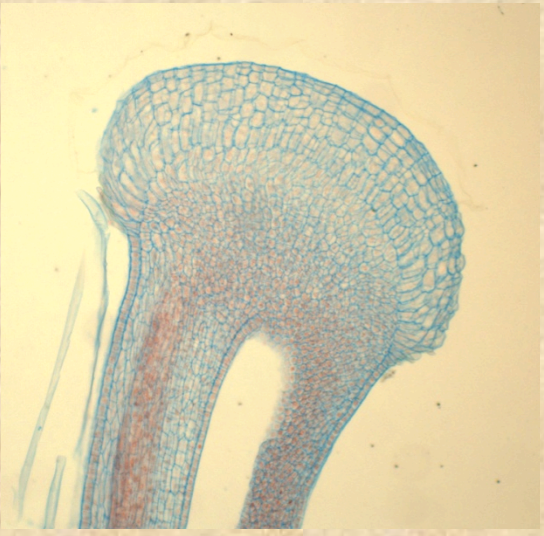

pétala
antera
estame
filete
estigma
estilete
carpelo
ovário
óvulo
sépala
receptáculo

Estigma

-Estigma: ápice da folha carpelar, geralmente coberto de papilas, que secretam em muitos casos substância pegajosa. O estigma é o local adequado para recepção dos grãos de pólen e sua posterior germinação





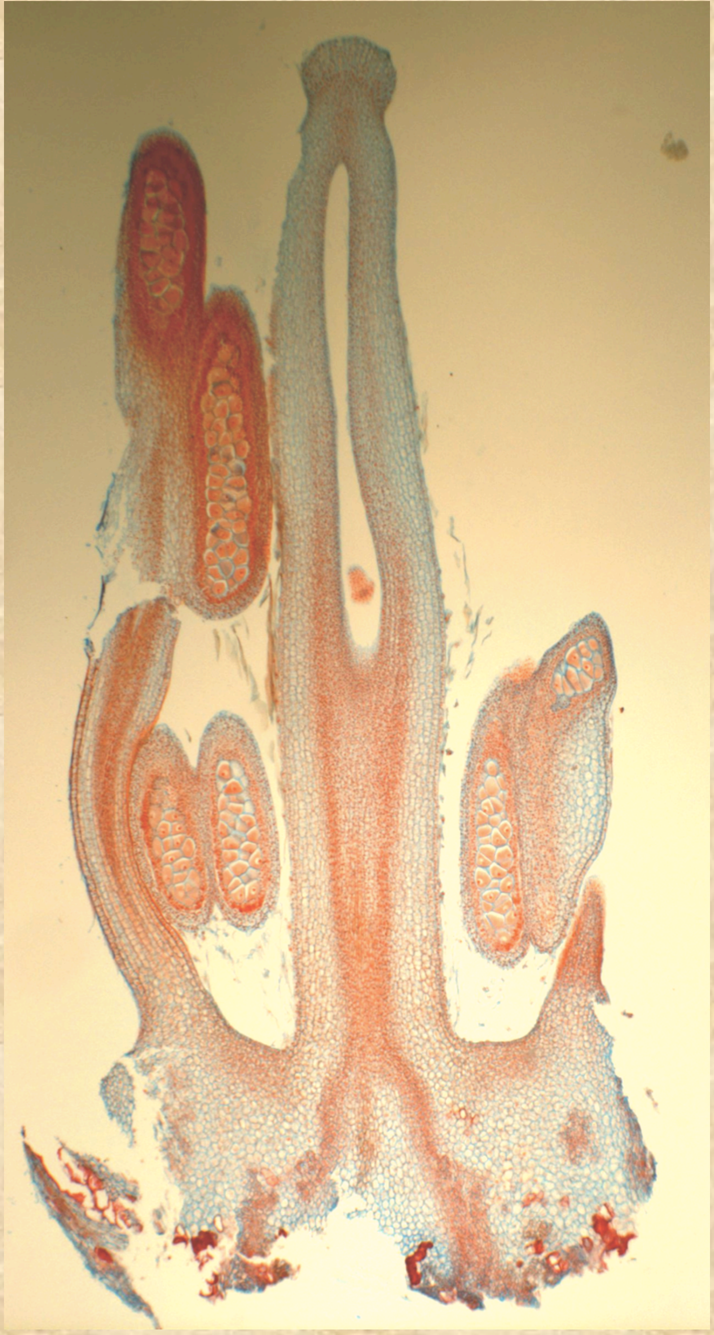


Estilete

Estilete: prolongamento da parte superior do ovário em um filamento.

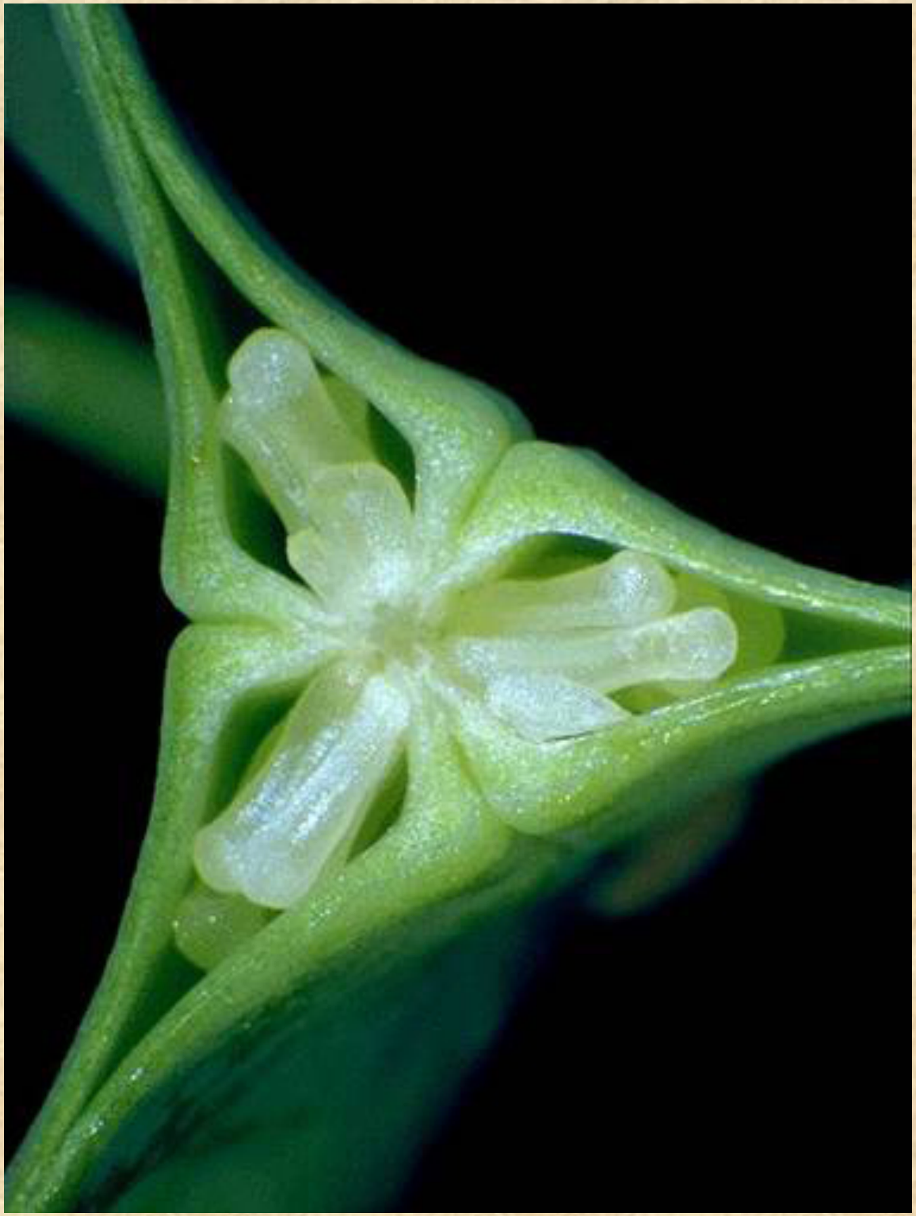
-tecido maciço (tecido condutor).

-ou um canal estreito (passagem do tubo polínico)



Ovário

-O interior do ovário contêm uma ou várias cavidades, os lóculos, em cada uma destas existem os óvulos, que estão fixos à região da placenta.

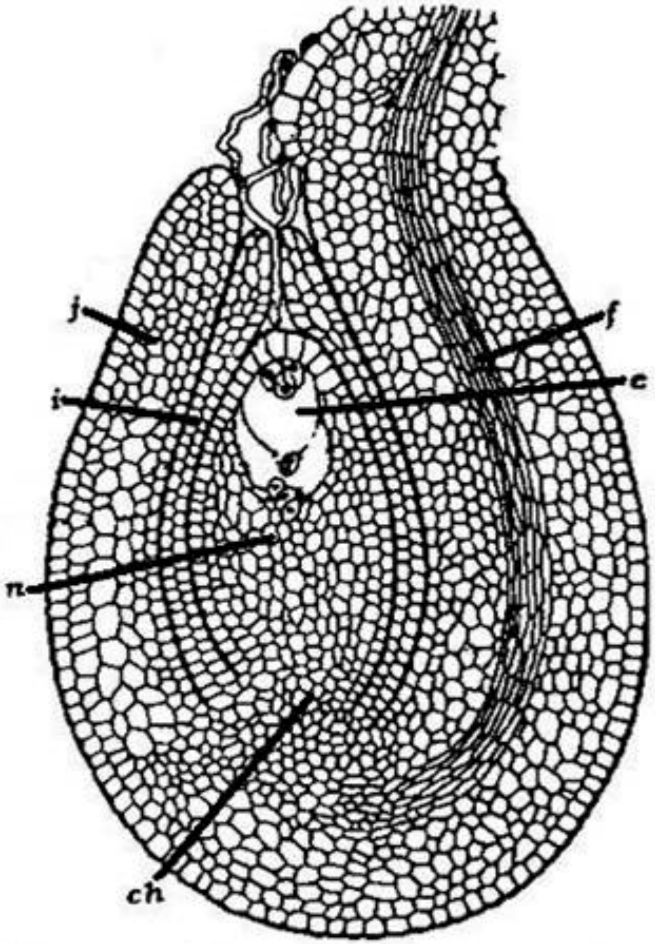


Óvulo

Óvulo:

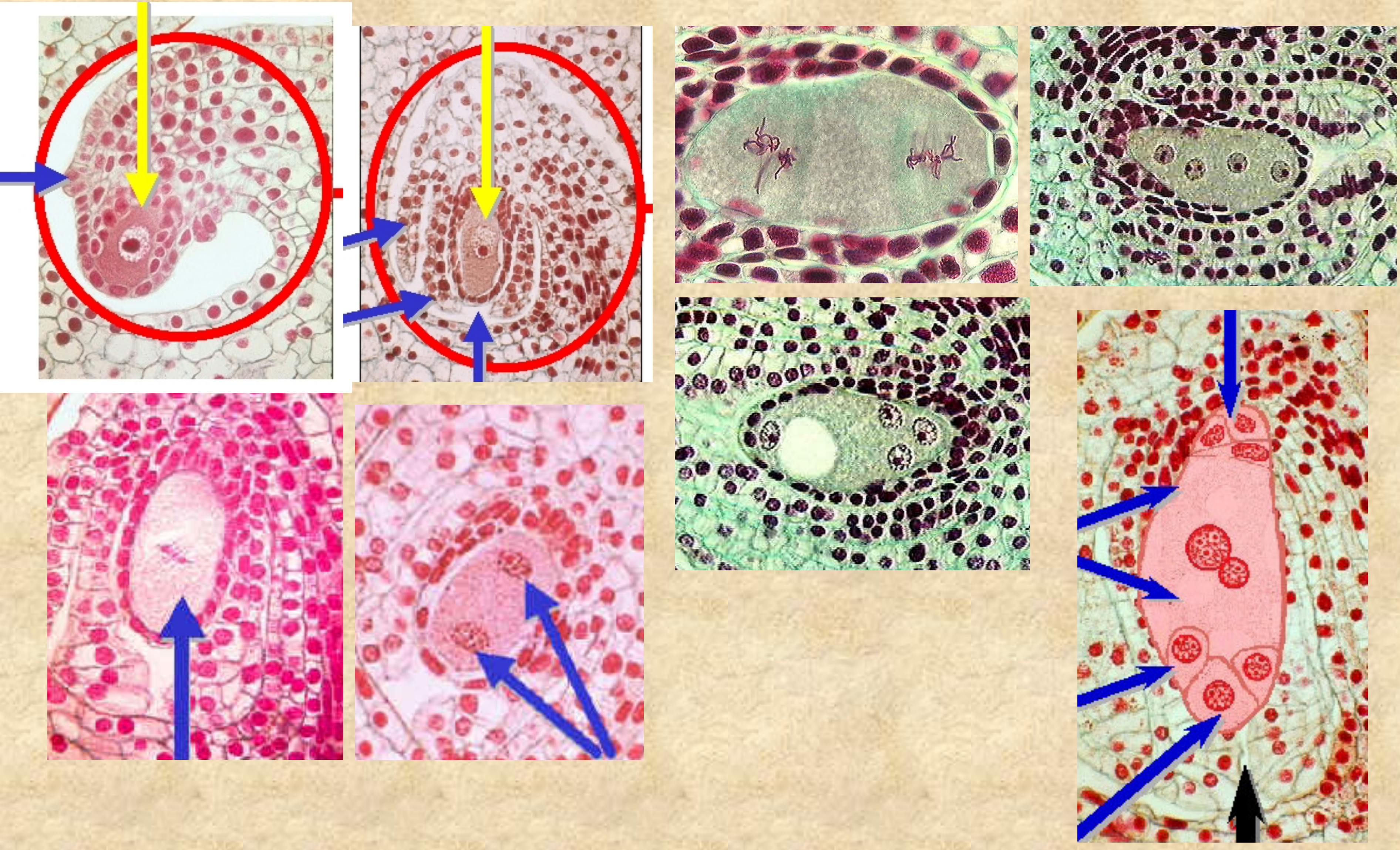
-desenvolve sobre a placenta,
-composto do nucelo,
-uma ou duas camadas de integumentos
-a micrópila.

Do óvulo, após a fecundação, se forma a semente

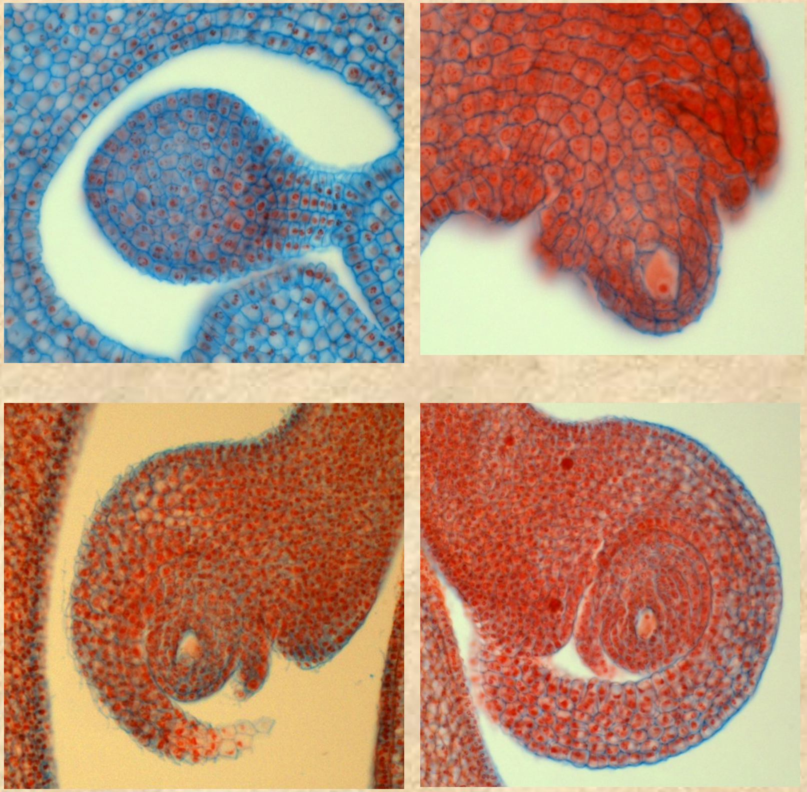


Rudimento seminal anátropo de una angiosperma, con un tubo polínico que ha penetrado por el micrópilo; *f*, funículo; *ch*, cálaza; *n*, nucela;

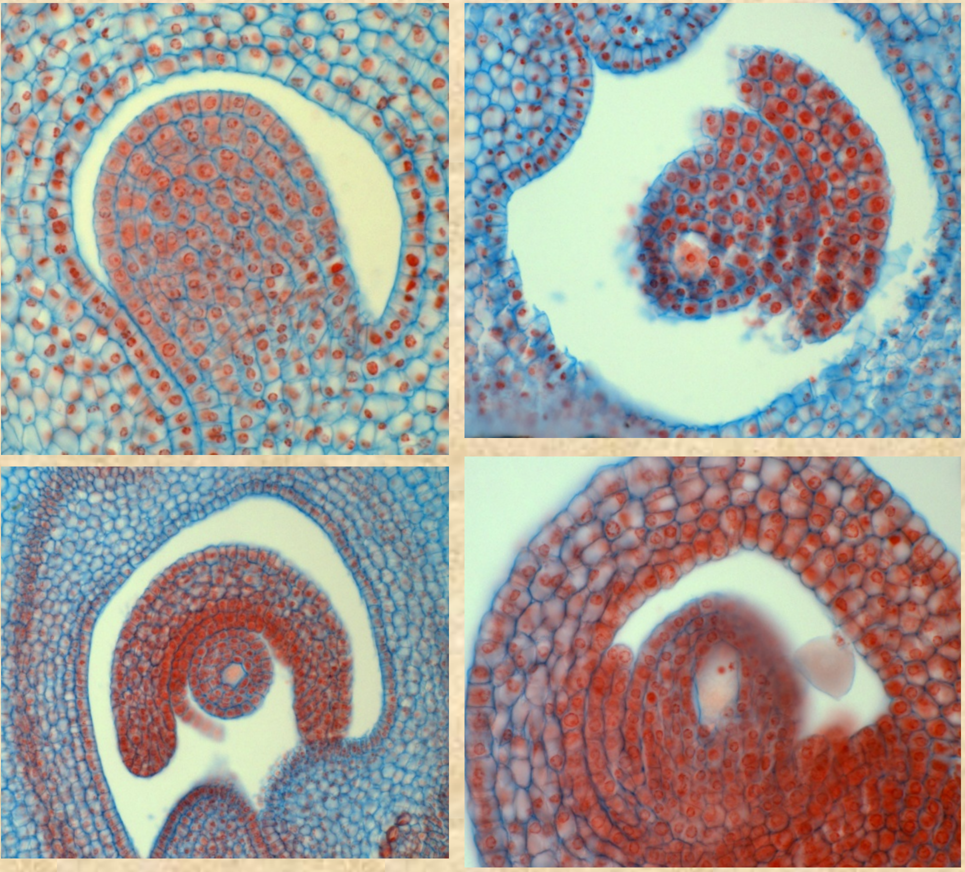
Processo de megasporogênese e megagametogênese



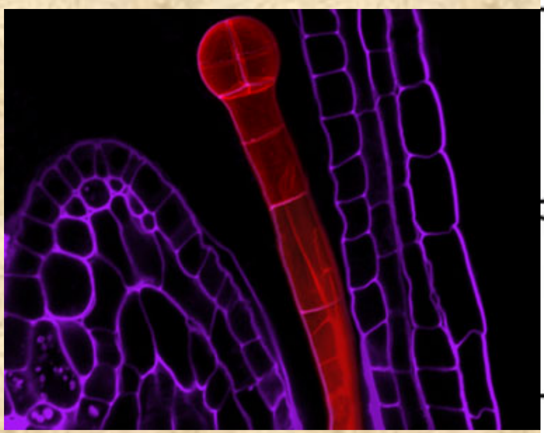
Mucuna japira – estágios iniciais

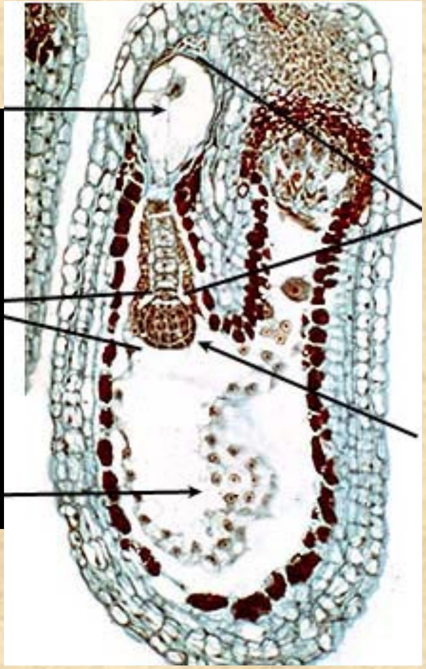


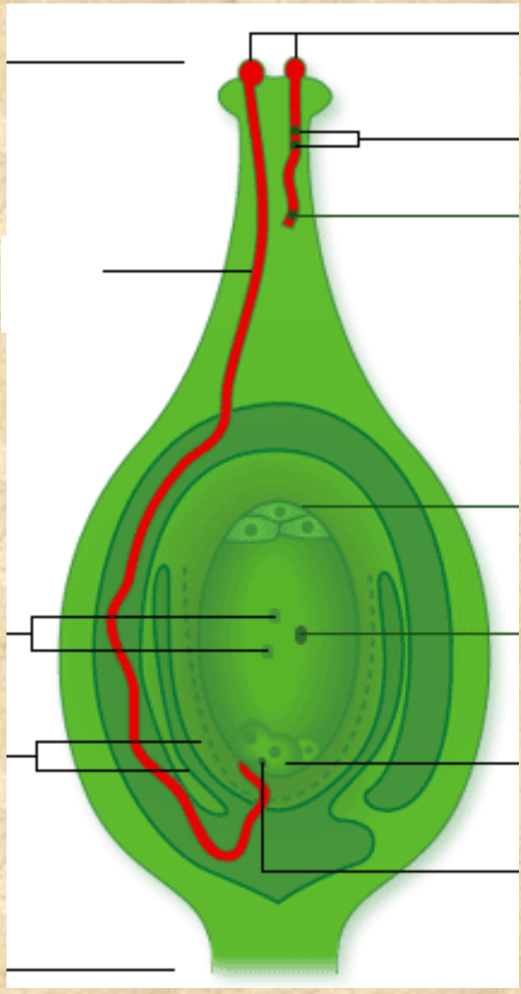
Mucuna urens estágios iniciais

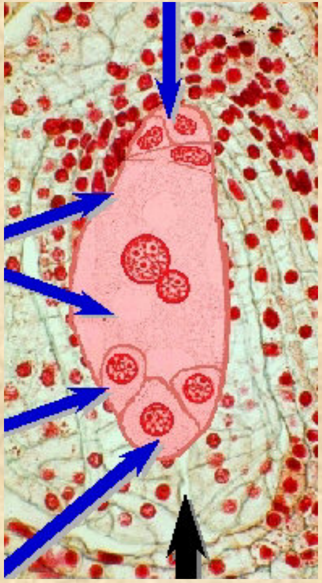


Processo de fecundação









Para que a formação de sementes e frutos seja bem sucedida, vários obstáculos devem ser vencidos, entre eles:

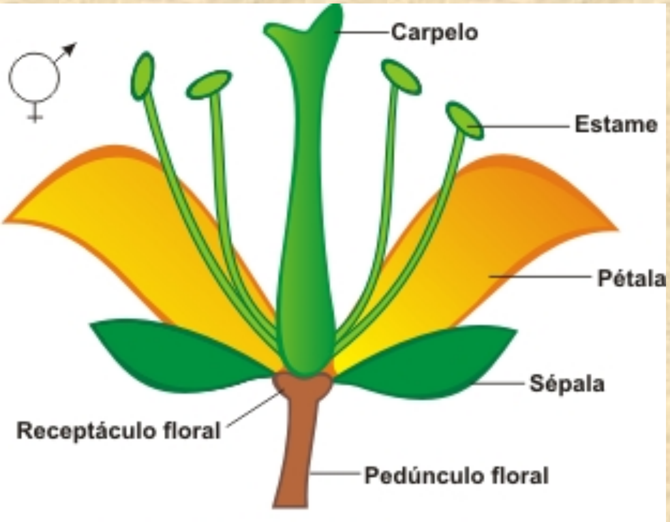
Formação do Grão de Pólen e do Óvulo

Mecanismos de compatibilidade

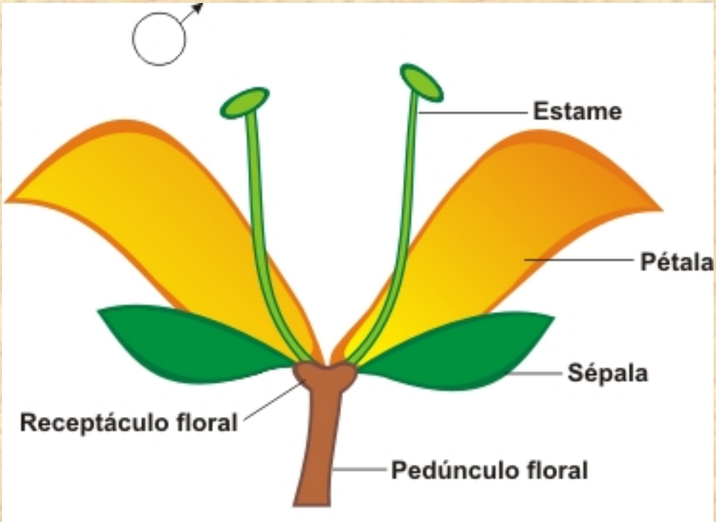
Desenvolvimento do Embrião

Sistemas Reprodutivos

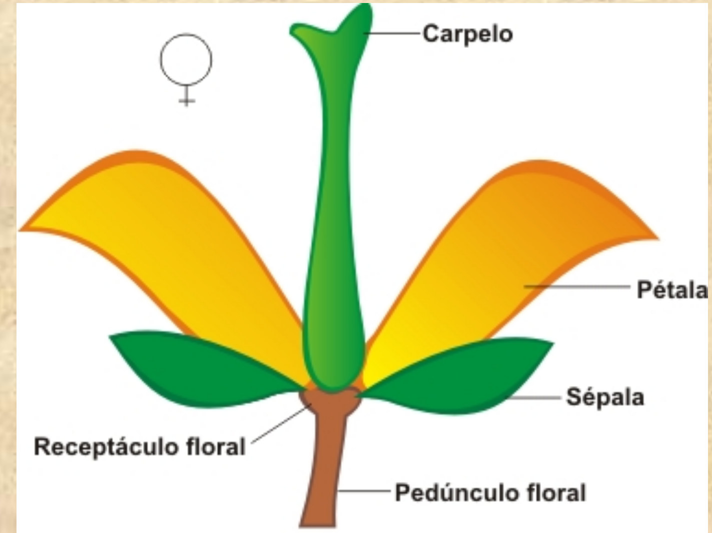
Quanto ao sexo as flores podem ser.....


♂
♀
Carpelo
Estame
Pétala
Sépala
Receptáculo floral
Pedúnculo floral

Flores bissexual ou perfeita

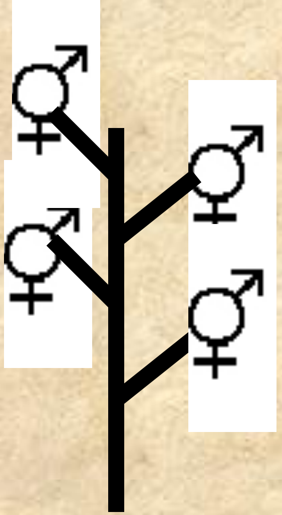

♂
Estame
Pétala
Sépala
Receptáculo floral
Pedúnculo floral

Flores estaminadas

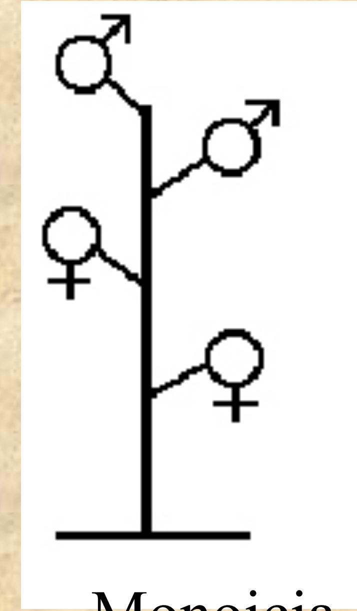

♀
Carpelo
Pétala
Sépala
Receptáculo floral
Pedúnculo floral

Flores pistiladas

Quanto ao sexo as **espécies** podem ser.......

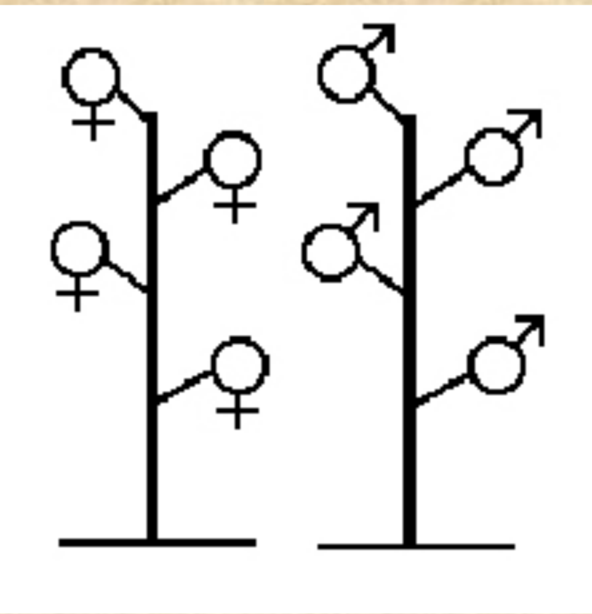


Hermafrodita



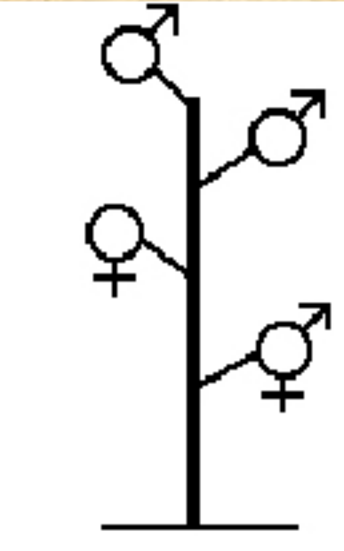
Monoicia

(ginomonoicia e andromonoicia)

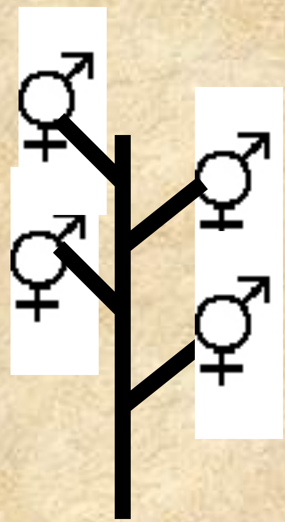


Dioicia

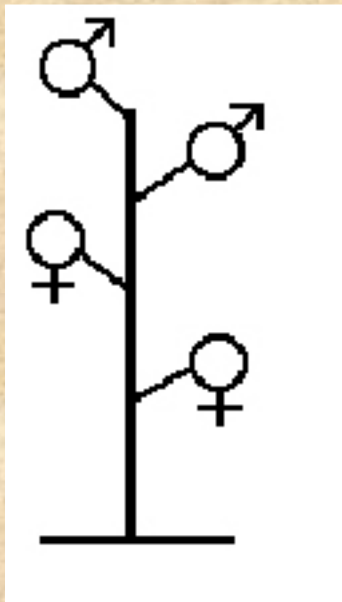
(ginodioicia e androdioicia)



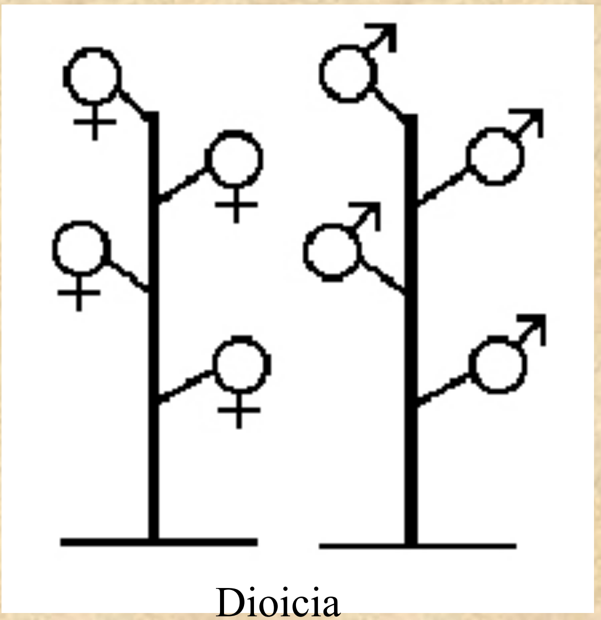
Poligamia



Hermafrodita

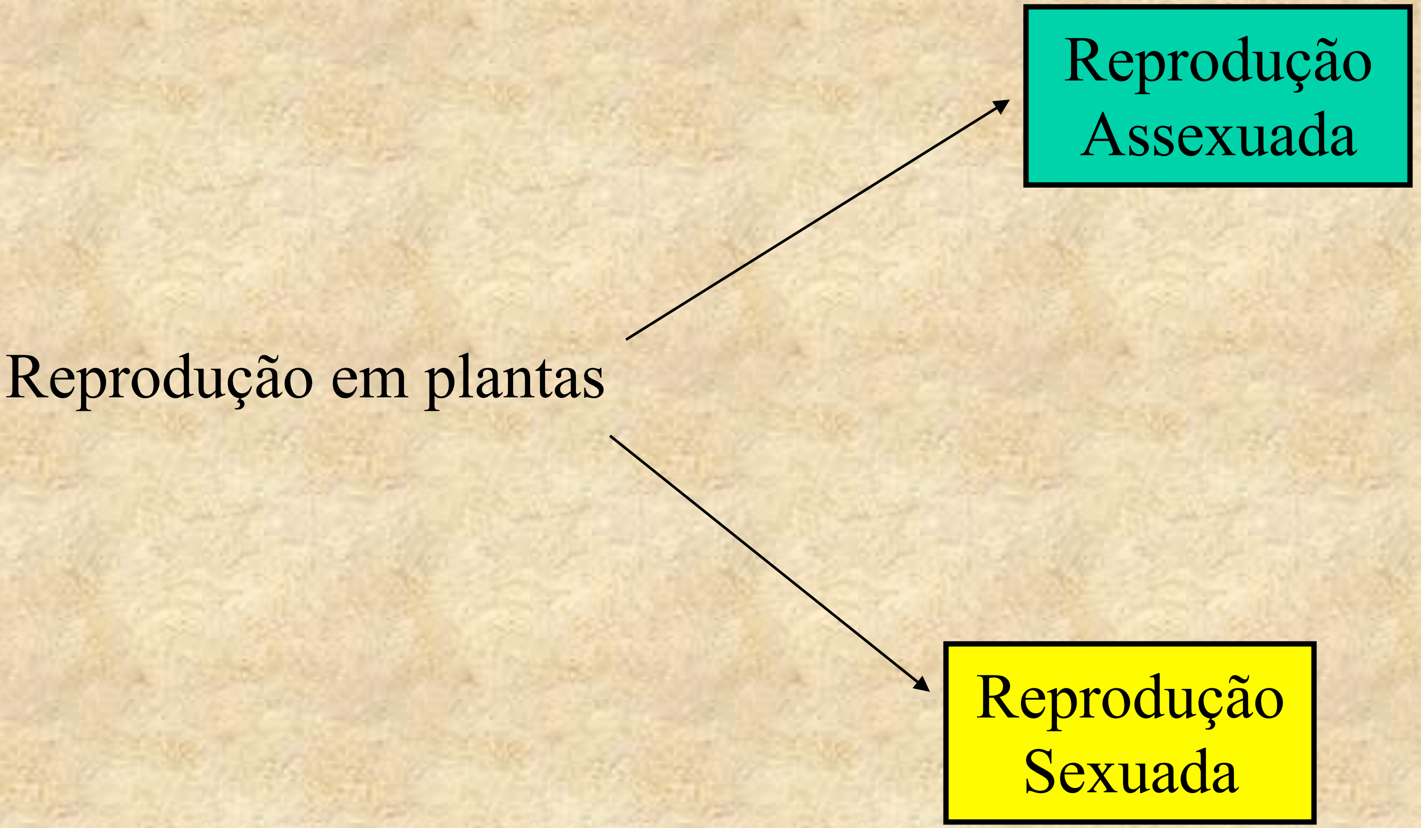


Monoicia



Dioicia

Expressão Sexual	% de espécies	
	Floresta Tropical	Floresta Temperada
Hermafrodita	68%	7%
Dióicas	10%	74%
Monóicas	22%	19%



Reprodução em plantas

Reprodução Assexuada

Reprodução Sexuada

Reprodução Assexuada

(não há envolvimento de gametas)

- Reprodução agâmica
  - propagação vegetativa
- reprodução agamospérmica (apomixia)
  - produção de sementes sem fertilização do óvulo

Reprodução Sexuada

- Autogamia
  - Óvulo é fertilizado com pólen da mesma flor
- Geitonogamia
  - Óvulo é fertilizado com pólen de flor diferente mas do mesmo indivíduo
- Alogamia
  - Óvulo é fertilizado com pólen de indivíduo diferente

Reprodução Sexuada

Auto-polinização

Vantagens:

- Preserva genótipos bem-adaptados;
- Assegura produção de sementes na ausência de polinizadores;
- Supera esterilidade .

Desvantagens

- Diminui ou mantém a variabilidade genética;
- "Beco-sem-saída" em termos de evolução;
- Não apresenta adaptação para mudanças das condições ambientais.

Reprodução Sexuada

Polinização cruzada

Vantagens :

- Aumenta variabilidade genética;
- Forte potencial evolutivo;
- Sucesso em longo prazo.

Desvantagens:

- Pode destruir genótipos que estão bem adaptados.

Reprodução Sexuada

Alogamia

Óvulo é fertilizado com pólen de indivíduo diferente

Mecanismos para evitar autopolinização

A. separação temporal

B. separação espacial

C. auto-incompatibilidade

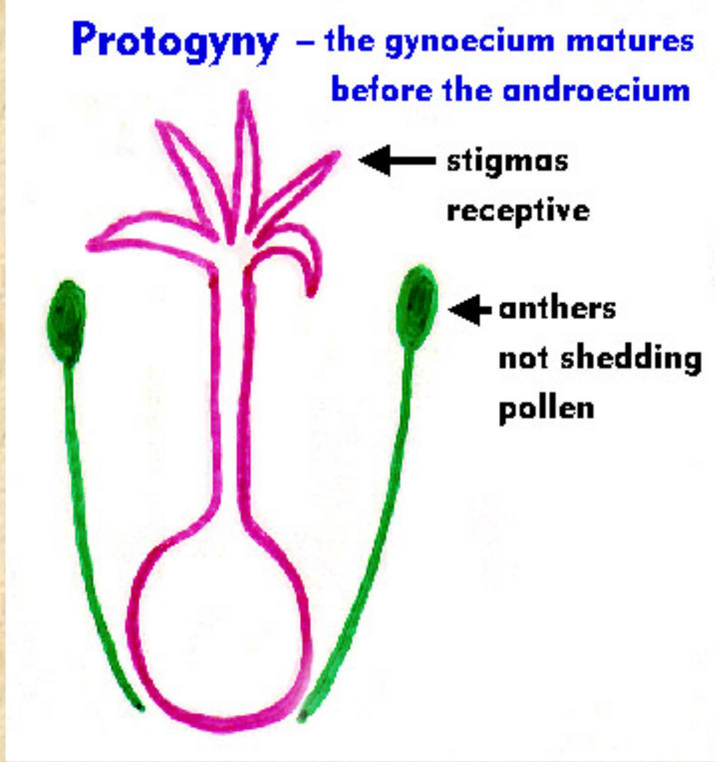
Reprodução sexual

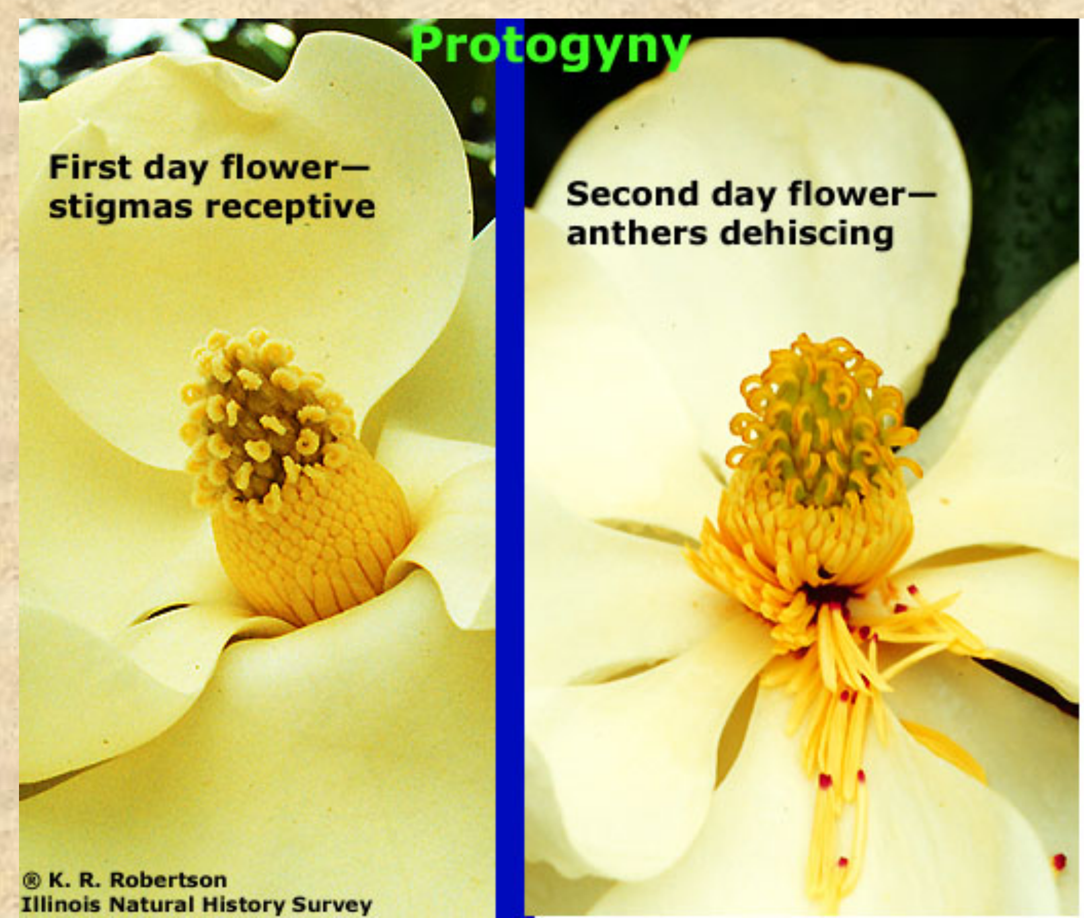
Alogamia = Polinização cruzada

A. Separação Temporal

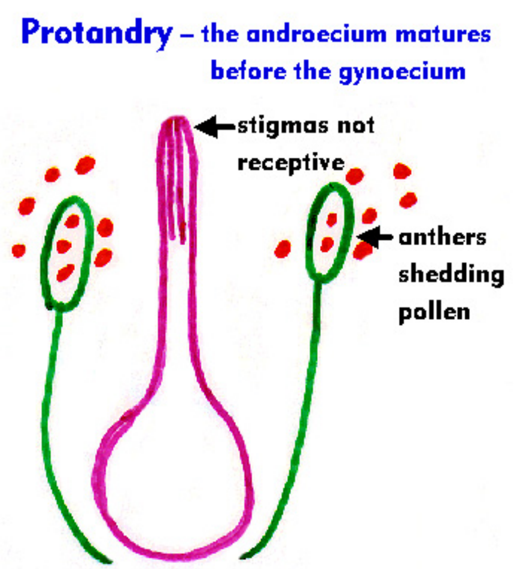
Androceu e gineceu amadurecem em tempos diferentes (separação temporal).
Portanto as flores não podem ser auto-polinizadas.

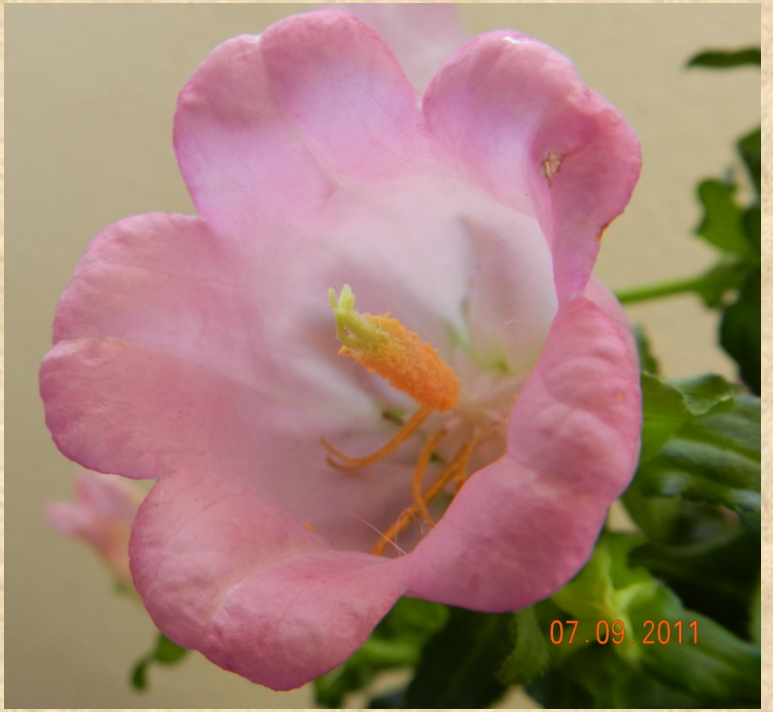
Protoginia - estigmas estão receptivos antes das anteras liberarem pólen.

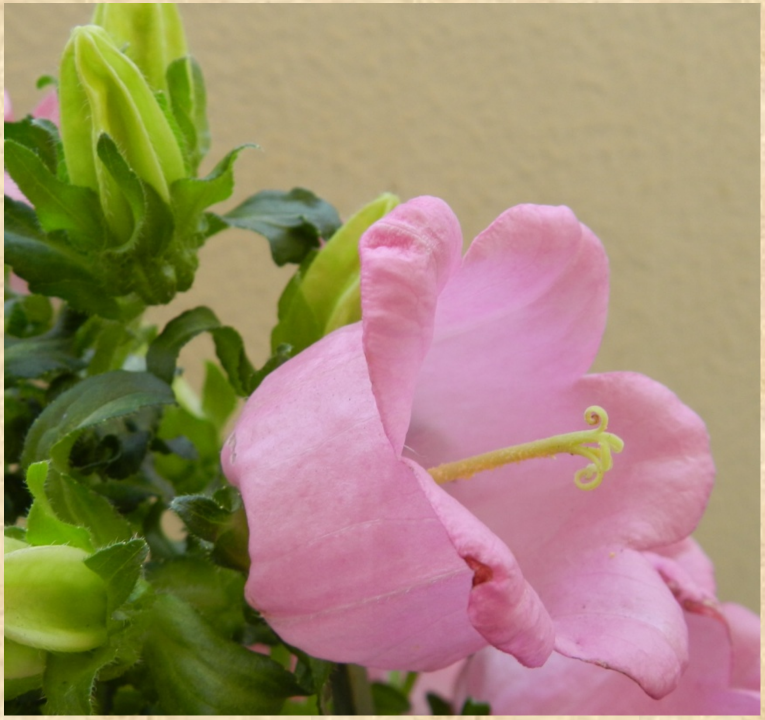

Protogyny – the gynoecium matures before the androecium
stigmas receptive
anthers not shedding pollen


Protogyny
First day flower— stigmas receptive
Second day flower— anthers dehiscing
® K. R. Robertson
Illinois Natural History Survey

Protandria - anteras liberam pólen antes do estigma estar receptivo


Protandry – the androecium matures before the gynoecium
stigmas not receptive
anthers shedding pollen



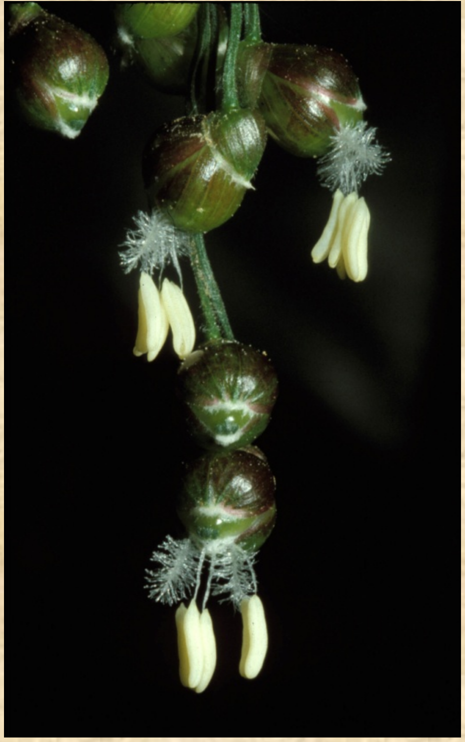


Reprodução sexual

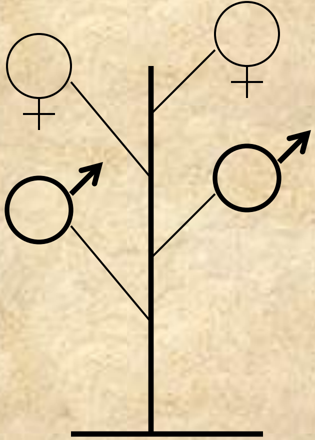
Alogamia = Polinização cruzada

B. Separação Espacial

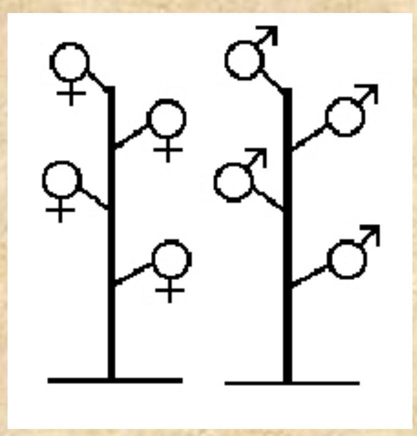
1- Dentro da mesma flor



2 – Dentro do mesmo indivíduo = monoicia



3 – Em indivíduos diferentes = dioicia



Reprodução sexual

Alogamia = Polinização cruzada

C. Auto incompatibilidade

1. Genética

2. Heterostílica

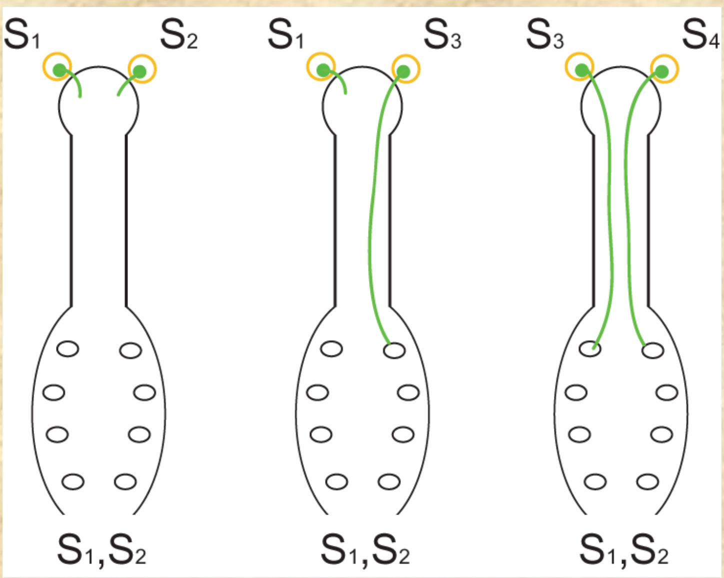
Reprodução sexual

Alogamia = Polinização cruzada

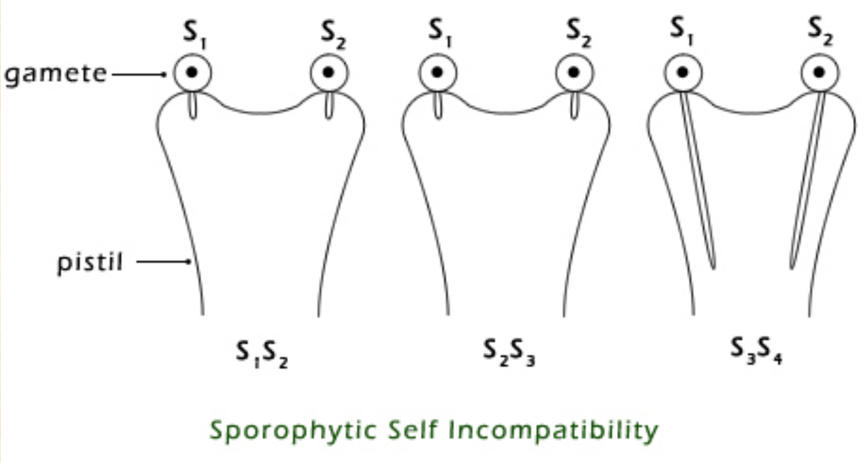
C. Auto - incompatibilidade

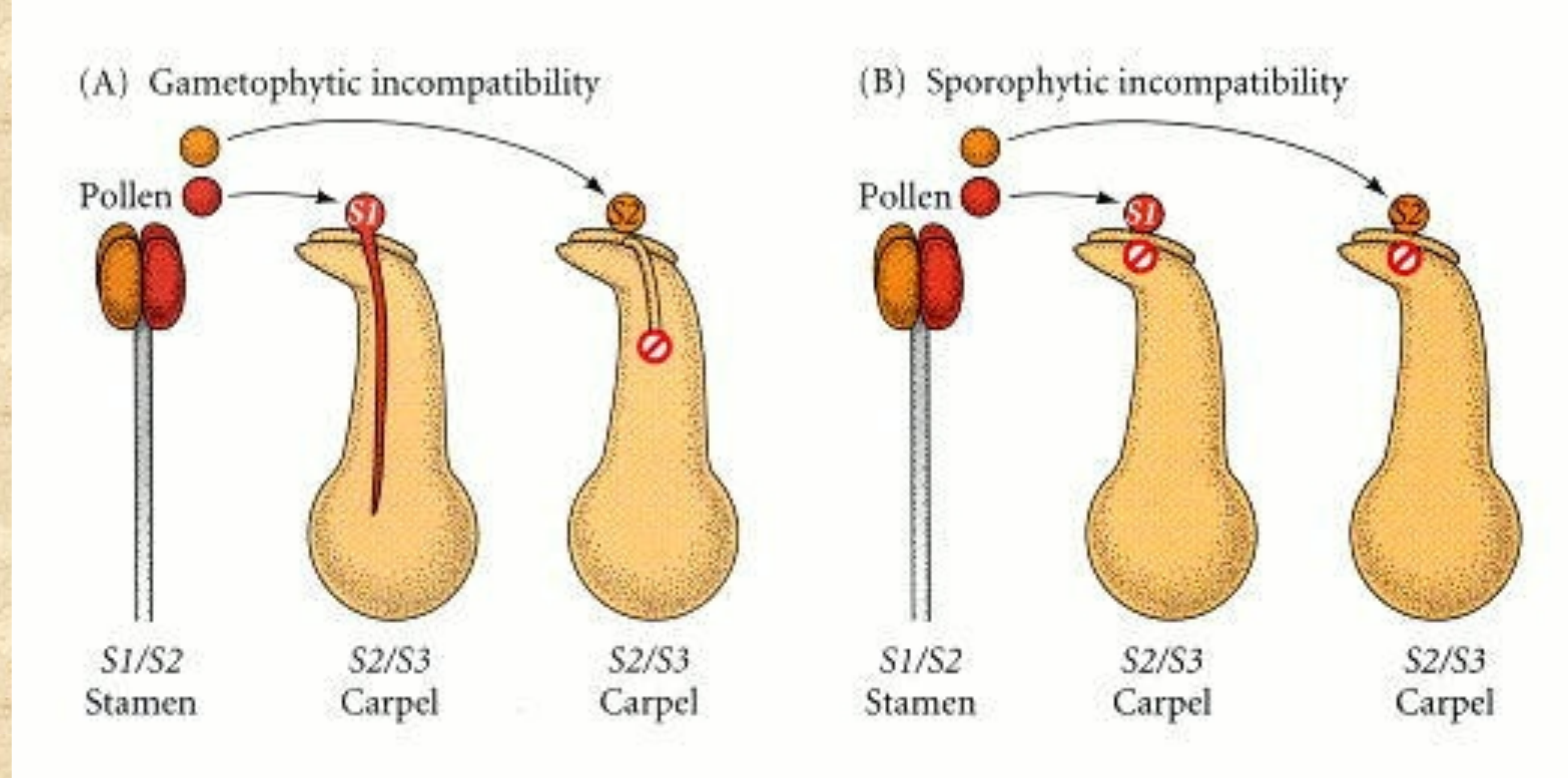
1. Genética

Gametofítica


S_1
S_2
S_1
S_3
S_3
S_4
S_1,S_2
S_1,S_2
S_1,S_2

Esporofítica

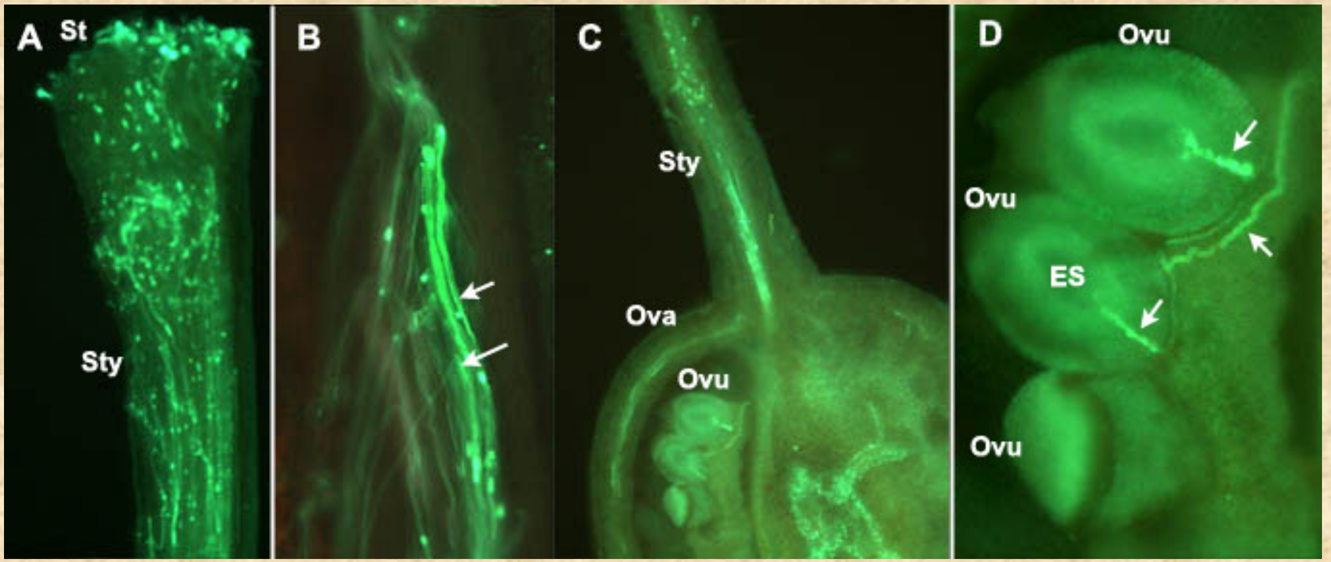

S_1
S_2
S_1
S_2
S_1
S_2
gamete
pistil
S_1S_2
S_2S_3
S_3S_4
Sporophytic Self Incompatibility

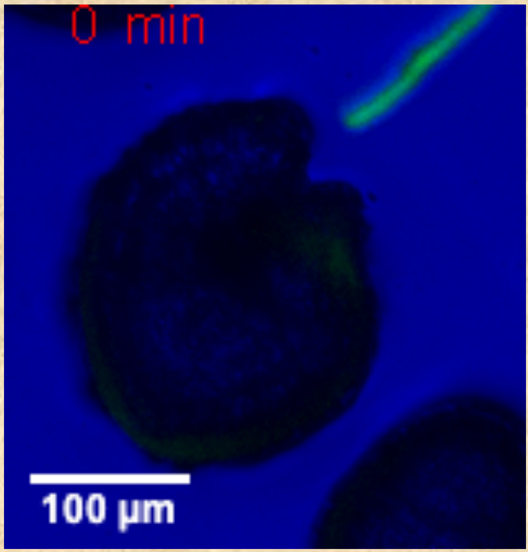


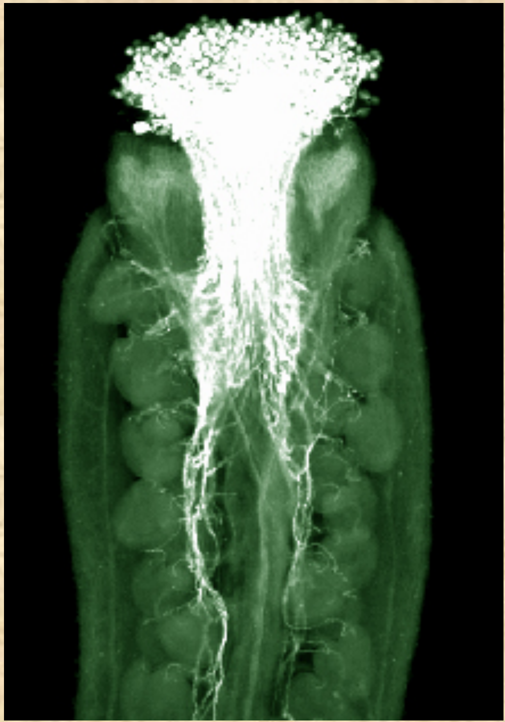
(A) Gametophytic incompatibility

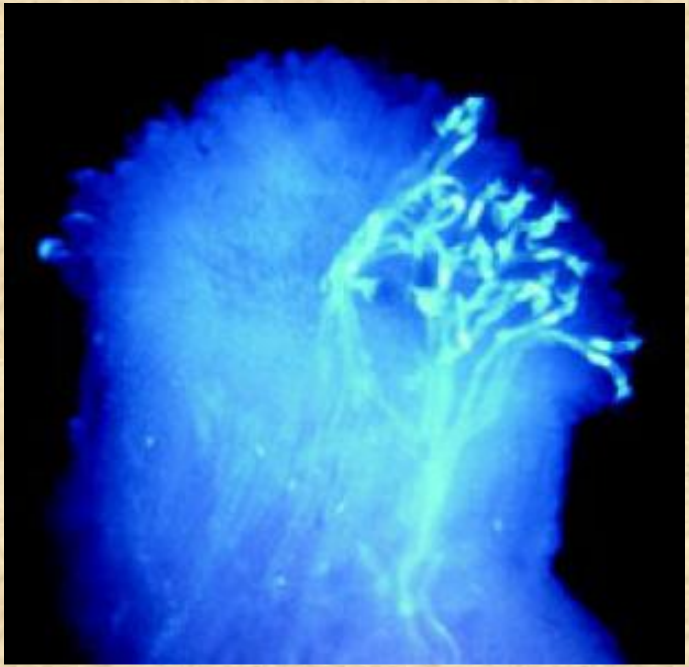
(B) Sporophytic incompatibility

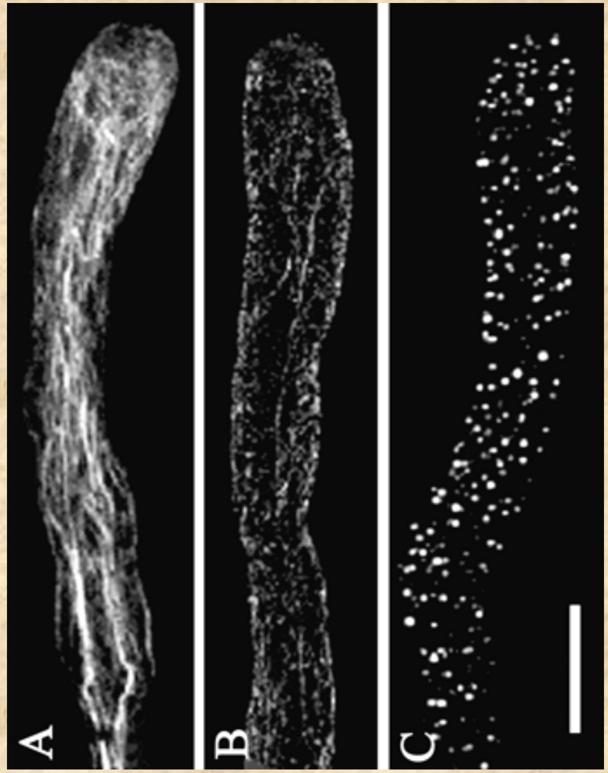
Pollen
S1
S2
S1/S2
Stamen
S2/S3
Carpel
S2/S3
Carpel
Pollen
S1
S2
S1/S2
Stamen
S2/S3
Carpel
S2/S3
Carpel


A
St
Sty
B
C
Sty
Ova
Ovu
D
Ovu
Ovu
ES
Ovu


0 min
100 µm






A
B
C

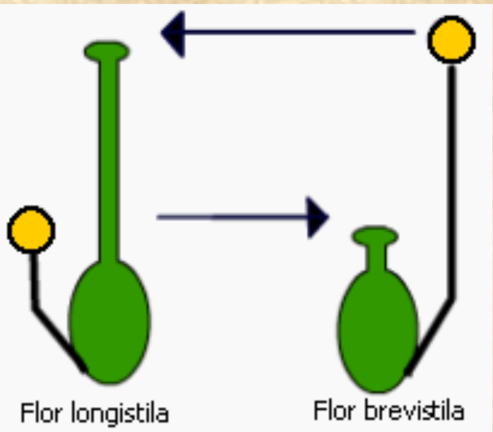
Reprodução sexual

Alogamia = Polinização cruzada

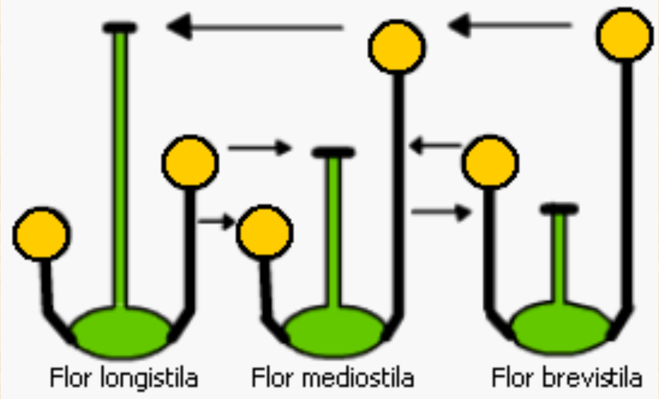
C. Auto - incompatibilidade

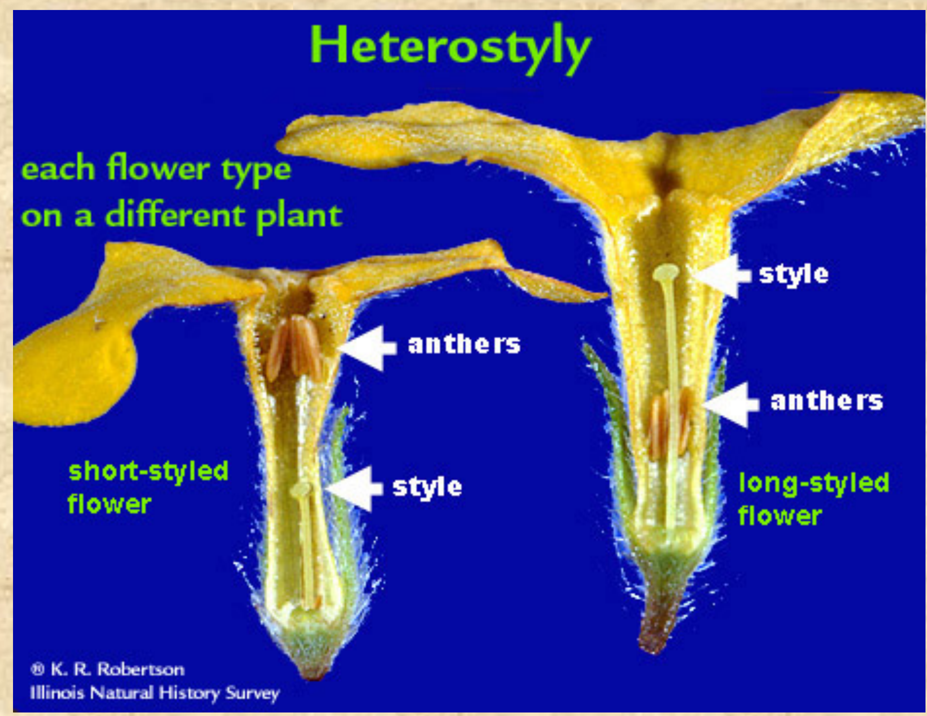
2. Heterostilia

Distilia


Flor longistila
Flor brevistila

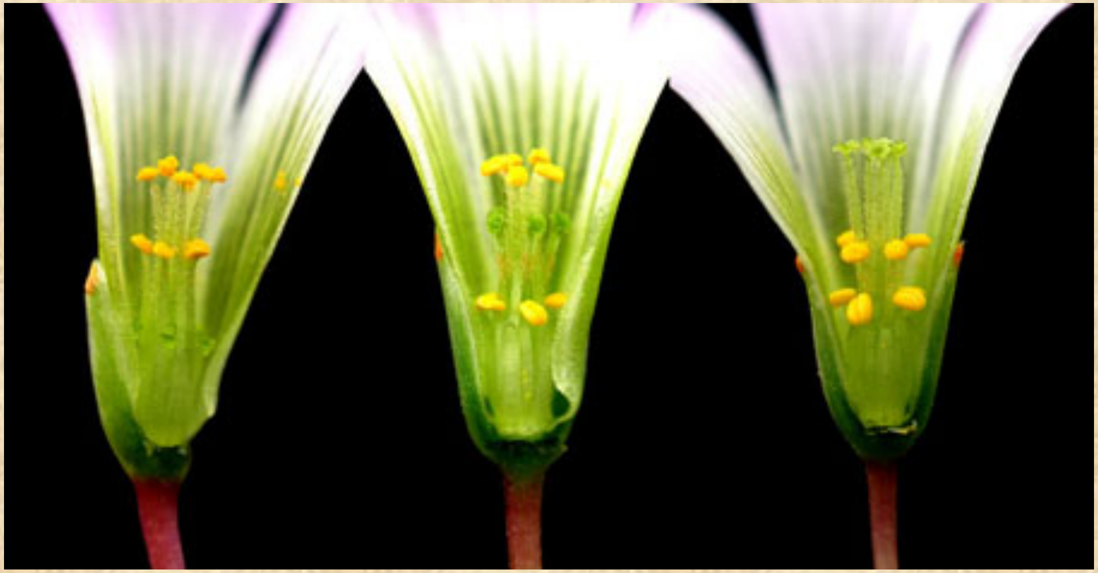
Tristilia


Flor longistila
Flor mediostila
Flor brevistila


Heterostyly
each flower type on a different plant
style
anthers
anthers
style
short-styled flower
long-styled flower
® K. R. Robertson
Illinois Natural History Survey

Distilia

Tristilia

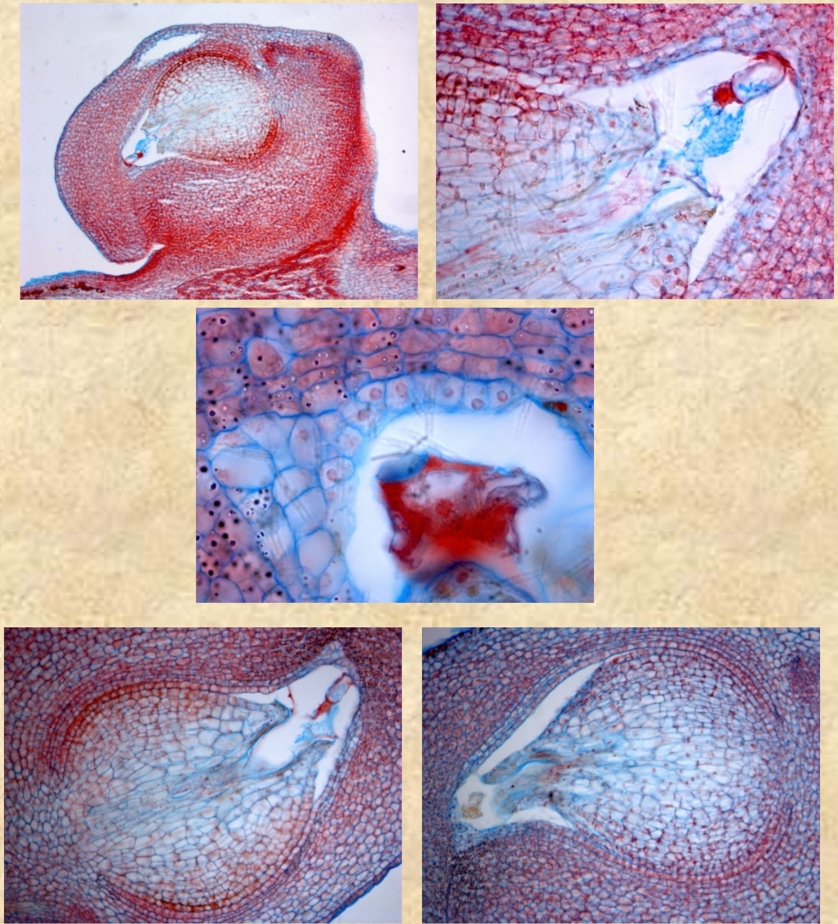


Para que a formação de sementes e frutos seja bem sucedida, vários obstáculos devem ser vencidos, entre eles:

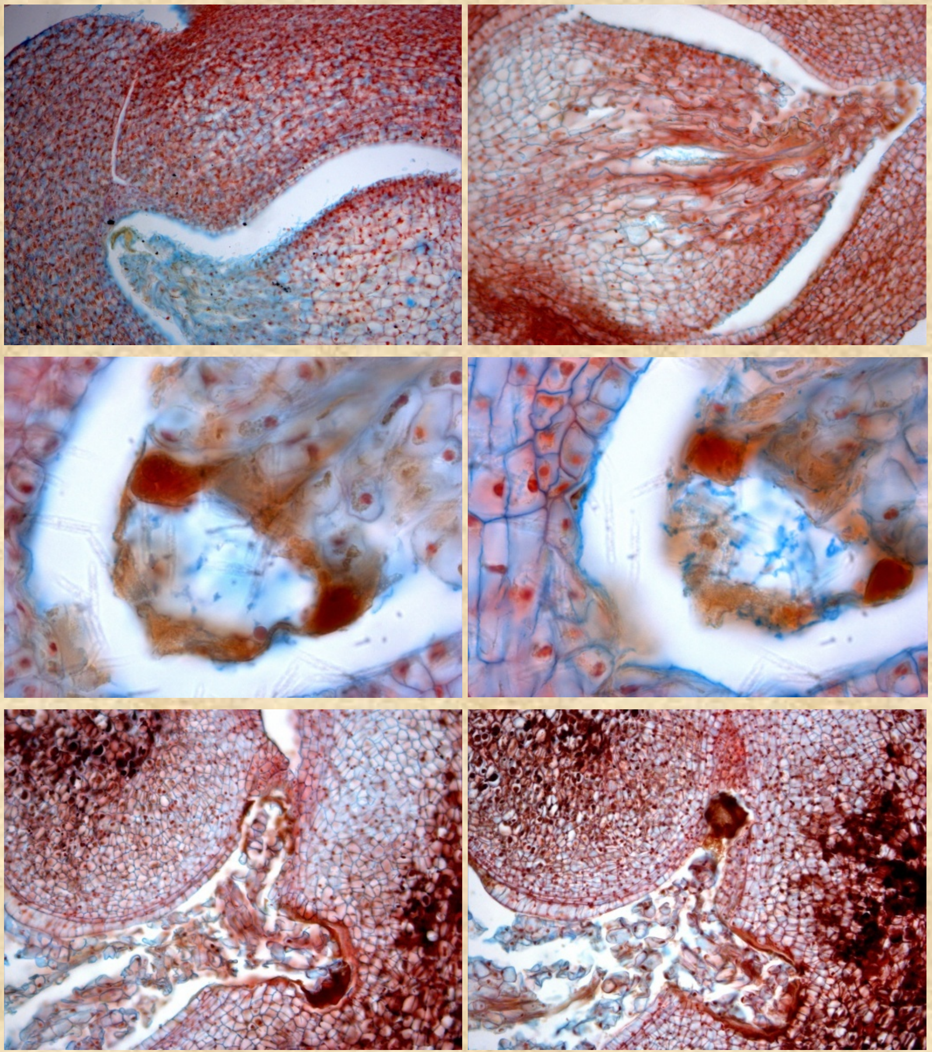
- Formação do Grão de Pólen e do Óvulo
- Mecanismos de compatibilidade
- Desenvolvimento do Embrião

Desenvolvimento Inicial do Zigoto

Saco embrionário de *Mucuna japira*



Saco embrionário de *Mucuna urens*



Obrigada !