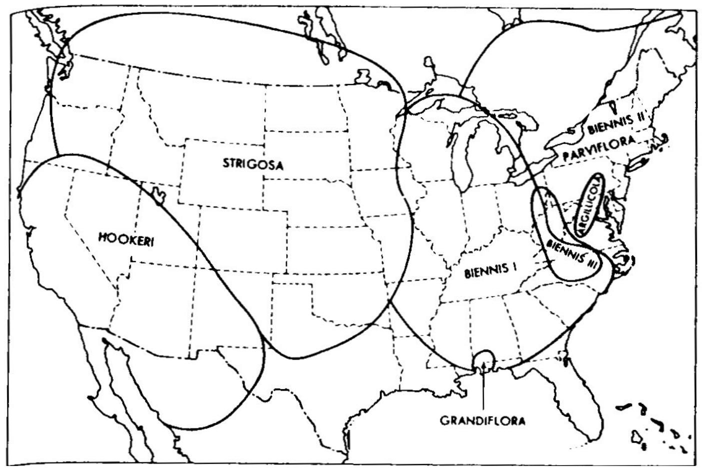
Oenothera cytogenetics

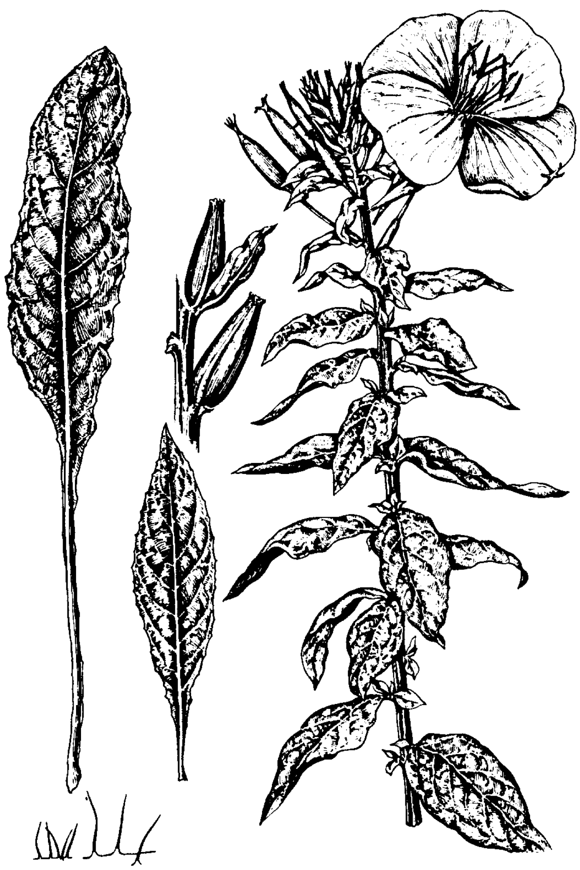
Based on Burham, 1962

- Gray's Manual of Botany, 1950: *Oenothera* is "a hopelessly confused and freely hybridizing group, early introduced into Europe and there cultivated and, like other plants of the garden, intermixed; then spreading to waste or open ground."

- Is a genus native to North America. Commonly known as primroses.



Distribution of some Oenothera in the United States.



DeVries, 1901 (Holland): Studied 8 generations of *O. lamarkiana*. Found:

- 53,500 plants of parental phenotype, plus
    - 1 gigas
    - 8 scintillans
    - 158 nanella
    - 32 rubinervis
    - 350 oblonga
    - 56 albida
    - 229 lata

- The origin of these true-breeding new types was viewed as supporting Lamark's view of species evolution

Characteristics

1 *Oenothera* species breed true on ⊗ (normally an indication of homozygosity)

2) When crossed, segregation occurs in F_1 (normally an indication of heterozygosity)
3) Different hybrids are obtained from reciprocal crosses

4) Hybrids from interspecific crosses breed true

5) All species are 2n = 2x = 14

6) Species have between 1 and 7 linkage groups, *O. lamarkiana* having 2 linkage groups

7) Each linkage group is known as a Renner complex, after the person who proposed it.

   - *O. lamarkiana* = velans & gaudens
   - *O. muricata* = rigens & curvans

8) When 2 linkage groups are present, one comes from each parent, and they separate again at meiosis without crossing over or independent assortment

9) Same 2 kinds of gametes are formed every generation

10) Zygotes homozygous for a complex are lethal (if the zygote ever forms in first place)

PROBLEM: Species breed true even though they are highly heterozygous and are not apomicts. I.e., they have evolved a way to keep complexes of the same type from forming a viable zygote, thus avoiding inbreeding.

1) Balanced lethals ensure true breeding

A. Gametic lethals E.g., *O. muricata*: Rigens is lethal in the pollen, curvans in the egg:

♀\♂	curvans	rigens (ℓ)
curvans (ℓ)		
rigens	curvans + rigens	

B. Zygotic lethals E.g., *O. lamarkiana*: Homozygous zygotes are lethal:

♀\♂	velans (ℓ1)	gaudens (ℓ2)
velans (ℓ1)	ℓ1/ℓ1 = lethal	gaudens + velans
gaudens (ℓ2)	gaudens + velans	ℓ2/ℓ2 = lethal

Effect of balanced lethals on production of F_1 hybrids

A. No lethals in common. ∴ each species produces 2 types of eggs and 2 types of sperm.
E.g., *O. grandiflora* × *O. lamarkiana*:

♀\♂	gaudens	velans
acvens	acvens + gaudens	acvens + velans
truncans	truncans + gaudens	truncans + velans

- The net result is that there are 4 different types of hybrids obtained as there are no lethals in common.

B. One species has no lethals, the other has a gametic lethal. Result is that one species has 2 types of gametes, the other only 1. E.g., *O. chicagoensis* × *O. lamarkiana*:

♀\♂	gaudens	velans
excellens	excellens + gaudens	excellens + velans

But in the reciprocal:

♀\♂	punctulans	
gaudens	gaudens + punctulans	
velans	velans + punctulans	

- Thus, for a given cross, there are only 2 types of hybrids, but these are different in the reciprocal crosses.

C. Each species only produces 1 type of egg and sperm. E.g., *O. chicagoensis* × *O. cockerii*:

♀\♂	elongans	
excellens	excellens + elongans	

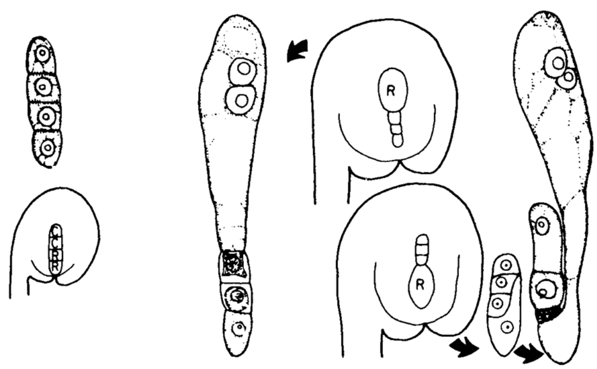
and, in the reciprocal:

♀\♂	punctulans	
curtans	curtans + punctulans	

2) Other factors:

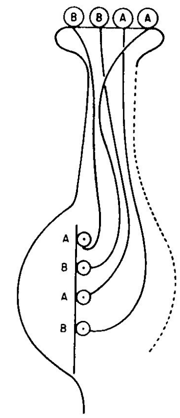
A. Renner effect (megaspore competition):

- In *O. muricata*, the rigens complex is more competitive than the curvans, and becomes the functional megaspore regardless of its position (normally, the top megaspore becomes the functional one)



The Renner effect and interpretive drawing (Renner, 1921)

B. Gametic competition



- Found in *O. bertriana*, which has 2 complexes. These are known simply as A and B
- A pollen only fertilizes B ovules, and vice versa
- Thought to be the response to a chemical signal from the ovule

C. Self incompatibility + lethal factors

- Found in *O. biennis*, which has alpha and beta complexes:

♀\♂	α^{SI}	$ß^{SF}$
α		αß
$ß_{\ell}$		

<u>D. Certation</u> -The ability of pollen grains with one complex to grow faster than the others

E.g., in *O. shulliana*: When used as a ♂, the maculans complex is transmitted preferentially over the jugens complex

CYTOLOGICAL EXPLANATION

- Gates, 1908, working with *O. rubrinervis*, was first to observe a ring, rather than random, arrangement of the chromosomes, as in the example at right out of *Rhoeo discolor*.

- 1922, 1923, cytogenetics worked out by Cleland (USA)

1) The number of chromosomes in a ring is constant for each race of *Oenothera*

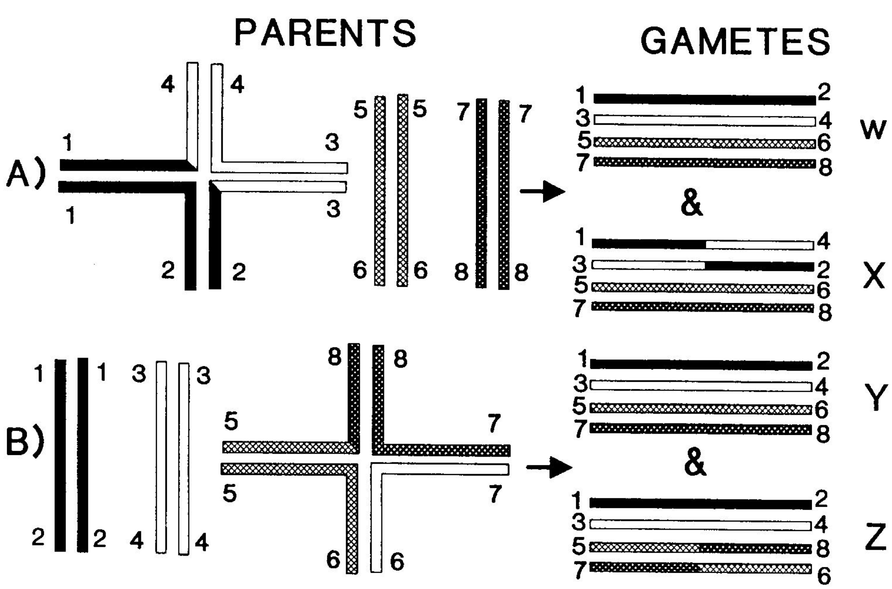
2) The position of each chromosome within the ring remains constant (1926)

3) There is a high degree of alternate disjunction at meiosis

4) There is a correlation between the number of chromosomes in a ring and the number of linkage groups:

⊙14	1 linkage group	*O. strigosa*
⊙12 + 1 II	2 linkage groups	*O. lamarkiana*
↓	↓	↓
7 II	7 linkage groups	*O. grandiflora*

5) Suggested an explanation in terms of a translocation heterozygote:



Where: W = 1-2 3-4 5-6 7-8
Y = 1-2 3-4 5-6 7-8

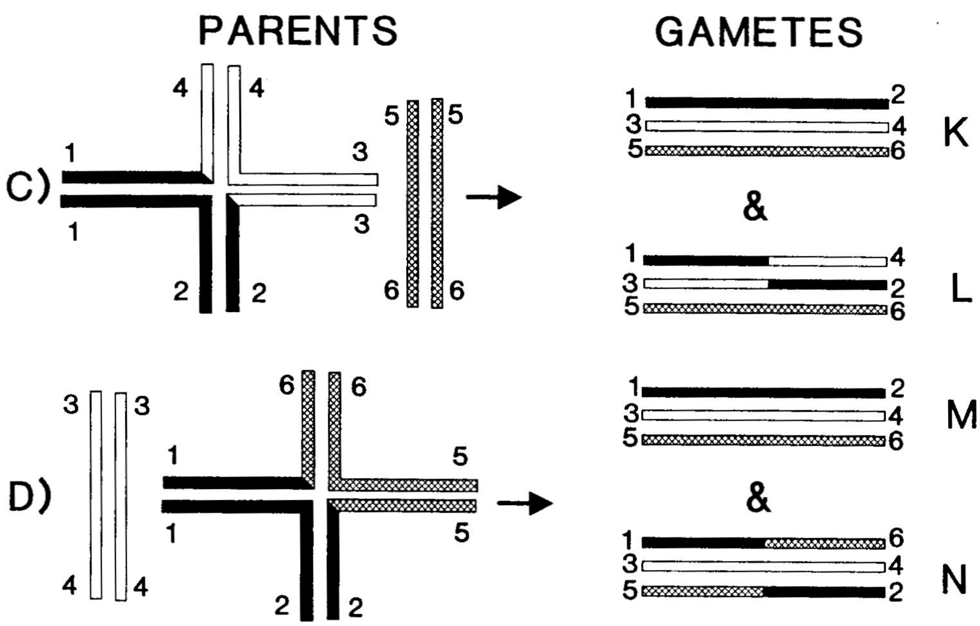
-Crossing A × B: - W & Y → 4 II

- W & Z → 2 II + ⊙ 4
- X & Y → 2 II + ⊙ 4
- X & Z → 2 ⊙

W = 1−2 3−4 (5−6 7−8)
Z = 1−2 3−4 (5−8 6−7)

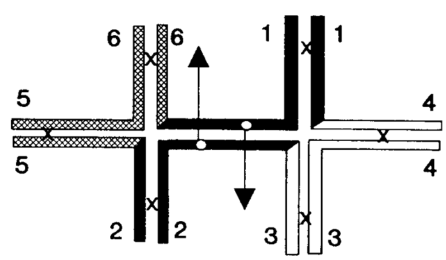
X = (1−4 2−3) 5−6 7−8
Y = (1−2 3−4) 5−6 7−8

X = (1−4 2−3) (5−6 7−8)
Z = (1−2 4−3) (5−8 6−7)



- Crossing C × D:

  - K & M → 3 II
  - K & N → ⊙ 4 + 1 II
  - L & M → ⊙ 4 + 1 II
  - L & N → ⊙ 6 (at right)



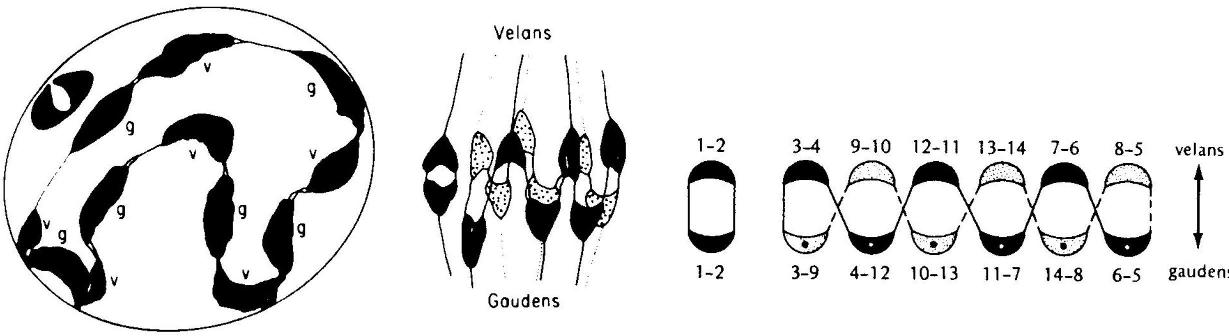
-Note: if one set of arms had not been involved in a crossover, a chain of 6 would have been formed instead of a ring.

- As the number of chromosomes involved in translocations increases, so does the size of the ring. Below, *O. lamarkiana*, which has 6 of its 7 chromosomes involved in reciprocal translocations:

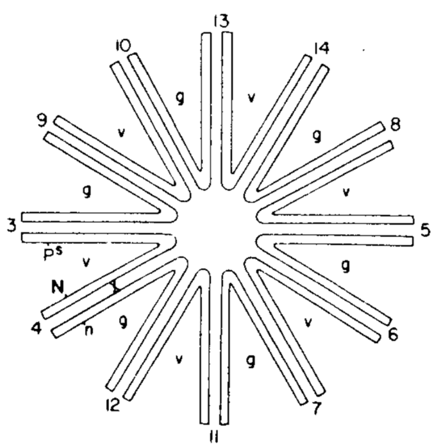
EXPLANATION OF DeVRIE'S PLANTS

- **gigas** = 4x

- **scintillans, oblonga, albida,** and **lata** = trisomics
    - produced by 3 ↔ 1 disjunction of the ring, instead of the normal 2 ↔ 2 disjunction:



A ring of 12+ 1II in O. lamarkiana, fr Emerson, 1935, & interpretative drawing from Strickberger, 1976.



After Emerson, 1935.

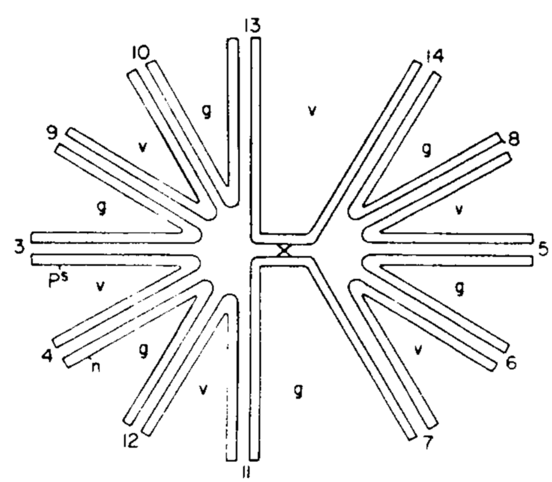
- **nanella**: resulted from a crossover in homologous ends:

- The crossover event moves *n* from the gaudens to the velans complex (left)

    - Velans (*N*) - glaudens (*n*) = wild type

    - Velans (*n*) - glaudens (*n*) = nanella (i.e., dwarf)

- The **rubrinervis** mutant (right) was due to a crossover in the interstitial region
- Disrups the gaudens and velans complexes, and creates 2 new linkage groups, each of which is partially gaudens and partially velans
- New complexes called rubrinervis and deserens
- Known as a <u>half-mutant</u>



After Emerson, 1935

IDENTIFICATION OF COMPLEXES MAKING UP THE *OENOTHERA* RACES

O. hookeri 7 II, labeled as follows: 1-2 3-4 5-6 7-8 9-10 11-12 13-14

O. flavens × *O. hookeri* → ⦿ 4 + 5 II ⇒ they differ by a translocation in 2 chromosomes

- assign arbitrarily to the first 2 chromosomes (1-3 and 2-4). Thus:

O. flavens = <u>1-4 2-3</u> 5-6 7-8 9-10 11-12 13-14
(or 1-3 2-4 5-6 7-8 9-10 ...)

O. velans × *O. hookeri* → ⦿ 4 + 5 II
O. velans × *O. flavens* → 2 ⦿ 4 + 3 II

velans differs from *hookeri* by a translocation, but the translocation on *velans* not that in *flavens*

- ∴, *O. velans* = 1-2 3-4 <u>5-8 6-7</u> 9-10 11-12 13-14
(or 1-2 3-4 5-7 6-8 ...)

O. johansen × *O. hookeri* → ⦿ 4 + 5 II
" × *O. flavens* → 2 ⦿ 4* + 3 II
" × *O. velans* → ⦿ 6** + 4 II

1 difference

1 difference

Therefore, *johansen* has two translocations different than those of *hookeri* & *velans*

- ∴, *O. johansen* = 1-2 3-4 5-6 <u>7-9 8-10</u> 11-12 13-14
(or 1-2 3-4 5-6 7-9 8-10 ...)

* implies 2 different sets of two
** 1 from *velans* and one other one