

Genome mapping in shellfish aquaculture species

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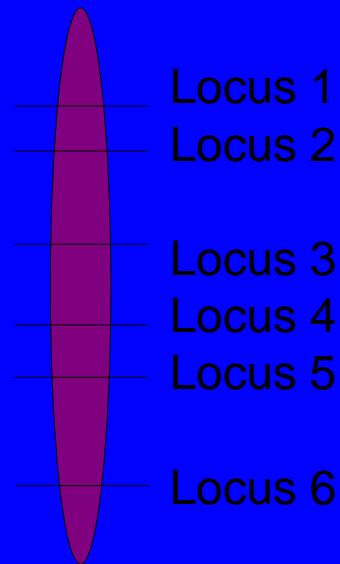
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Workshop “From genomics to applications in European temperate
and Mediterranean Aquaculture: Basis and prospects”
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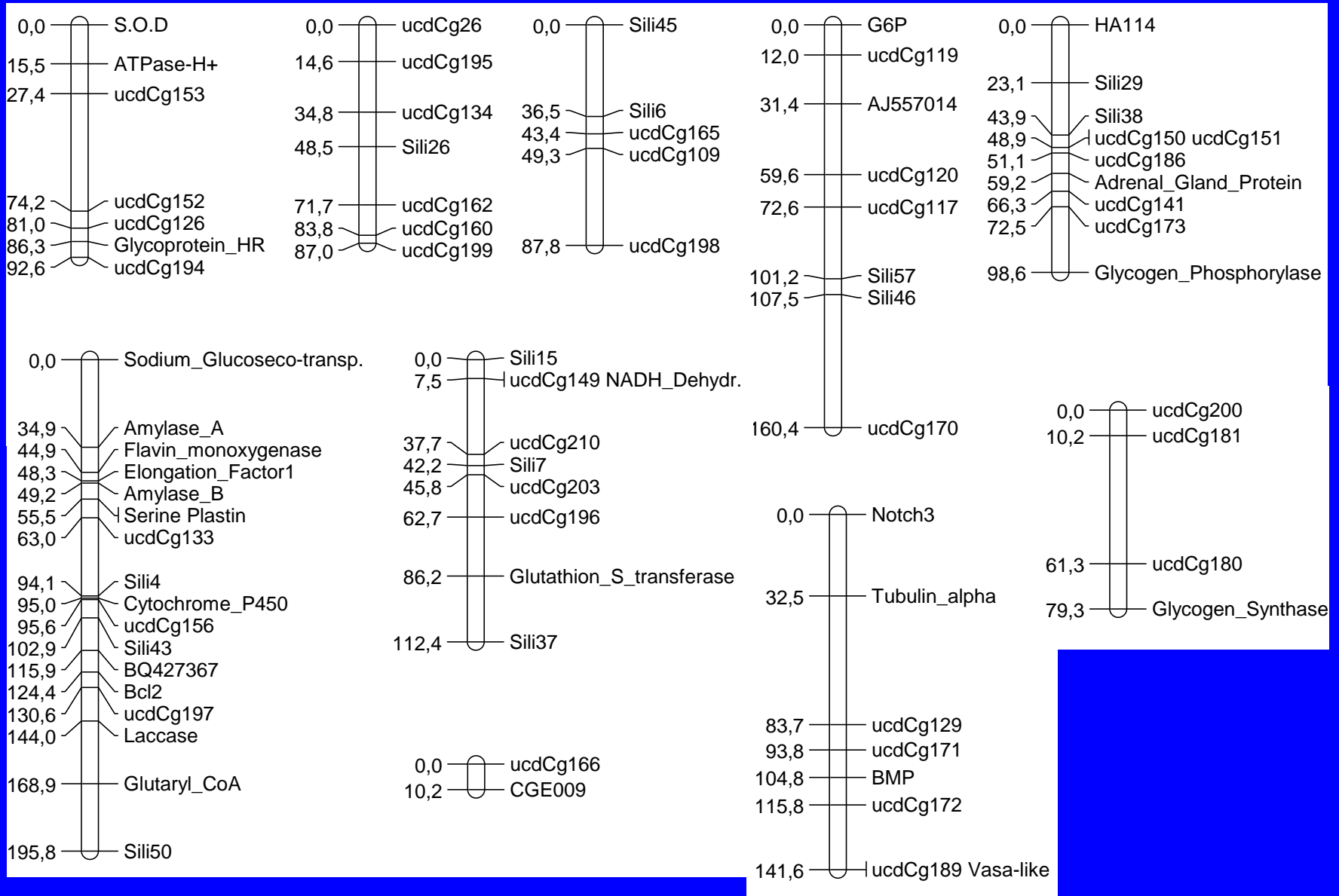
What does a genetic map show ?

- The ordering of marker loci on chromosomes
- The relative distances between them



Chromosome 1 = Linkage group 1

What does a genetic map show ?



How do we construct such maps ?

- Based on the estimation of the recombination frequency between two loci

- as this frequency is linked to the distance between the two loci:

The further apart on a chromosome two loci are,
The greater the probability is that one or more cross-overs will occur while gametes are produced (chiasmata in prophase of meiosis I)



Old principle (Morgan, 1911) but lack of markers
 N chromosomes = N linkage groups (LG)

A concrete example

$\begin{array}{c} \underline{A \ B \ C} \\ \underline{A \ B \ C} \end{array} \times \begin{array}{c} \underline{a \ b \ c} \\ \underline{a \ b \ c} \end{array}$	Homozygous for the 3 markers	
$\begin{array}{c} \underline{A \ B \ C} \\ \underline{a \ b \ c} \end{array}$	Heterozygous for the 3 markers	
$\begin{array}{c} \underline{A \ B \ C} \\ \underline{a \ b \ c} \end{array} \times \begin{array}{c} \underline{a \ b \ c} \\ \underline{a \ b \ c} \end{array}$	F1 gametes	Number of progeny
<p>A B C</p> <p>a b c</p> <p>I II</p>	ABC (p)	103
	abc (p)	120
	ABc (r II)	51
	abC (r II)	49
	Abc (r I)	14
	aBC (r I)	7
	AbC (r I+II)	24
	aBc (r I+II)	32
Total	400	

From frequency (r) to distances (D)

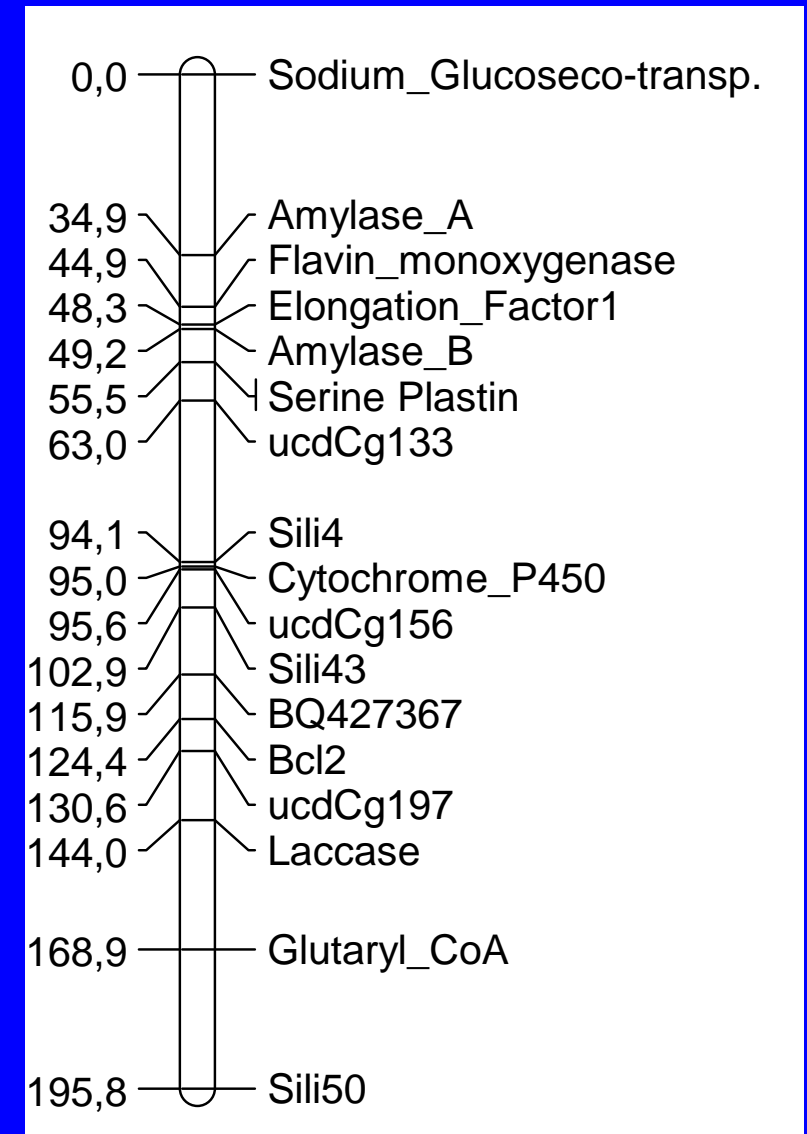
Several functions exist:

For example

$$D = \ln \left[\frac{1 + 2r}{1 - 2r} \right]$$

D is in cM : distance separating two loci between which the number of crossing over is expected to be 0.01

Physical link but statistical estimation



What do we need ?

- Polymorphic markers (microsatellites, AFLPs, RFLPs,...)
- Offspring allowing the analysis of alleles segregation (specific cross design)
- Software (Linkage, Mapmaker, Joinmap, Crimap,...)

Genetic maps in shellfish

Prawns and Shrimps:

<i>Penaeus japonicus</i>	Moore et al, 1999	AFLPs
	Li et al., 2003	AFLPs
<i>Penaeus monodon</i>	Wilson et al., 2002	AFLPs
<i>Penaeus chinensis</i>	Li et al., 2006	AFLPs
<i>Penaeus vannamei</i>	Perez et al., 2004	AFLPs
	Zhang et al., 2006	AFLPs, microsatellites
<i>Marsupenaeus japonicus</i>	Lyons et al., 2007	AFLPs

Abalones:

<i>Haliotis discus</i>	Liu et al., 2006	AFLPs, RAPDs, microsatellites
	Li et al., 2007	AFLPs
<i>Haliotis rubra</i>	Baranski et al., 2007	microsatellites

Genetic maps in shellfish

Urchins:

Strongylocentrotus

Zhou et al., 2006

AFLPs

Scallops:

Chlamys farreri

Whang et al., 2004

AFLPs

Li et al., 2005

AFLPs

Wang et al., 2005

AFLPs

Argopecten irradians

Wang et al., 2007

AFLPs, microsatellites

Genetic maps in shellfish

Oysters:

<i>Crassostrea virginica</i>	Yu and Guo, 2003	AFLPs, microsatellites, ESTs
<i>Crassostrea gigas</i>	Hubert & Hedgecock, 2004 Li and Guo, 2004 Sauvage et al. to be submitted	microsatellites AFLPs



Microsatellites Markers

- 46 from Hubert & Hedgecock (2004)
- 3 from Yu & Li (2007)

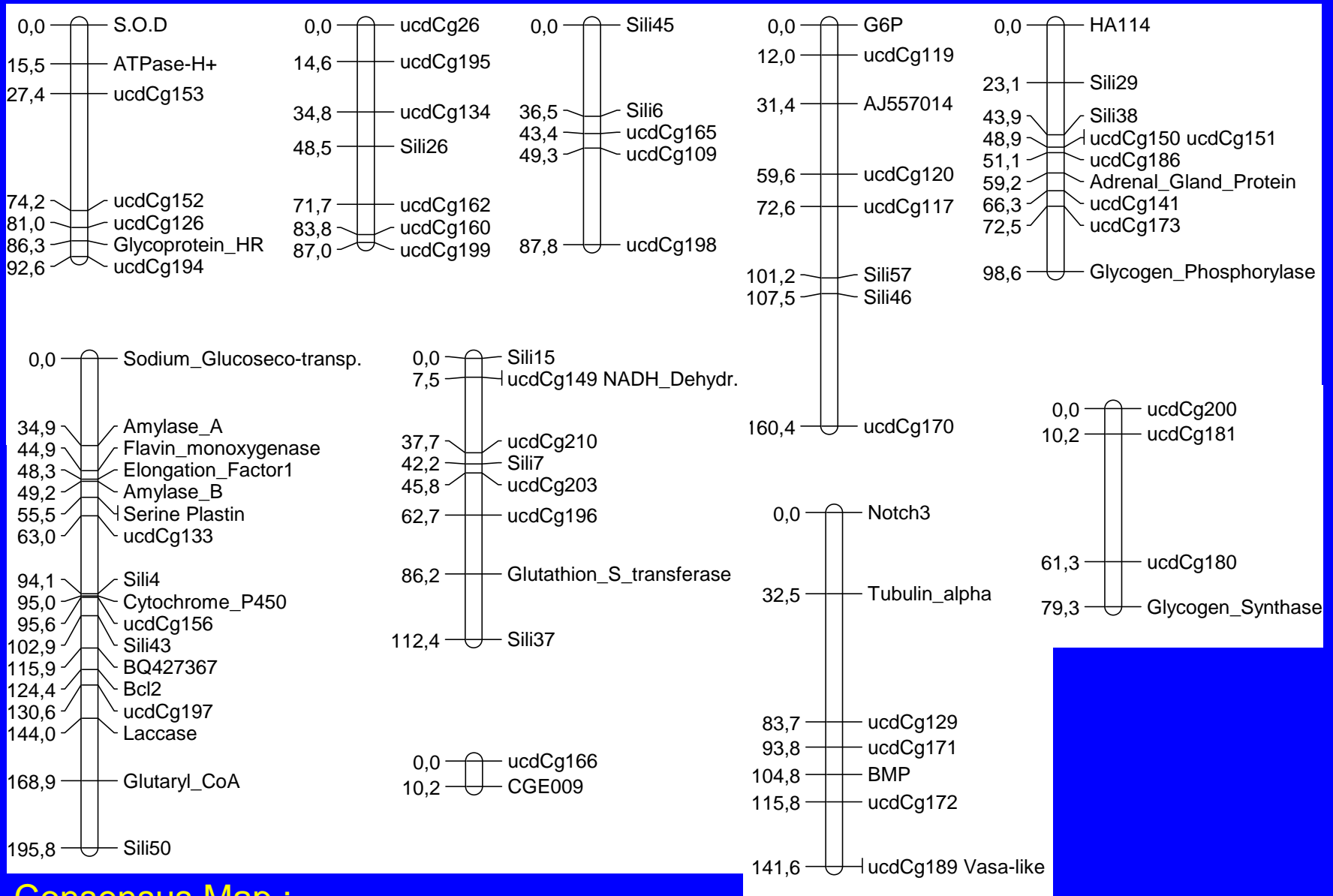
In silico SSR derived form ESTs

- 18 from Sauvage et al. (2008, submitted)

SNP markers

- 47 from Sauvage et al. (2007)

Genetic map in the cupped oyster *C. gigas*



Consensus Map :

10 LG / Length 1218cM / 82 Markers / average spacing of 13.5 cM/ Coverage=93%

Genetic maps in shellfish

Oysters:

Ostrea edulis

Lallias et al., 2007

AFLPs, microsatellites,

doi:10.1111/j.1365-2052.2007.01647.x

A first-generation genetic linkage map of the European flat oyster *Ostrea edulis* (L.) based on AFLP and microsatellite markers

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Mussels:

Mytilus edulis

Lallias et al., 2007

AFLPs

doi:10.1111/j.1365-2052.2007.01611.x

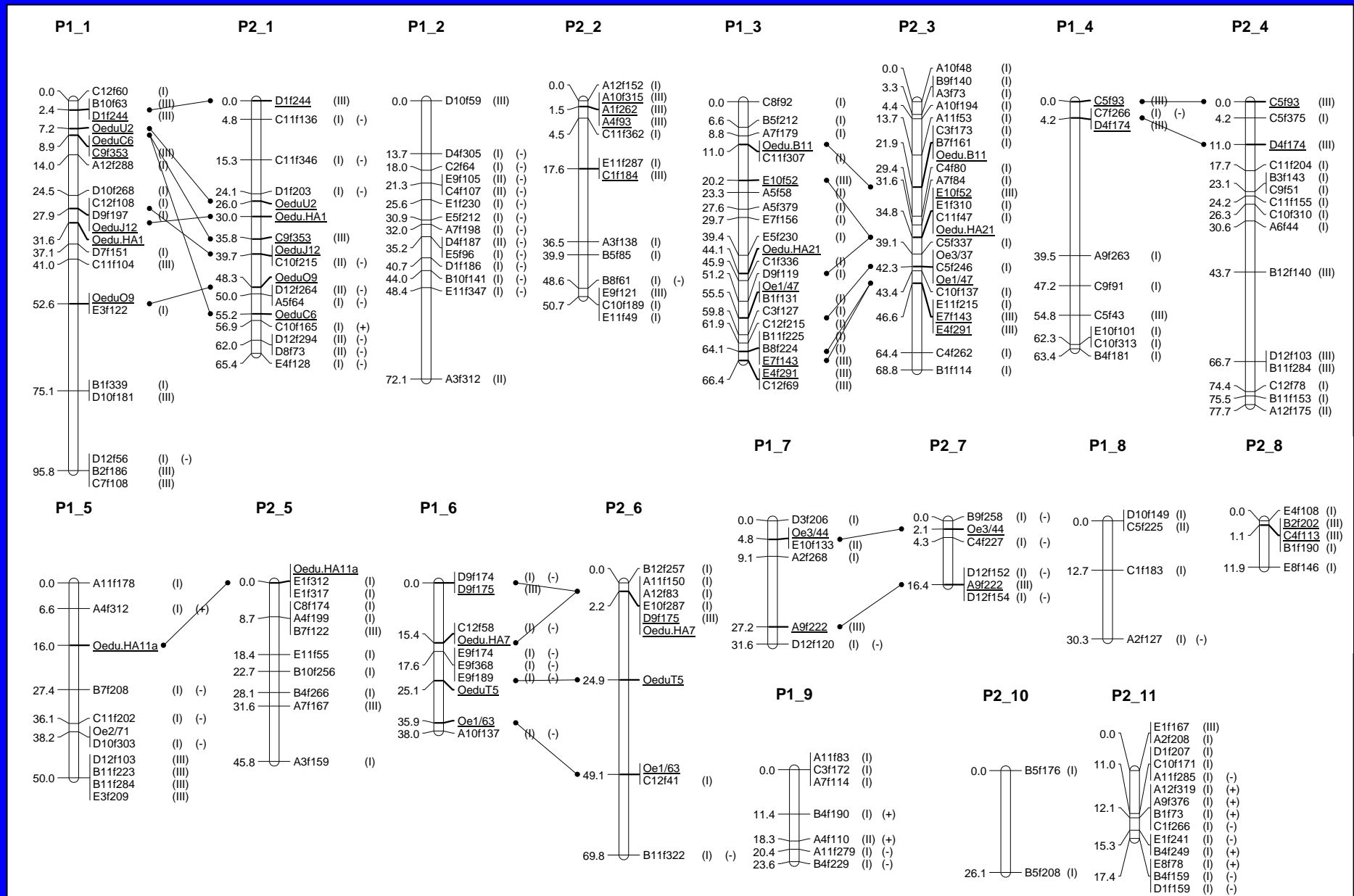
AFLP-based genetic linkage maps of the blue mussel (*Mytilus edulis*)

D. Lallias^{*,†}, S. Lapègue^{*}, C. Hecquet^{*}, P. Boudry^{*} and A. R. Beaumont[†]

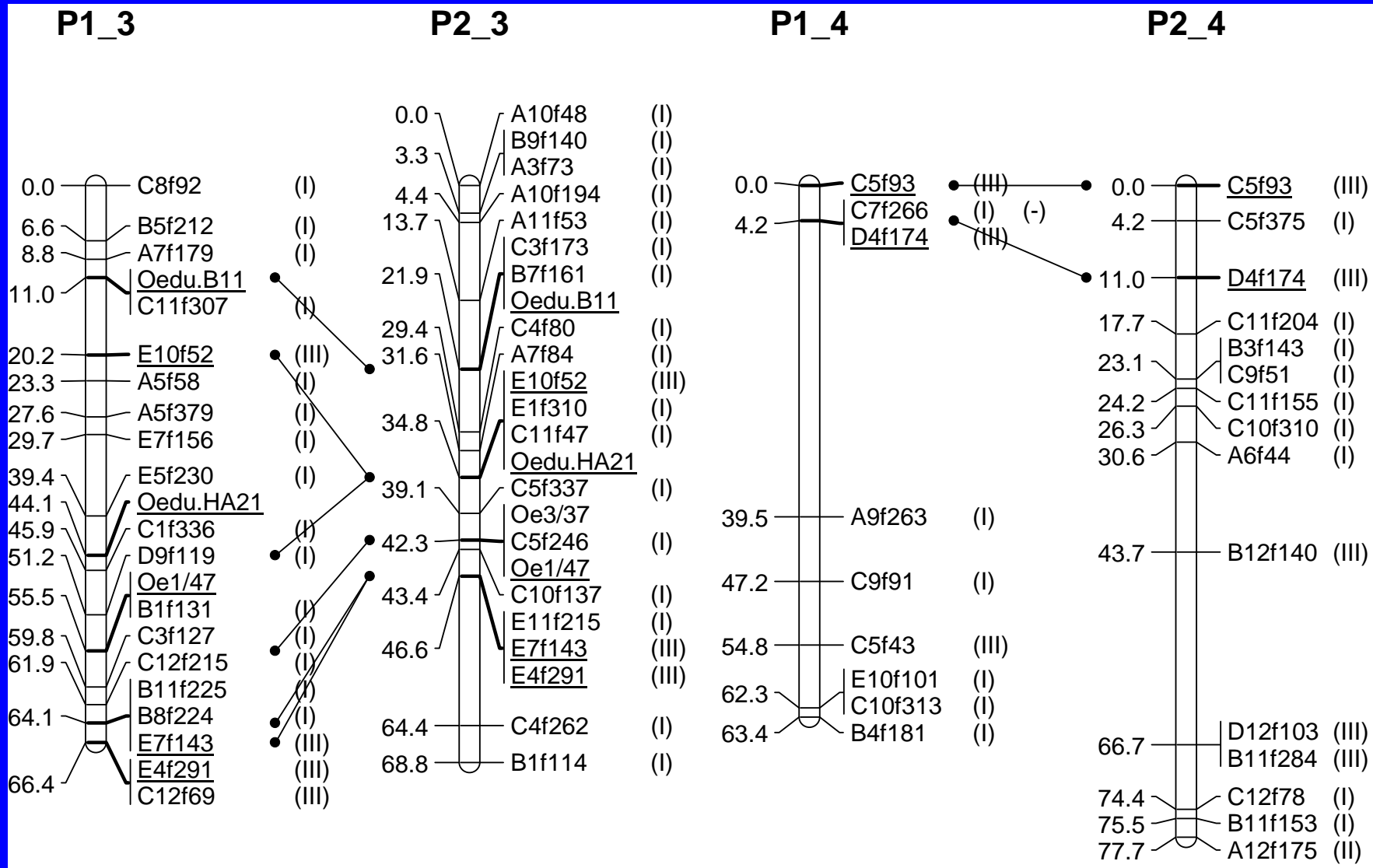
^{*}Ifremer, Laboratoire Génétique et Pathologie, Ronce-les-bains, 17390 La Tremblade, France. [†]School of Ocean Sciences, College of Natural Sciences, University of Wales, Bangor, Menai Bridge, Gwynedd LL59 5AB, UK

Genetic map in the European flat oyster *Ostrea edulis*

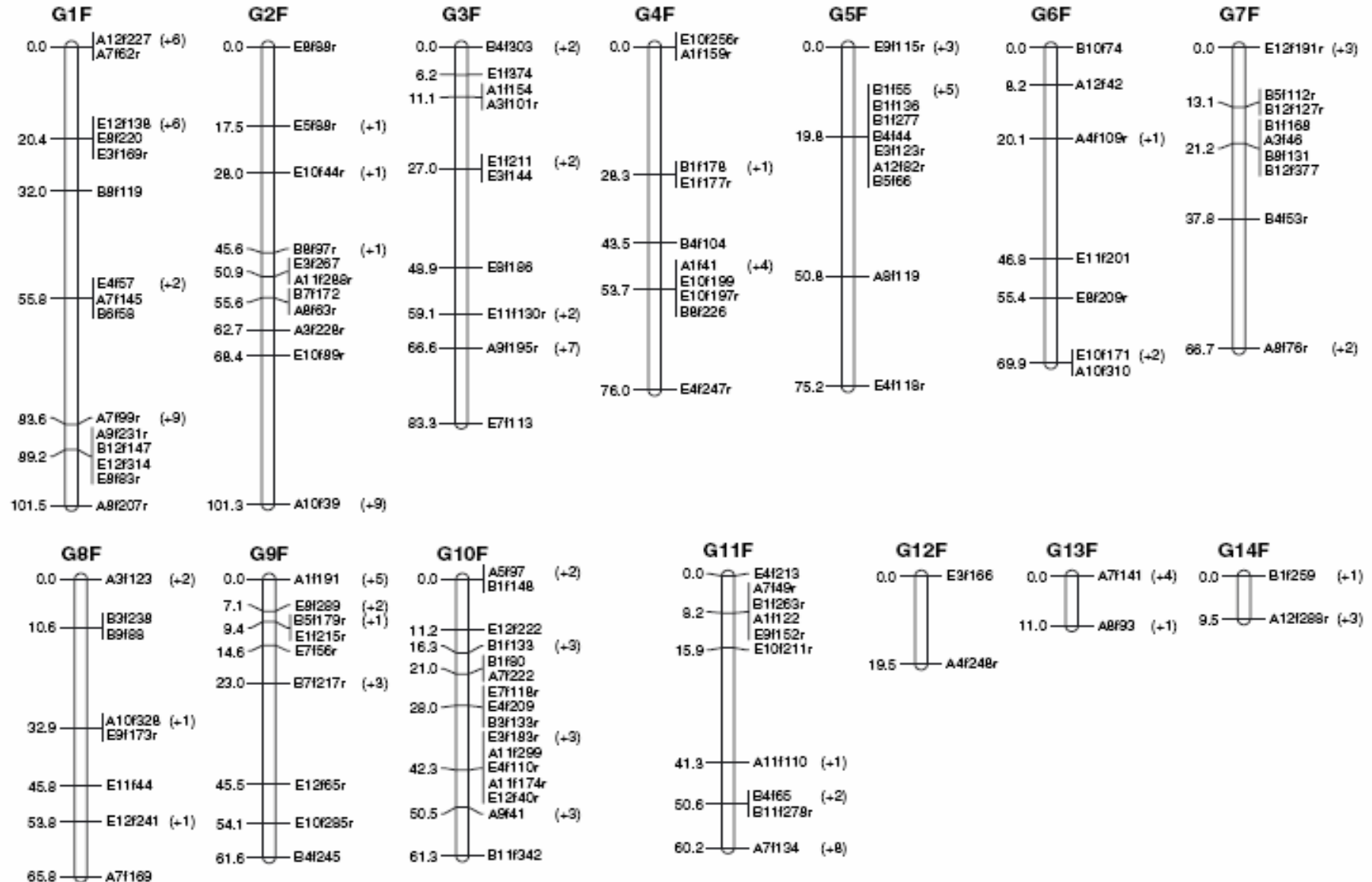
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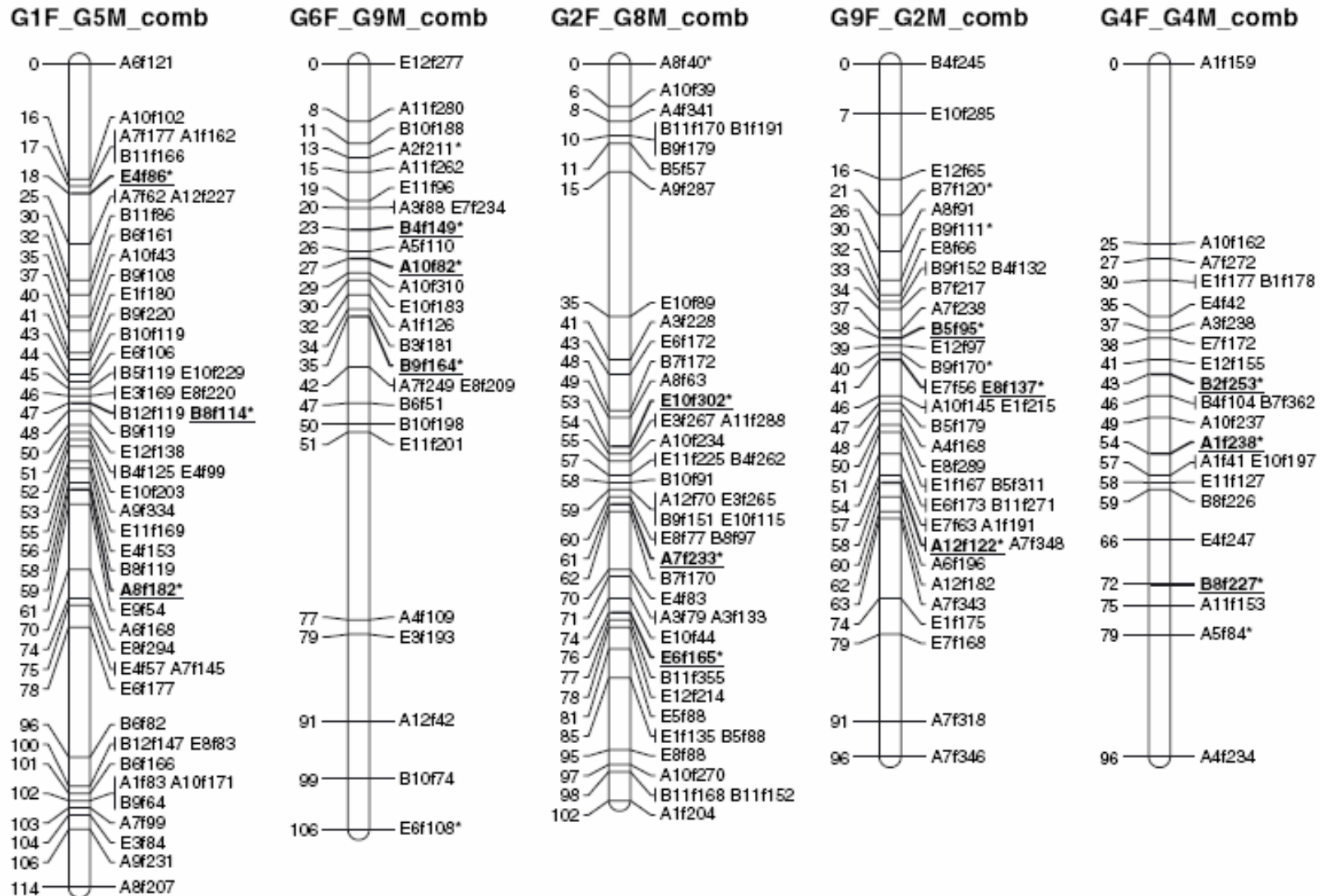
Genetic map in the European flat oyster *Ostrea edulis*



Genetic map in the blue mussel *Mytilus edulis*



Genetic map in the blue mussel *Mytilus edulis*



General features of genetic maps

- Preliminary maps ...
- ...But already useful to look for links between markers and phenotypes (QTLs)
- Segregation distortion
- Clustering of markers (AFLPs)
- Sex specific differences in recombination rates
- Need of more codominant markers for a better coverage

Future in genome mapping

- High numbers of EST sequences
22323 hits for ESTs in *C. gigas* (06/02/08)

Development of new markers:
in silico microsatellites
SNPs

- High Troughput genotyping technics
- Link between a marker and a candidate gene
SNPs and ESTs
- Developement for the use for QTL mapping, and MAS