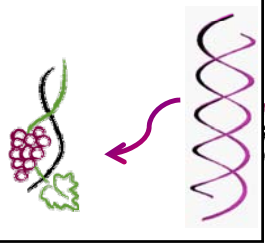
Grape Genome at Work in the Industry

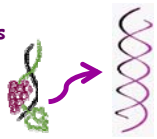
Anne Fennell, PhD
South Dakota State University
MGGA February 14, 2009



Grape Genome

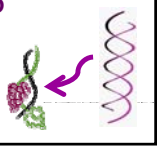
What is it?
- genome and genomics defined

How is the information used for the grape industry?
- cultivar identity
- disease resistance
- flowering & fruit characteristics
- cold climate viticulture



Genome and genomics ≠ GMO

Genome:
Is the "book" that contains all of the information needed to build and maintain a living organism - grapevine

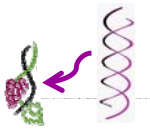


Genomics

identifying (sequencing) and organizing all the letters that make up the book and determining how the book is put together

Functional Genomics

translating and using the book at all levels of interaction:
DNA (genotype),
RNA (transcriptome),
protein (proteome)



Understanding the genome

"Heredity units/factors" Mendel

"DNA makes RNA, RNA makes protein and proteins make us" Francis Crick

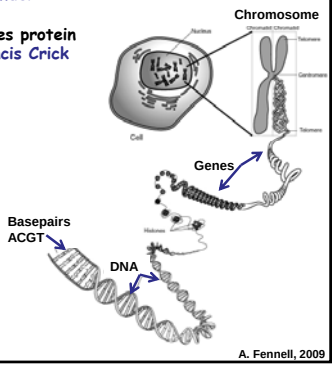
Genome: the book

Chromosome: chapters

www.eduplace.com: pages

Gene: sentences (instructions) that code for a protein

Sequence (basepairs ACGT): letters



Human genome stored on DNA is analogous to instructions stored in a book:

- The book is over one billion words long;
- The book is 5000 volumes, each 300 pages long;
- The book fits into a cell nucleus the size of a pinpoint;
- A copy of the book (all 5000 volumes) is contained in almost every cell;

Wikipedia Analogy

However DNA is not just 2-D!

Genome sequencing

Nature 2001

- 1976: first entire genome sequenced (bacteriophage MS2)
- 1984: first suggestion to sequence the human genome
- 1991: human genome sequencing begun
- 1992: first genome sequenced from a free-living organism (*E. coli*)
- 1996: first entire eukaryote genome sequenced (*S. cerevisiae*)
- 2000: incomplete draft of human genome
- 2001: First plant genome Arabidopsis
- 2003: human genome complete sequence
- 2006: first woody plant – poplar genome
- 2007: grape genome – 1st fruit crop & 4th flowering plant genome to be sequenced

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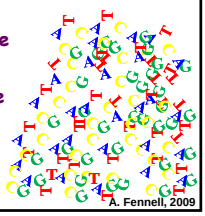
Grape Genome

- Now we have the sequence (all the letters of the book) and much of it sorted to chromosomes (chapters).
  - number and type of genes
  - gene/genome structure (splice junctions, base composition, gene spacing, redundancy)
  - tools for investigating gene function.
- Grape genome is about 1/6 the size of human genome.
- Genes are only a portion of genome
- Identifying the parts doesn't mean we know how it all works



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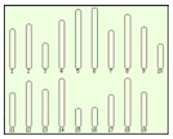
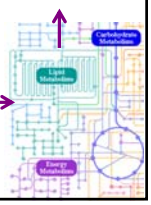
Grape Genome

- Two genomes PN400024 (Pinot noir inbred) and Pinot Noir
- ~490,000,000 bp on 19 chromosomes (haploid)
- ~29,500 predicted genes (human 20-25,000 genes)
- ~21,900 genes have a "known" function (conserved domain, similar to,etc.)
- 13,149 genes we have a more precise function for and have linked to metabolic pathways (Grimplet et al. 2009)





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Grape genome in use

- Unraveling mysteries of the grapevine
  - Aroma
  - Color
- Genotyping
  - Ancestry
  - Identity
- Marker assisted selection/breeding
- Improve production systems

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Genes for Aroma & Flavor

- Grapevine genome shows a selective amplification of genes belonging to the metabolic pathways of terpenes and tannins
- Analysis of the grape *MYB R2R3* gene subfamily reveals expanded wine quality-related groups

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Genes for color

- *VvmybA1* & *VvmybA2* genes : variations, mutations, transposable elements cause a large portion of color variation (Chromosome 2 & 14)
- White grapes arose through the mutation of two similar and adjacent regulatory genes. Suggest single genetic origin for white grapes (Walker et al. 2007)

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Grape genome in use

DEPARTMENT OF THE TREASURY

Bureau of Alcohol, Tobacco and Firearms

27 CFR Part 4

[Notice No. 941]

RIN 1512–AC65

Proposal To Recognize Synonyms for Petite Sirah and Zinfandel Grape Varieties (2001R–251P)

AGENCY: Bureau of Alcohol, Tobacco and Firearms, Department of the Treasury.

ACTION: Notice of proposed rulemaking.

SUMMARY: The Bureau of Alcohol, Tobacco and Firearms is proposing two amendments to its list of prime grape variety names used to designate American wines. The first amendment would recognize the name "Durif" as a synonym for the Petite Sirah grape, while the second would recognize the name "Primitivo" as a synonym for the Zinfandel grape. The Bureau's proposal is based on recent DNA research into the identity of these grapes.

DATES: Written comments must be received by June 10, 2002.

ADDRESSES: Send written comments to: Chief, Regulations Division, Bureau of

Zinfandel came to the United States in 1820s.

Ampelography suggests that Zinfandel and Primitivo (IT-1700s) have similarities.

DNA fingerprinting indicates two are molecularly similar.

Not synonyms: Clones?

Where did it come from?

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"A DNA Match Reveals Zinfandel's Parent"

New York Times WINE TALK; By FRANK J. PRIAL
Published: September 11, 2002

"a vine strongly resembling Zinfandel was found in a mixed vineyard in Kaštela, a coastal town near the city of Split (Croatia). SSR analysis with 10 markers revealed that this vine, subsequently determined to be the rare cultivar Crljenak kastelanski, has the same SSR profile as Zinfandel".
Maletic et al. 2003 Acta Hort. 603:251-254

"Vines of the cultivars Crljenak katelanski and Pribidrag, found in two different locations in Dalmatia in 2001 and 2002, respectively, were shown to match the microsatellite genotype of Zinfandel."
Miletiae et al. 2004 AJEV 55:174-180

"An additional synonym for Zinfandel has been identified: Kratoija, an old variety growing in Montenegro."
Calo et al. 2008 AJEV 59:205-209

SSR = Single Sequence Repeats, (1-6 bp) repeating sequence

Crljenak Kastelanski "Zinfandel"

UNIVERSITY OF ZAGREB, CAROLE MEREDITH PHOTOS Wikipedia.com

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Foundation Plant Services

UNIVERSITY OF CALIFORNIA • ONE SHIELDS AVENUE • DAVIS, CALIFORNIA 95616-8600
PHONE: (530) 752-3590 • FAX: (530) 752-2132 • WEB: http://fps.ucdavis.edu
UCDAVIS

- DNA-based grape varietal identification and profiling services on a fee-for-service basis.
- Cultivar identity: 8 SSR (Simple Sequence Repeat) markers
- New cultivar passport: 10 SSR markers

And what about those stories on the wine labels:

"The ability to detect differences by SSR analysis may force a clarification of the economic definitions of cultivar and clone with respect to wine grapes"

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What is in a name? What is in the genome?

- Gray Riesling: Trousseau Gris (mutation of Trousseau)
- Napa Gamay: Valdiquié
- Gamay Beaujolais: is a clone of Pinot Noir
- 4 of the seven Petite Sirahs in the UC Davis collection are Durif, one is "true" Syrah, one is Peloursin, and one is Pinot Noir. Majority of "Petite Sirah" grown in the CA North Coast today are actually "Durif"

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Grape Genomics and Cold Climate Viticulture

Identifying markers for fruit quality, stress, disease and insect resistance to aid breeders.

Develop an understanding of genes involved in quality, disease, stress responses and winter hardiness. Use the information to improve cropping systems.

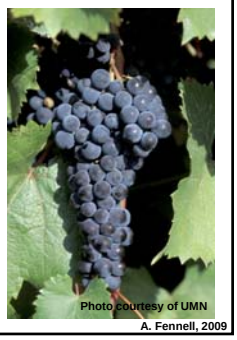

Photo courtesy of UMN

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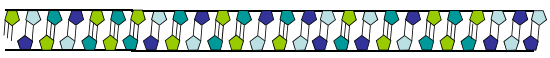
Marker Assisted Breeding

- Identify traits of interest
- Accurately phenotype (measure) trait
- Identify molecular markers
  - Genome sequences (small number of base pairs – "words" or "letters", chromosome position known)
  - Number of markers is increasing
  - Ease of use increasing – automation



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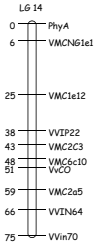
SSR: Single Repeat Sequences (1-6 bp repeating sequence)

- Marker location → lab work
- SSR Marker associated phenotypes
  - Identify Phylloxera resistance
  - Identify Disease resistance
    - Powdery mildew
    - Pierce's disease



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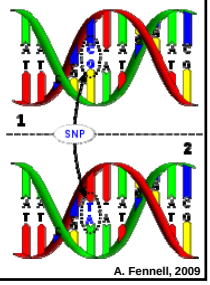
SNP: Single Nucleotide (base pair) Polymorphism

- Genome: Search DNA sequence of different cultivars. Most abundant type of sequence variation (1/30 to 60 bp)
  - Pinot Noir 1.7 million SNPs
  - Large number of disease resistance
- Transcriptome: Searching expressed gene sequences for candidate SNPs
  - disease & insect resistance
  - volatile aroma production
  - other genes of physiological interest



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Identifying Markers for Winter Survival

Need plant materials with differences in:

- endodormancy induction, maintenance and release
- chilling requirement
- freezing tolerance
- timing of bud break

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Identifying Markers for Winter Survival

- *V. riparia* – Manitoba, Canada (52°N)
- *V. cv.* 'Seyval' (Seyve Villard 5276)
- F_1: *V. riparia x V. cv.* 'Seyval'
- F_2: (F_1 selfed) mapping population

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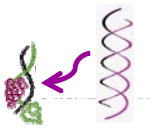
Identifying Markers for Winter Survival

Characterize population for:

- Early acclimation
- Timing & length of Dormancy
- Low temperature survival
- Delayed budbreak

- SD: Anne Fennell, Kathy Mathiason
- MN: James Luby, Steve McKay
- NY: Amanda Garris, Chris Owens



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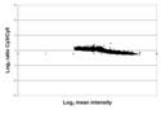
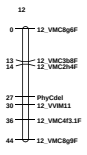
Lots of Field & Lab Work





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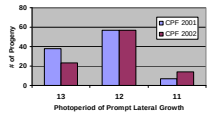
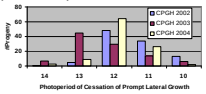
Acclimation Responses

Monitor:
- Shoot elongation
- Summer lateral emergence
- Growth Cessation

Critical Photoperiod for Growth Cessation (Field)



Critical Photoperiod for Growth Cessation (Greenhouse)



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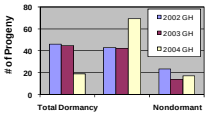
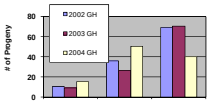
Dormancy Induction Responses

Monitor:
- Bud dormancy
- Cambium dormancy
- Shoot tip abscission



Dormancy at 11h



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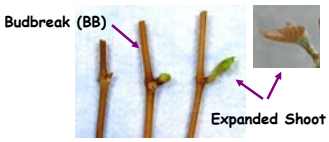
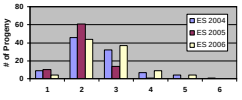
Budbreak Characteristics

Grapevines transferred from 4°C to 20°C
Monitor number of days required to reach budbreak and expanded shoot





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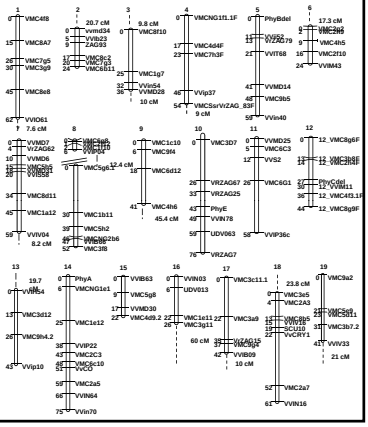
First Stage

1. Linkage map.
2. Phenotype population for timing of:
   budbreak
   dormancy induction,
   photoperiod response
   winter survival
3. Identify QTLs
4. Expand number markers



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Determine whether traits are correlated with specific SSR and location on chromosome (QTL)

- Critical Photoperiod, Growth Cessation, or Dormancy
- Budbreak (BB,ES)
- Winterhardiness

} QTLs identified for these traits

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Potential Winter Hardiness Chromosome Regions Identified

- Test in other populations
- Identify additional Markers
- Test in cultivars
- Use in selection

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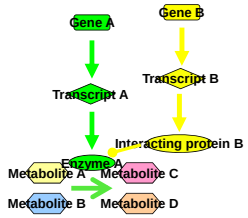
Systems Biology of Grapevine Dormancy (1 component of Winterhardiness)

- Unravel gene story behind dormancy
- Use information to identify tools for production management and breeding



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Systems Biology

- Unravel gene expression and use information to develop:
- Tools for management decisions:
  - Irrigation, optimizing flavor, quality,
  - Selection of cultivars for environment
  - Crop load,
- Tools for breeding
  - Disease resistance
  - Insect resistance
  - Stress tolerance

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The grape genome at work in the midwest, where

the vines are strong, the clusters are goodlooking, and the growers are above average

Midwest Terrior, A. Fennell
Adaptation from the Prairie Home Companion Theme

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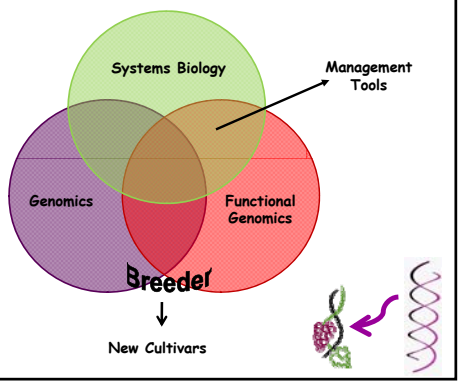

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