StarGenetics – Implementation, evaluation, outreach, & development

Education Group Meeting

March 11, 2011

Lourdes Alemán, Ph.D.

Stacie Bumgarner, Ph.D.

The Education Group of the MIT Department of Biology

&

star Software Tools for Academics & Researchers

Massachusetts Institute of Technology

oeit Office of Educational Innovation and Technology

HHMI

Upcoming events….

http://educationgroup.mit.edu

Seminars

HHMI Professor Rich Losick

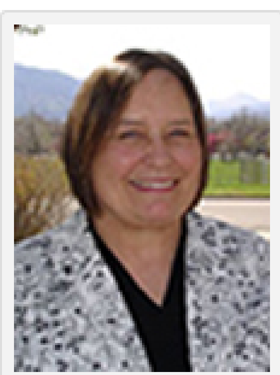
Topic: *Long-Term, Hands-on Research Experiences Engage Students from Diverse Backgrounds*

Date & Time/Location: Friday, April 15th @ 2:00 pm/Whitehead Auditorium

Professor Mike Klymkowsky

Topic: *Bioliteracy and the BCI (Biology Concept Inventory)*

Date & Time/Location: Friday, April 22 @ 2:30 pm/Whitehead Auditorium



Dr. Laura Border

Topic: *The Graduate Teacher Program – Synergy between teaching & science*

Date & Time/Location: Wednesday, May 25th @ 2:30 pm/66-110

Seminars

HHMI Professor Rich Losick

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Dr. Laura Border

Topic: *The Graduate Teacher Program – Synerg*

Date & Time/Location: Wednesday, May 25th @ 2:3

Sign up sheet:
Lunch w/ speakers

Education Group Meeting

Dr. Ishara Mills-Henry

Topic: *Science of the Eye Outreach Program (Jon King)*

Date & Time/Location: Thursday, April 7th @ 3:00 pm/ 68-180

Education Group Meetings

Dr. Ishara Mills-Henry

Topic: *Science of the Eye Outreach Program (Jon King)*

Date & Time/Location: Thursday, April 7^{th} @ 3:00 pm/ 68-180

Sign up sheet:
Ed Group meetings participants

Help build DNA LEGO molecules sets for Boston Public Schools

Dr. Kathy Vandiver/Dr. Amanda Gruhl (CEHS/MIT Museum/Edgerton Center)

See Movie1: DNA LEGO molecule sets

Help build DNA LEGO molecules sets for Boston Public Schools

Dr. Kathy Vandiver/Dr. Amanda Gruhl

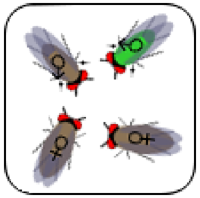
Date & Time: Monday, March 21st @ 6 – 9 pm

Location: 56-202 (CEHS conference room)

Sign up sheet: Volunteers!

star Software Tools for Academics & Researchers

Biology tools

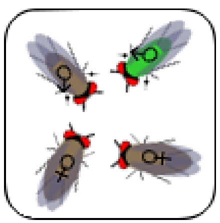


http://web.mit.edu/star/

STAR biology tools

- **StarBiochem:** protein 3D viewer

- **StarGenetics:** virtual genetics laboratory



- **StarORF:** gene finger (six frame translator)

Design process of STAR tools

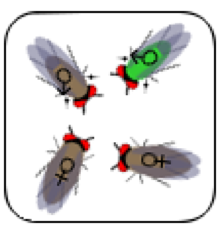
StarBiochem

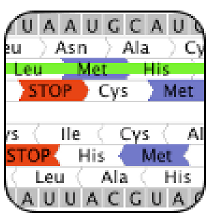
Professor: Graham Walker

OEIT: Chuck Shubert

Introductory Biology Series (7.01X)

StarGenetics/StarORF





Professor: Chris Kaiser

OEIT: Ivan Ceraj

Introductory Biology Series (7.01X)

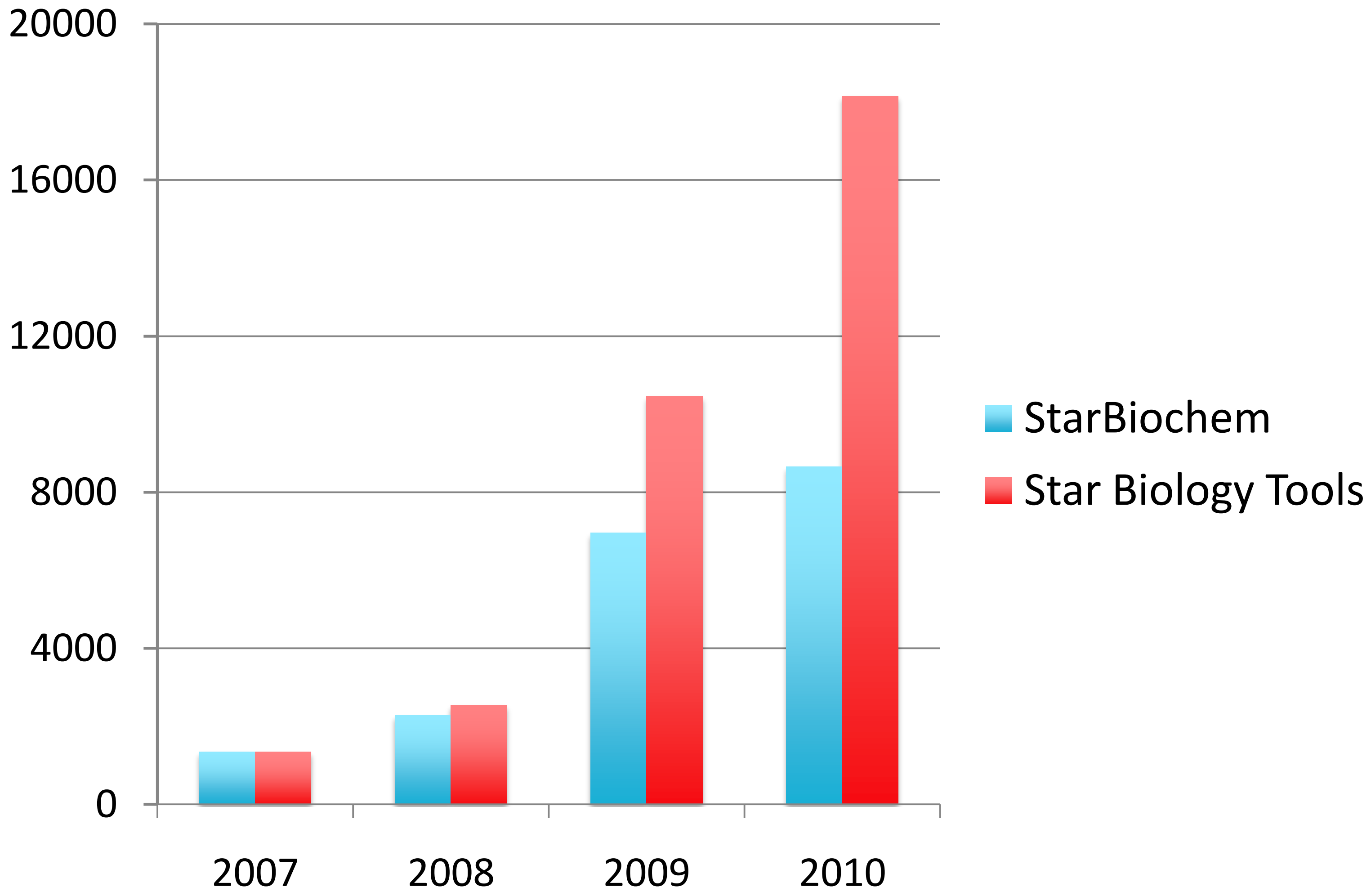
Genetics

Summer Pre-graduate Bridge Program

What **we** did to make tools more accessible to others and increase usage

- Create curriculum modules
- Conduct teacher/faculty training workshops
- Design and implement outreach activities
- Collaborate with wide range of educational institutions
- Assess how software tools impact students' learning experience
- Presented at scientific meetings and educational technology conferences
- Advertised through mail campaign and Google AdWords

STAR tools usage from 2007-2010



What IS StarGenetics?

StarGenetics: A virtual genetics laboratory

Developers:

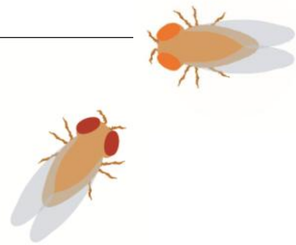
Faculty: Professor Chris Kaiser

Biology Education Group: Lourdes Alemán, Stacie Bumgarner

OEIT-STAR: Ivan Ceraj

Educational Goal:

To teach genetic concepts, experimental design & data interpretation



WHY was StarGenetics developed?

Limitations of traditional methods for teaching genetics concepts

Typical genetics problem:

Provides

Experiment

↓

Data

↓

Asks for

Analysis/
Conclusions

Limitations of traditional methods for teaching genetics concepts

Typical genetics problem:

Provides

Experiment

↓

Data

↓

Asks for

Analysis/
Conclusions

What's missing?

Limitations of traditional methods for teaching genetics concepts

Typical genetics problem:

Provides

Experiment

↓

Data

↓

Asks for

Analysis/
Conclusions

What's missing?

Doesn't teach students how to develop and test a hypothesis!

Teaching genetics in a real genetics lab is ideal, but is not always an option…

Cost

Establishing a genetics lab can be costly ($10,000 - $50,000).

Time

Genetics experiments can take longer than the time available to explore a concept.

Course design

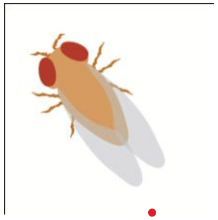
Not all genetic courses offer a lab component.

Virtual genetic cross simulator → **StarGenetics**

- Freely accessible: http://web.mit.edu/star/genetics/
- Platform independent (Windows, Mac, Unix/Linux)
- Simulates actual experimental process
- Address cost and time issues associated with traditional genetic labs
- Allows for in-class demos & new dimension to homeworks

StarGenetics Fruit Fly Visualizer

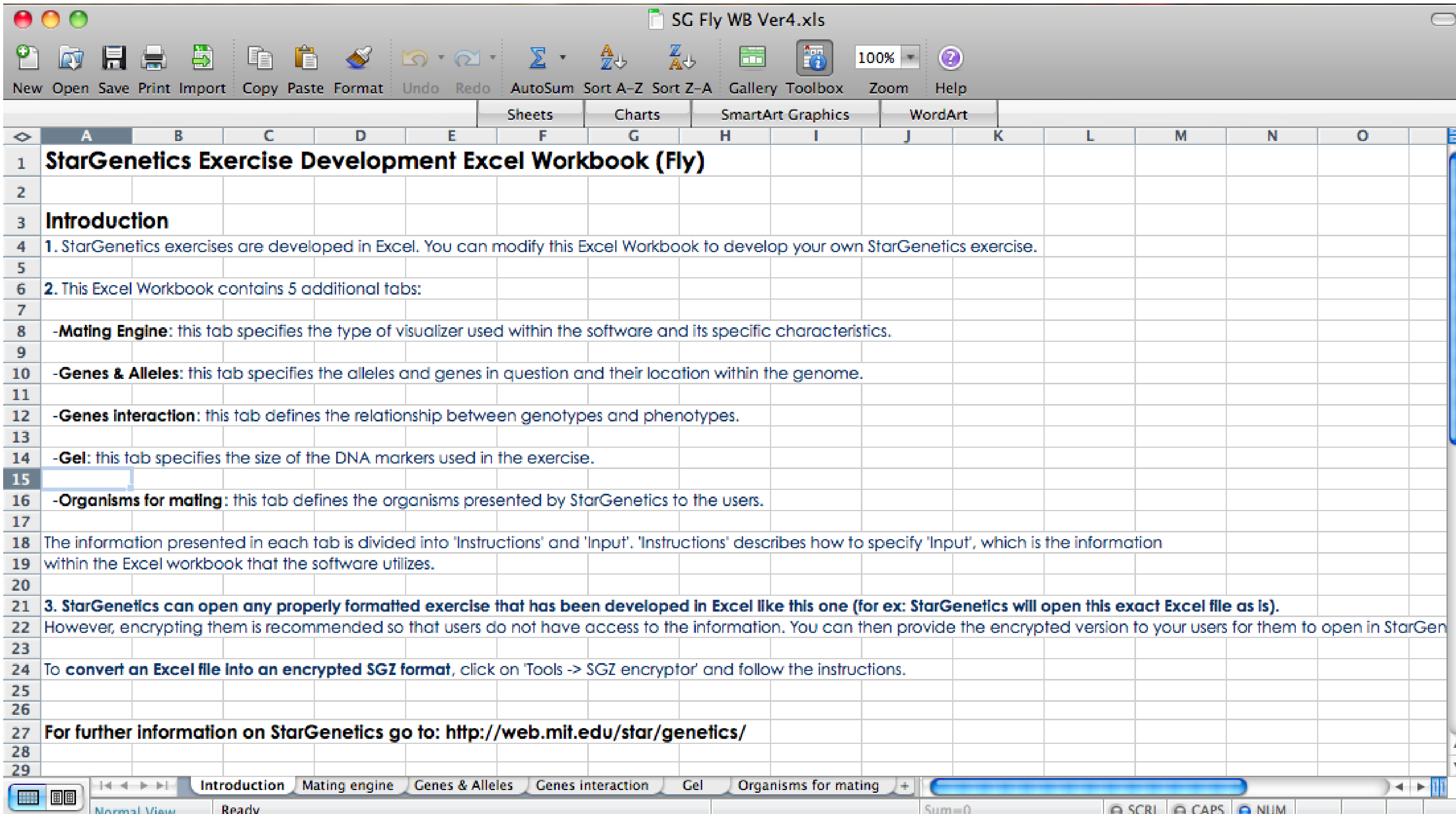
Let's Take a Quick Tour!



See Movie2: StarGenetics Fly Tour

StarGenetics allows for easy customization of exercises

Source Files = Encryptable Excel Workbooks



Modifiable characteristics in StarGenetics Fly

organism characteristics

progeny per cross, # of matings per organism, recombination rates for X & Y

genotypes & corresponding phenotypes

fly: 6 visible phenotypes, 1 nonvisible phenotype

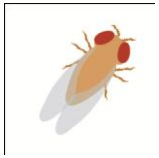
genes interactions

epistatic relationships, linkage

organisms

define which organisms will be available in Strains window

Concepts that can be taught using StarGenetics



genetic concepts

modes of inheritance

- **genotype → phenotype**
- **dominant vs. recessive alleles**
- **allele series (>2 alleles)**
- **multiple phenotypes**
- **autosomal vs. sex-linkage**

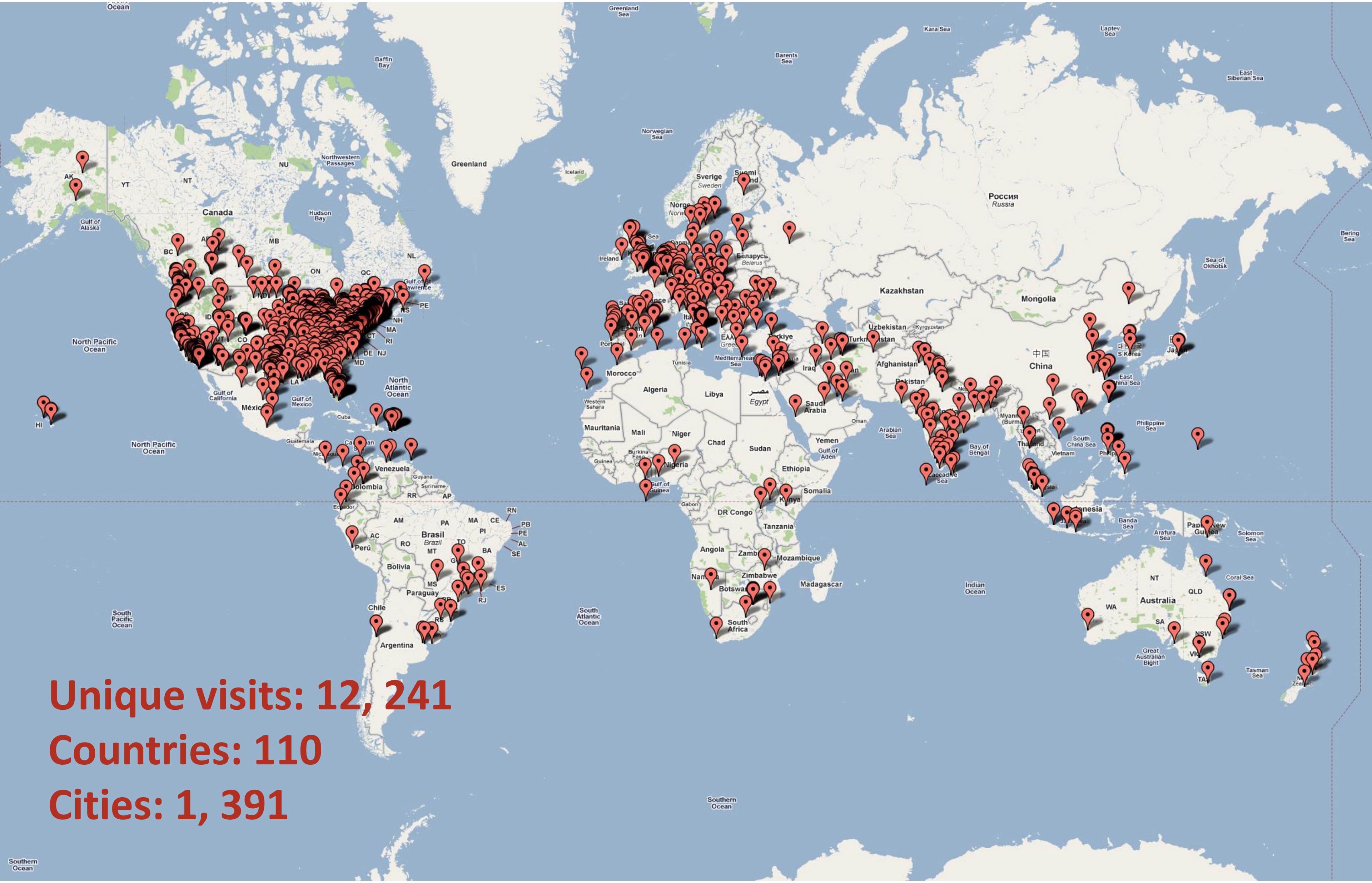
gene interactions

- **epistasis**
- **linked genes**
- **complementation**

genetic tools

- **genetic crosses**

  (P/F1/F2; testcross, backcross; dihybrid cross; reciprocal etc.)
- **chi square analysis**
- **punnett squares**



Unique visits: 12, 241

Countries: 110

Cities: 1, 391

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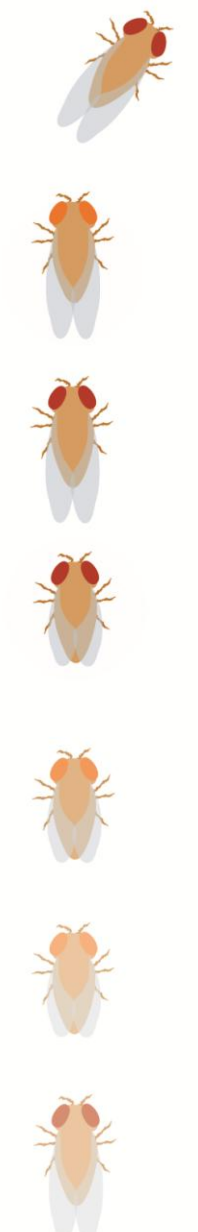

Talk Overview:

- Implementing StarGenetics at Suffolk University –

  Trying out StarGenetics
  in a variety of educational activities

- Pilot study to evaluate learning outcomes –

  So much to learn about
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- Outreach efforts

  Spreading the word and supporting others

- Further development

  Additional software, more curriculum

Classical Genetics Lecture & Laboratory

Fall 2008 – Prior to StarGenetics Implementation

Fall 2009 – Full implementation of StarGenetics

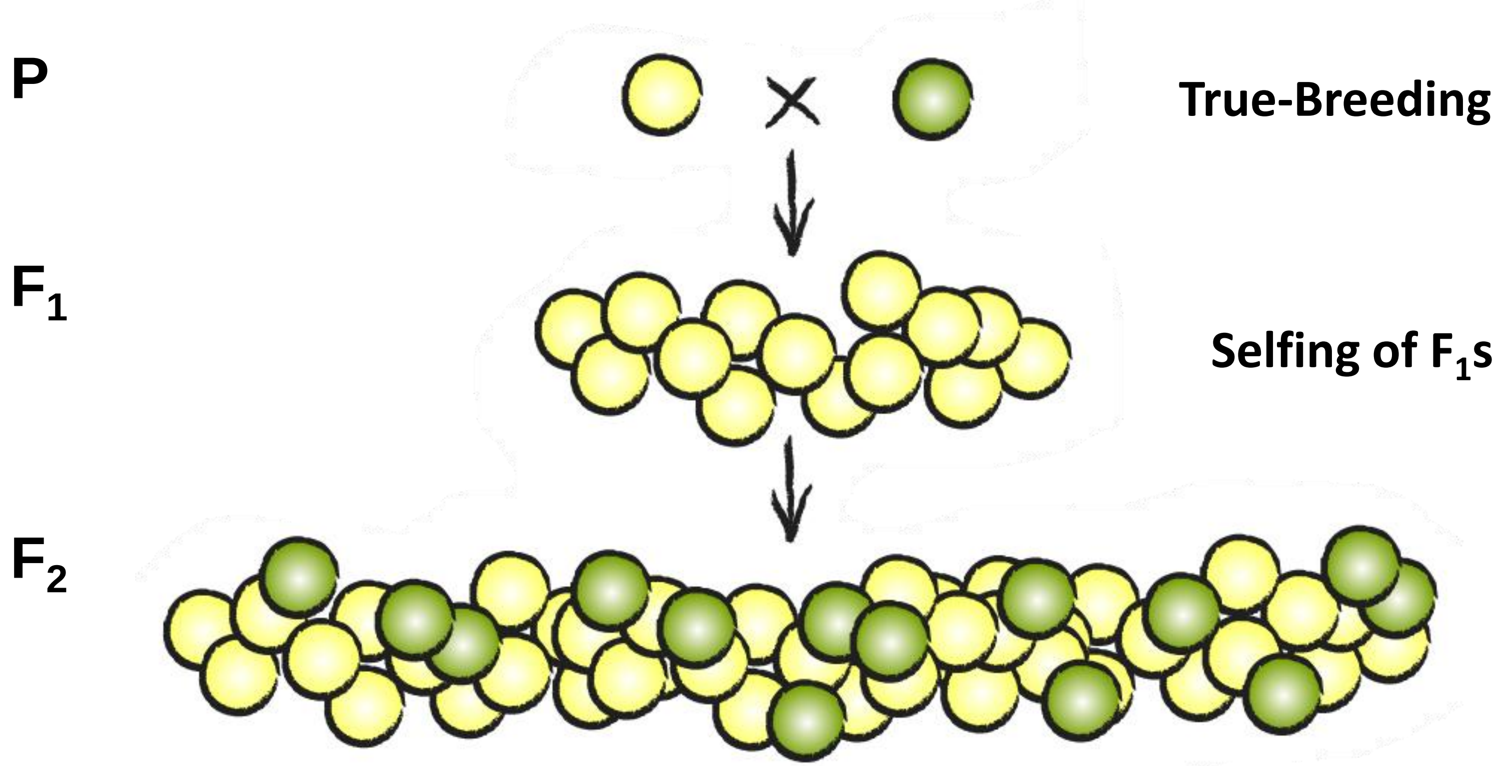
- **Small class size** (~20)
  - Intro course conducted like a seminar
  - Knew all of my students
- **Limited resources**
  - Had a laboratory component, but not well resourced
  - Lots of contamination, fly death, student frustration
- **Heterogeneous student population**
  - Preparation, ability?, interest, departmental culture

Trying out StarGenetics in a variety of educational activities…

- **Lecture demos**
  - Effect of sample size and deviations due to chance
  - Genetic linkage
- **Dry laboratory fly exercise**
  - To help prepare students for wet lab fly exercise
  - Enrich their learning experience, given obstacles
- **Homeworks**
  - 1 to 2 weeks to work on each; increased in complexity
  - Added dimension: Experimental thinking

StarGenetics Lecture Demo: Why deviations due to chance?

How we typically introduce deviations due to chance…



6022 yellow : 2001 green

Approximately **3 : 1**

StarGenetics Lecture Demo: Why deviations due to chance?

How we typically introduce deviations due to chance…

- **The SIZE of an experimental population (<u>the sample size</u>) is an important component of statistical significance.**

- **The larger the sample size, the closer observed percentages can be expected to match values predicted by an experimental hypothesis, if that hypothesis is correct.**

StarGenetics Lecture Demo: Why deviations due to chance?

Intuitive demonstrations with non-genetic examples…

Hypothesis……………….This is a fair coin.

Results expected………..Heads 50%, Tails 50%

Suppose we flip this coin	**<u>10 times</u>:**	**<u>1000 times</u>:**
And observe:	**4 heads : 6 tails**	**400 heads : 600 tails**
Do the observed results fit the hypothesis?	**Yes**	**No** ***Even though the ratio (2:3) is exactly the same!***

StarGenetics Lecture Demo: Why deviations due to chance?

Examples can be GENETIC! And can then perform statistical analysis…

When observing *SMALL* numbers of progeny, we sometimes observe deviations from the expected ratio due to chance…

Expect 3 WT : 1 ebony
Observe 4 WT : 1 ebony

Phenotypes			TOTAL
Count	10 (20%)	40 (80%)	50
Female	8	20	28
Male	2	20	22

But as the sample size of F_2 progeny grows *LARGER*, deviation from the expected ratio is diminished if hypothesis is correct…

Expect 3 WT : 1 ebony
Observe 3 WT : 1 ebony

Phenotypes			TOTAL
Count	100 (25%)	300 (75%)	400
Female	61	140	201
Male	39	160	199

Trying out StarGenetics in a variety of educational activities…

- **Lecture demos**
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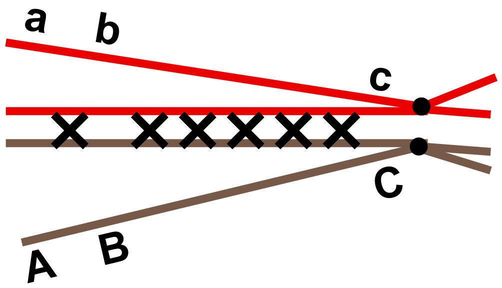
StarGenetics Lecture Demo: Why Linkage?

Lecture material on gene linkage usually goes something like this:



Recombination during meiosis in heterozygote AaBbCc

- **The farther apart two genes are located from one another on the same chromosome, the more likely their alleles are to be separated from one another by recombination during meiosis.**

- **Genes located close together on the same chromosome assort together with a frequency that depends on the distance between them.**

StarGenetics Lecture Demo: Why Linkage?

Often text-based examples are presented:

"You obtain the following testcross progeny…"

Brown body, Red eyes	**35**
Brown body, White eyes	**14**
Yellow body, Red eyes	**17**
Yellow body, White eyes	**34**
Total:	**100**

StarGenetics Lecture Demo: Why Linkage?

Often text-based examples are presented:

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Total:	**100**	

$$\text{Recombination Frequency (RF)} = \frac{\text{\# of Recombinants}}{\text{\# of Total Progeny}} \times 100$$

1% RF = 1 unit of measure along a chromosome
= 1 centimorgan (cM)
= 1 map unit (m.u.)

StarGenetics Lecture Demo: Why Linkage?

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Total:	**100**	

When genes are unlinked, Parentals = Recombinants

50% 50%

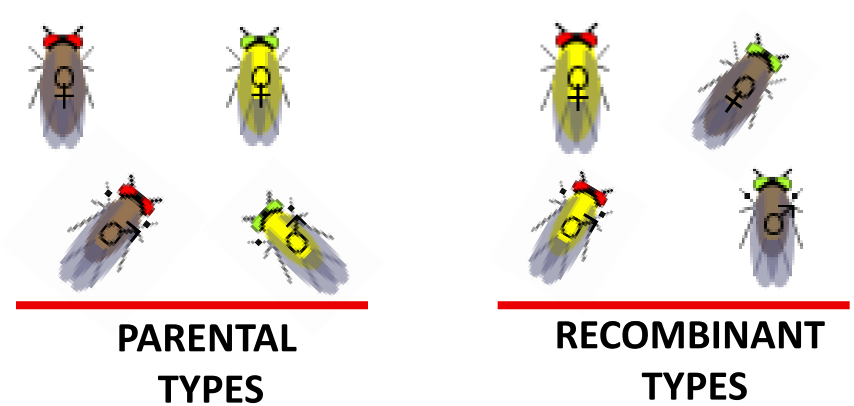
Linkage is defined as Parentals > Recombinants

StarGenetics Lecture Demo: Why Linkage?

We thought that this information might seem very abstract to many students….

… and we wondered if we could more richly support the concept of gene linkage using StarGenetics in a concept demo.

… A visual real-time demonstration of gene linkage!!



See Movie3: StarGenetics Linkage Demo

StarGenetics Lecture Demo: Linkage!

Custom Source file constructed using Excel Template on website…

http://web.mit.edu/star/genetics/problemsets/development/index.html

On the "Genes & Alleles" Tab in Excel Source File:

INPUT

Alleles	Gene	Chromosome	Gene Location	Notes
G, g	Green eyes	2	1	recessive
Y3, y3	Yellow body	2	5	recessive
Y2, y2	Yellow body	2	30	recessive
Y1, y1	Yellow body	2	50	recessive

Trying out StarGenetics in a variety of educational activities…

- **Lecture demos**
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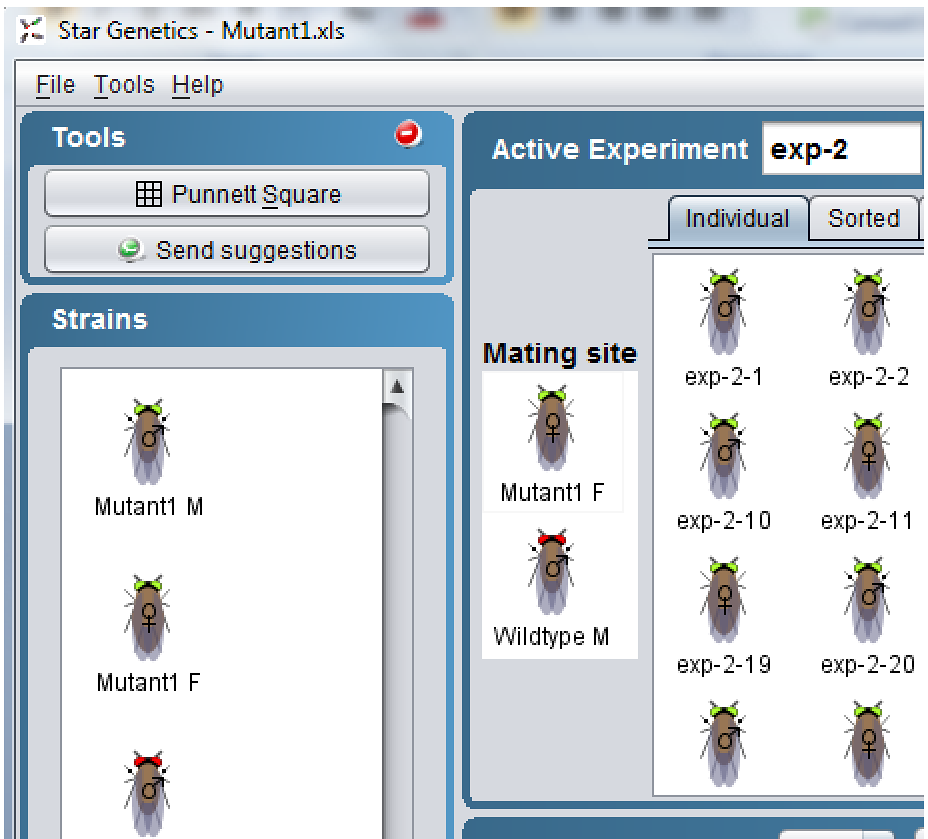
StarGenetics Dry Laboratory: Fly lab simulation

In preparation for live fly cross experiment:

- familiarize with modes of inheritance in active learning exercise
- improve interpretation of data collected from actual fly crosses

Given 4 StarGenetics source files containing WT flies + mutant flies:



1. Autosomal recessive
2. Autosomal dominant
3. X-linked recessive
4. X-linked dominant

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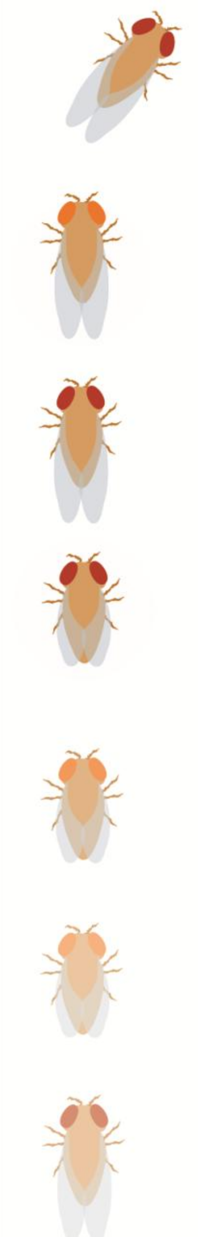
StarGenetics Homeworks:

- **Started with simple concepts**
  - Students need time to get familiar with the software
  - Builds confidence
- **Increased complexity over time**
  - Followed increasing complexity of course curriculum
  - Limit matings
  - Limit provided flies (so students generate flies they need)
- **Versions of homeworks used now available on website**

  http://web.mit.edu/star/genetics/problemsets/index.html

See Movie4: StarGenetics Homework Sample 1

See Movie5: StarGenetics Homework Sample 2



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  Trying out StarGenetics
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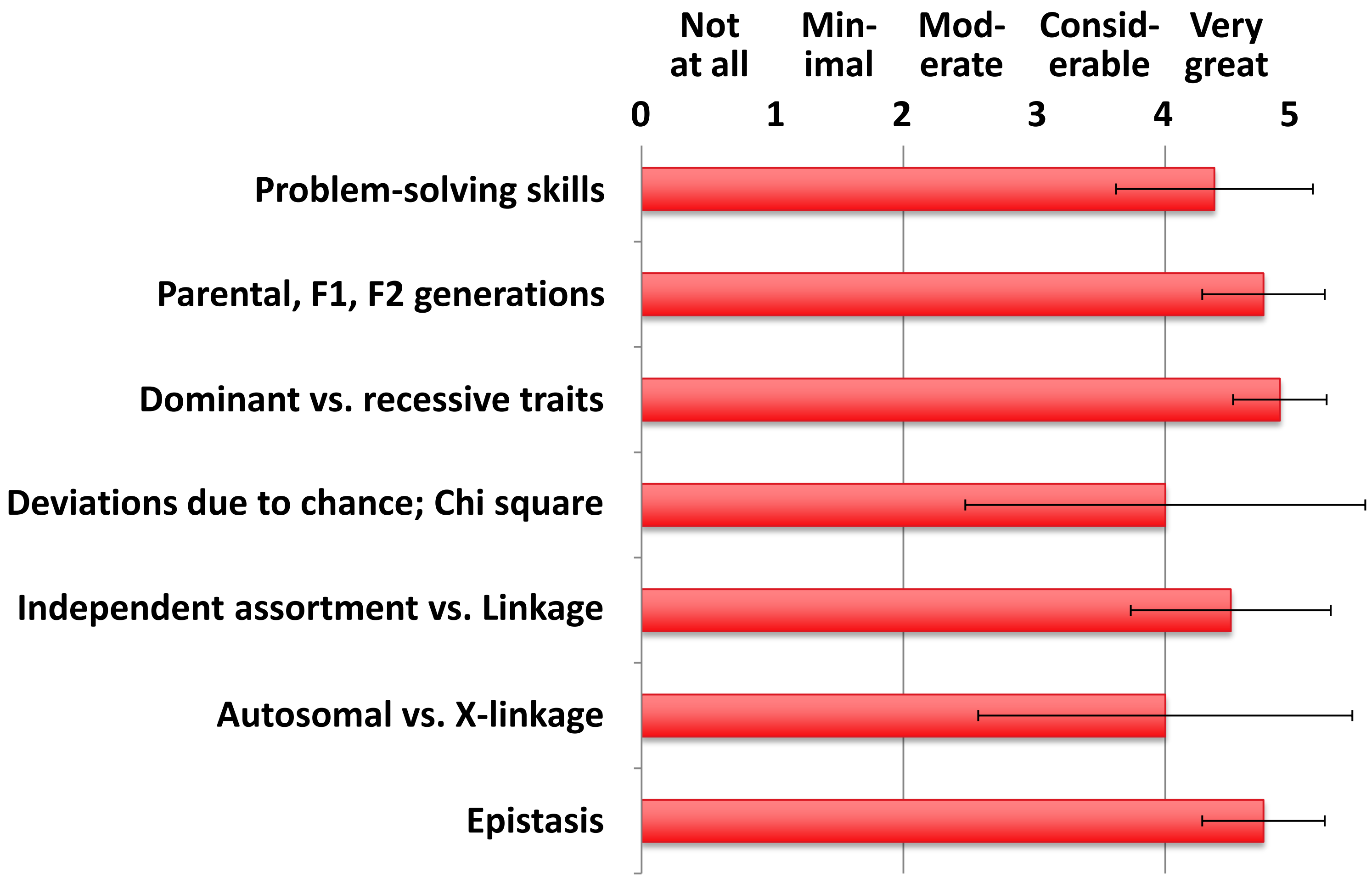
- Pilot study to evaluate learning outcomes –
  So much to learn about
  how to study learning outcomes!
- Outreach efforts
  Spreading the word and supporting others
- Further development
  Additional software, more curriculum

Pilot Study to Evaluate Learning Outcomes

How effective is StarGenetics in supporting student learning?

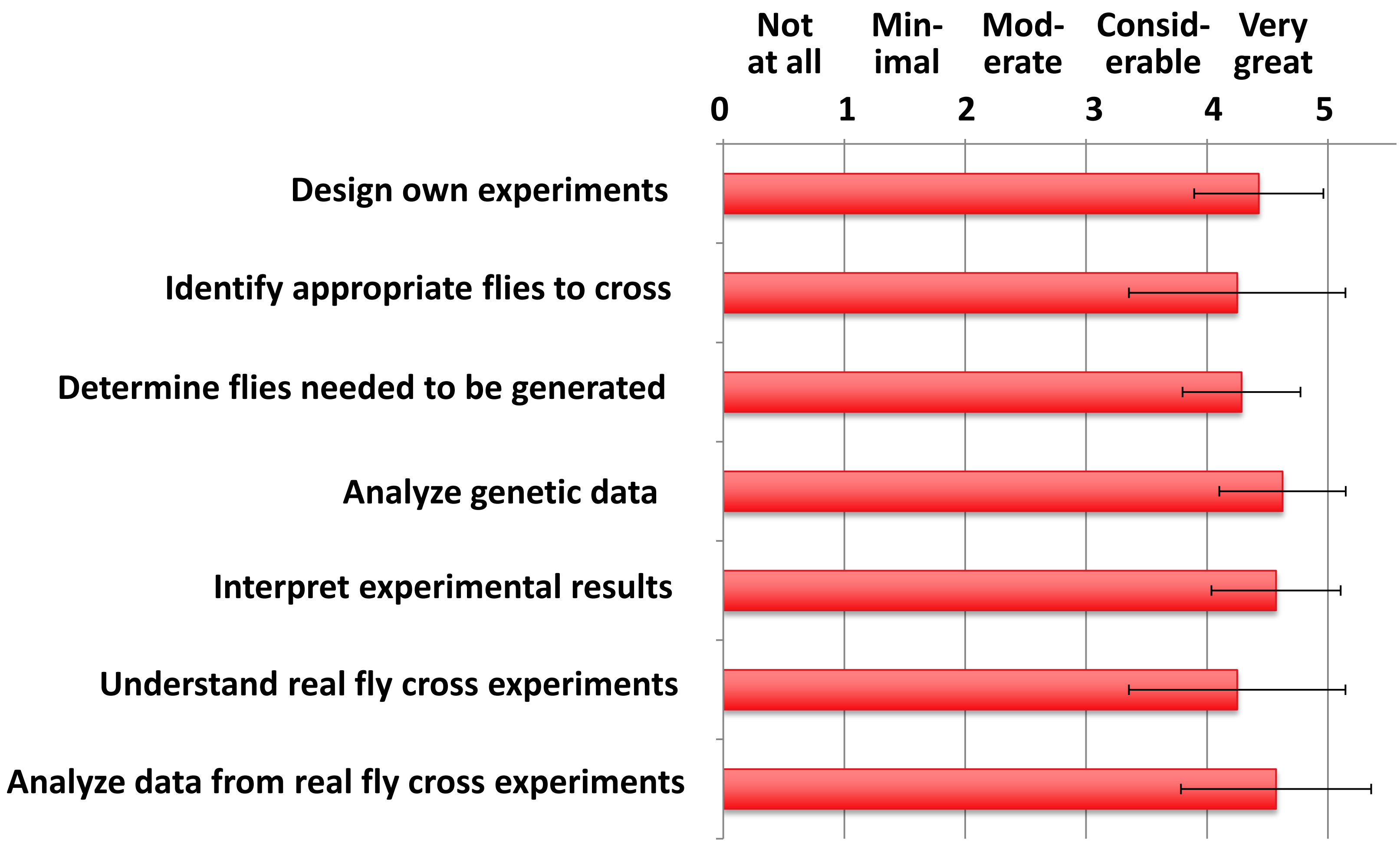
Student Survey Results… Learning specific Skills & Concepts



Pilot Study to Evaluate Learning Outcomes

How effective is StarGenetics in supporting student learning?

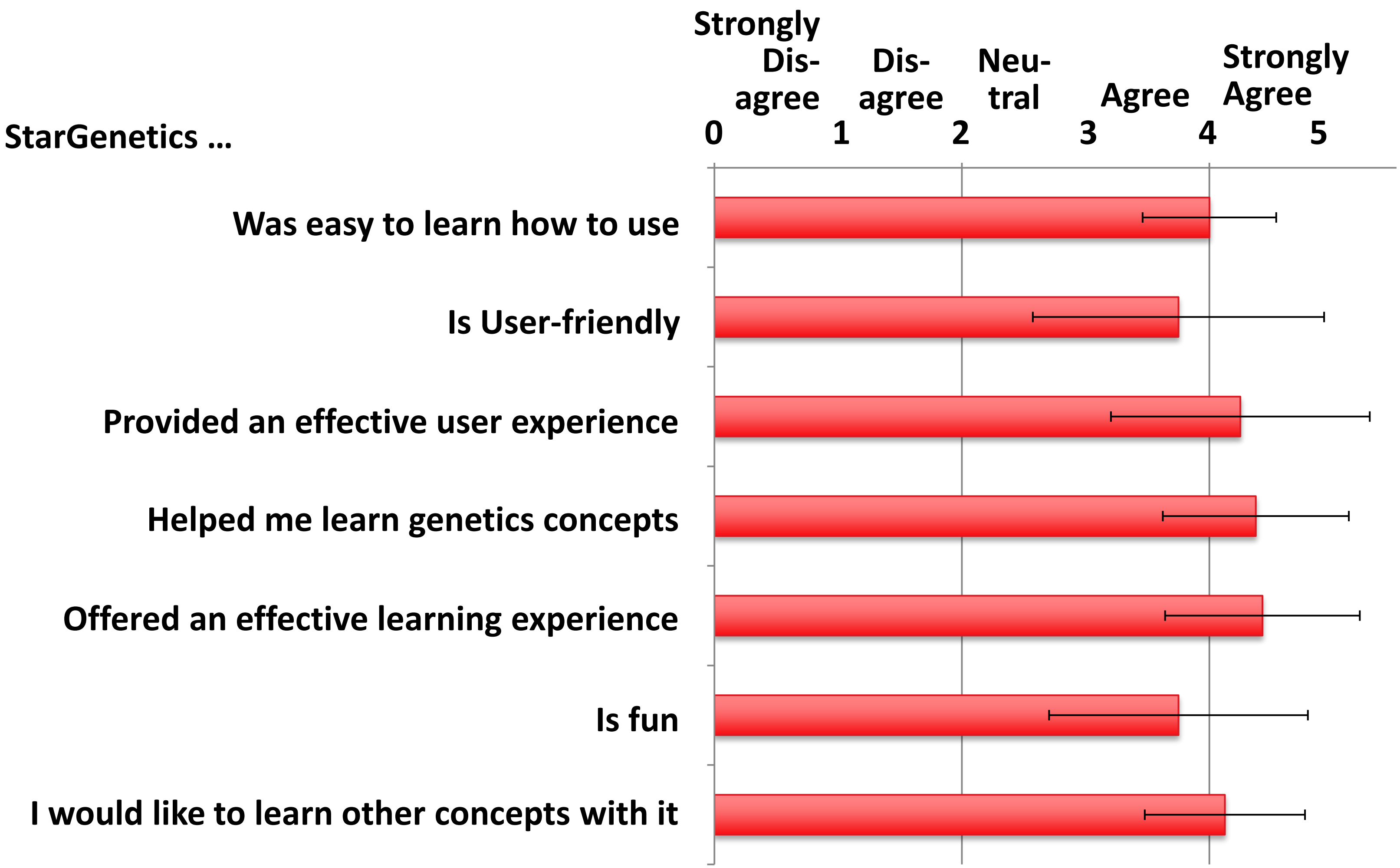
Student Survey Results… Learning how to Design Experiments

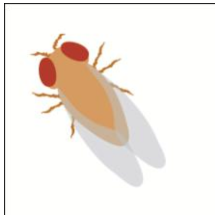


Pilot Study to Evaluate Learning Outcomes

How effective is StarGenetics in supporting student learning?

Student Survey Results… Providing a Positive Learning Experience





Caveat of surveys…

- Rely on Self-reporting by Students
- Students often want to please you…

We wanted to go further with evaluation…

Challenges of evaluating educational outcomes…

- Our first time doing THIS kind of research…
- Different methodologies and analyses
- Small sample size (n < 20)
- Ethical considerations…
  - human subjects
  - students ≠ guinea pigs
  - cases versus controls

Helpful resources available!

- Existing vetted assessment tools

  - Go to www.visionandchange.org to download AAAS/NSF report:

    VISION AND CHANGE IN UNDERGRADUATE BIOLOGY EDUCATION: A CALL TO ACTION (see page 25)

- MIT Teaching & Learning Lab

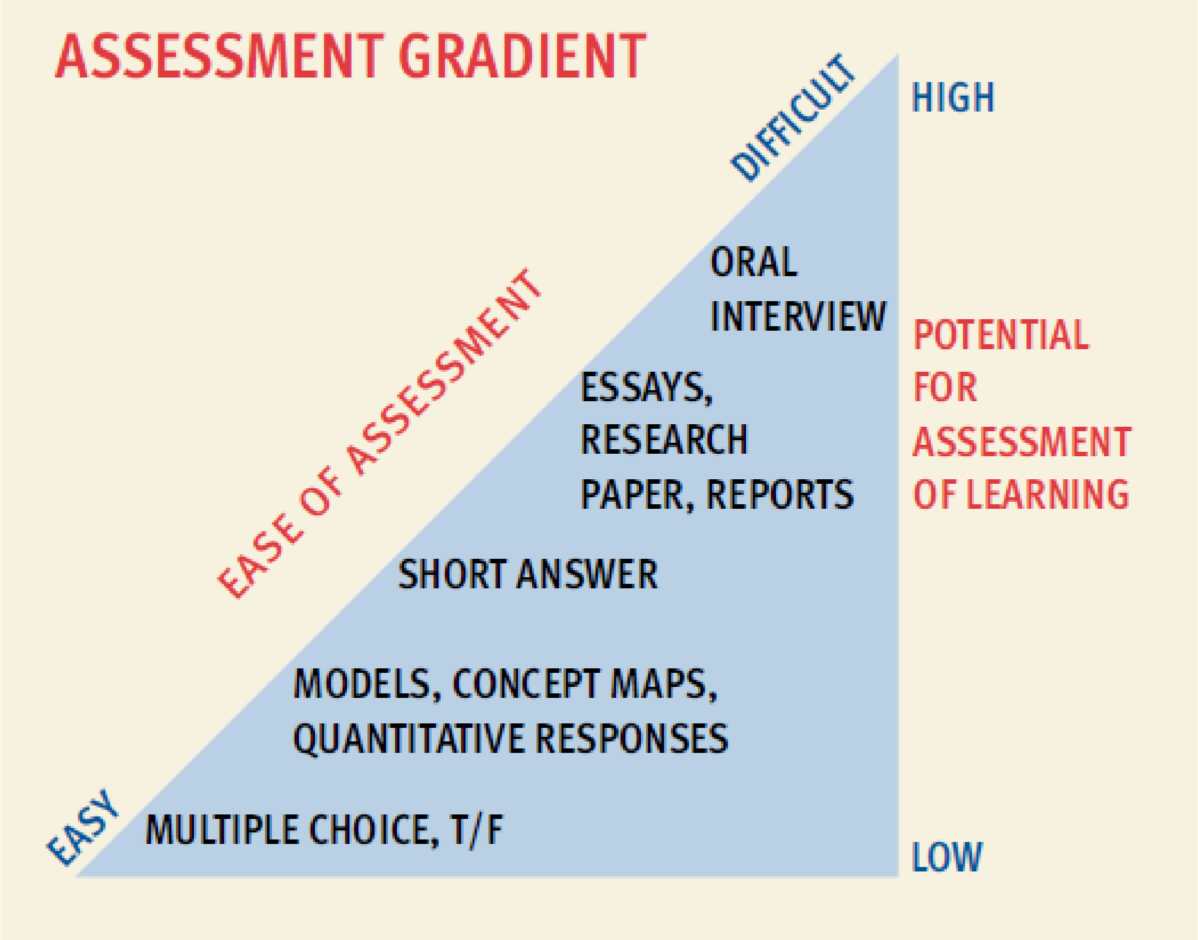
  - Dr. Lisa Shuler, Dr. Rudy Mitchell, Dr. Lori Breslow (Director)

- MIT COUHES & IRB

  - Ethics Training, Informed consent, Approval, etc.

Pilot Study to Evaluate Learning Outcomes

Choosing tools to use in our evaluation…



From Janet Batzli, Biology Core Curriculum, University of Wisconsin-Madison & Tammy Long, Plant Biology, Michigan State University

Pilot Study to Evaluate Learning Outcomes

Tools used for evaluation of StarGenetics in Pilot Study

- Surveys
- Pre/Mid/Post Concept Quiz
  - BCI Assessment test (M. Klymkowsky & K. Garvin-Doxas)
- Open-Ended Exam Questions
  - Assess ability to design experiments appropriate to answer a given question
- Rubric-based comparison of formal lab reports
  - Before & after StarGenetics implementation
  - Rubric available: http://web.mit.edu/tll/teaching-materials/rubrics/LabReportRubric-Fall09.pdf

Tools used for evaluation of StarGenetics in Pilot Study

BCI Assessment test (M. Klymkowsky & K. Garvin-Doxas)

- > 18,000 student responses to 69 open-ended, short essay questions
- Responses analyzed with Ed's Tools system (http://edstools.colorado.edu) to identify response categories & student language
- Researchers used responses to generate "think-aloud" interview protocols
- ~20 students were interviewed "in depth"
- Lead to construction of multiple-choice questions with distractors
- Follow-up interviews conducted for validation
- Piloted in a number of University biology classes across country

Tools used for evaluation of StarGenetics in Pilot Study

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- Pre/Mid/Post Concept Quiz
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Pilot Study to Evaluate Learning Outcomes

How effective is StarGenetics in supporting student learning?

A work in progress… (analogous to a lab meeting!)

- Now in process of analyzing collected data
- Plan to share results here and in publication
- Much learned from experience with pilot study
- Better prepared for larger study
  - MIT faculty open to evaluations in their courses

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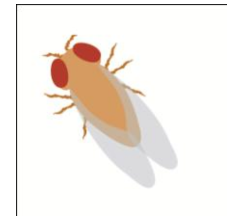
Outreach: A critical component of Education Innovation



- Without active outreach, many education initiatives die at the site of local innovation.

Fairweather, J. (2008). **Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Education: A Status Report.**

Commissioned paper presented at NRC workshop on Evidence on Selected Promising Practices in Undergraduate Science, Technology, Engineering, and Mathematics (STEM) Education

(Washington, D.C., The National Academies National Research Council Board of Science Education).

Example Users:

- **Undergraduate college students**

  Introductory Biology (MIT, Tufts, Howard University)

  Introductory Genetics (MIT, Suffolk University)

  University Outreach Programs (MIT Quantitative Biology WS, MIT Summer Bridge Program)

- **High school students**

  Medford HS & Monument HS (Boston Public Schools)

  Teacher training programs (Boston Public Schools)

  High School Outreach Programs (Broad Institute)

  High School Fieldtrips (MIT Biology Department)

Outreach Efforts

Workshops & Demos for faculty, instructors, & TAs:

E.g., Howard University, University of Colorado, Roxbury Community College, Florida International University, MIT QBW2011, Brazilian Santander Universities and CERTI, MIT-Haiti Initiative, JFY Networks, Whitehead Teacher Partners

Support for remote users: star@mit.edu

E.g., University of Chicago, Colchester High School (VT), New College of Florida, Pacific Lutheran University (WA)

Focus groups:

E.g., High School Teachers (Whitehead Teacher Partners)

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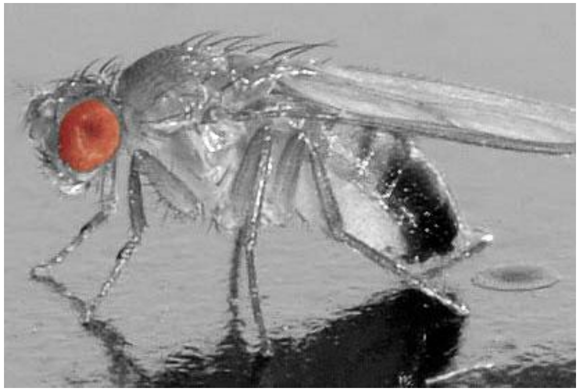
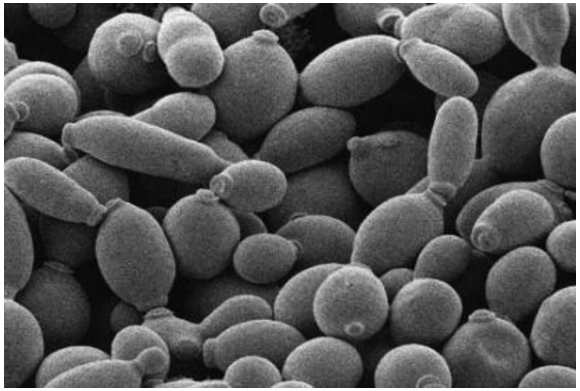
StarGenetics visualizers

Currently Available:

Flies



Yeast

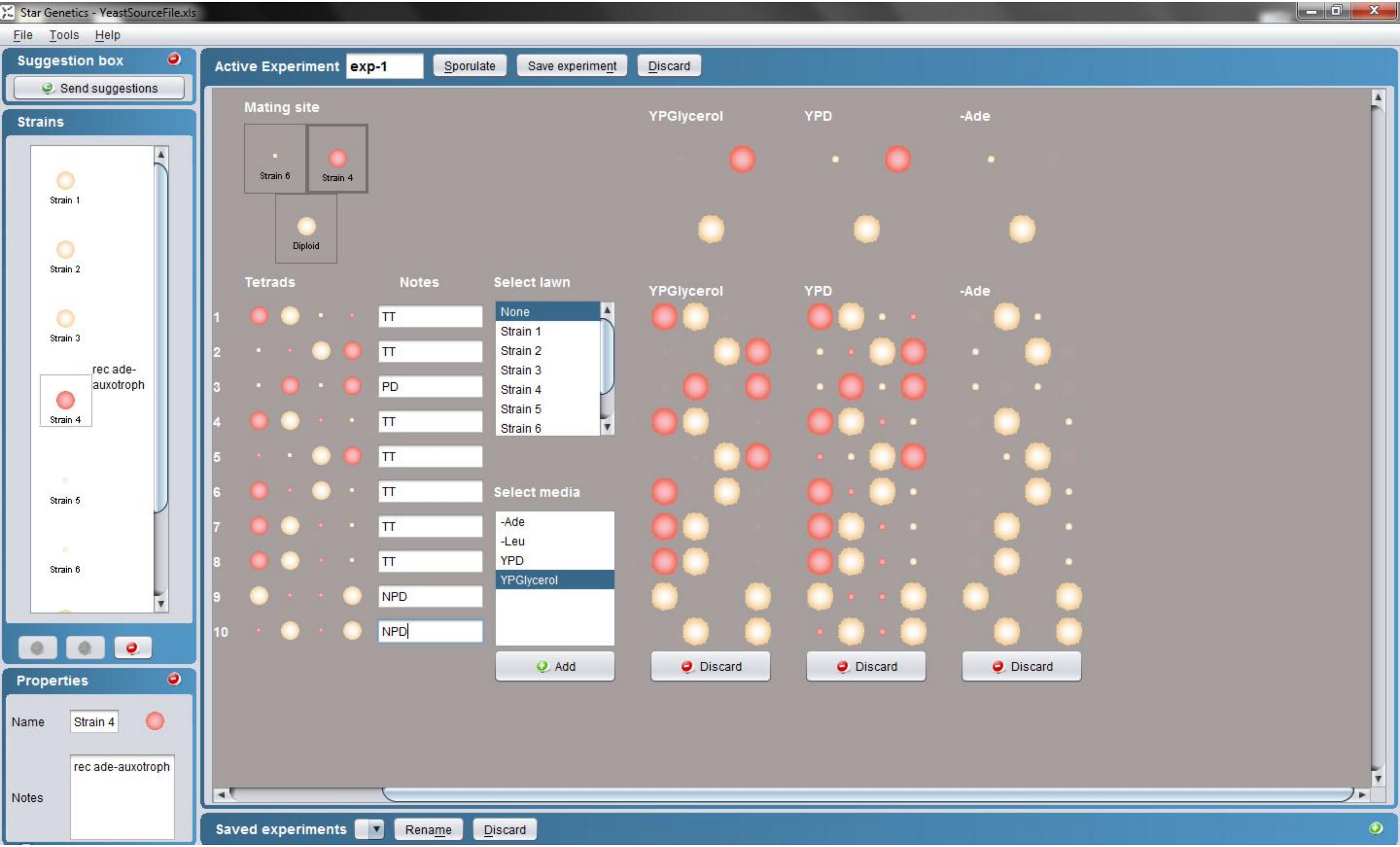


plus:

Smileys
&
Lego fish

In progress:

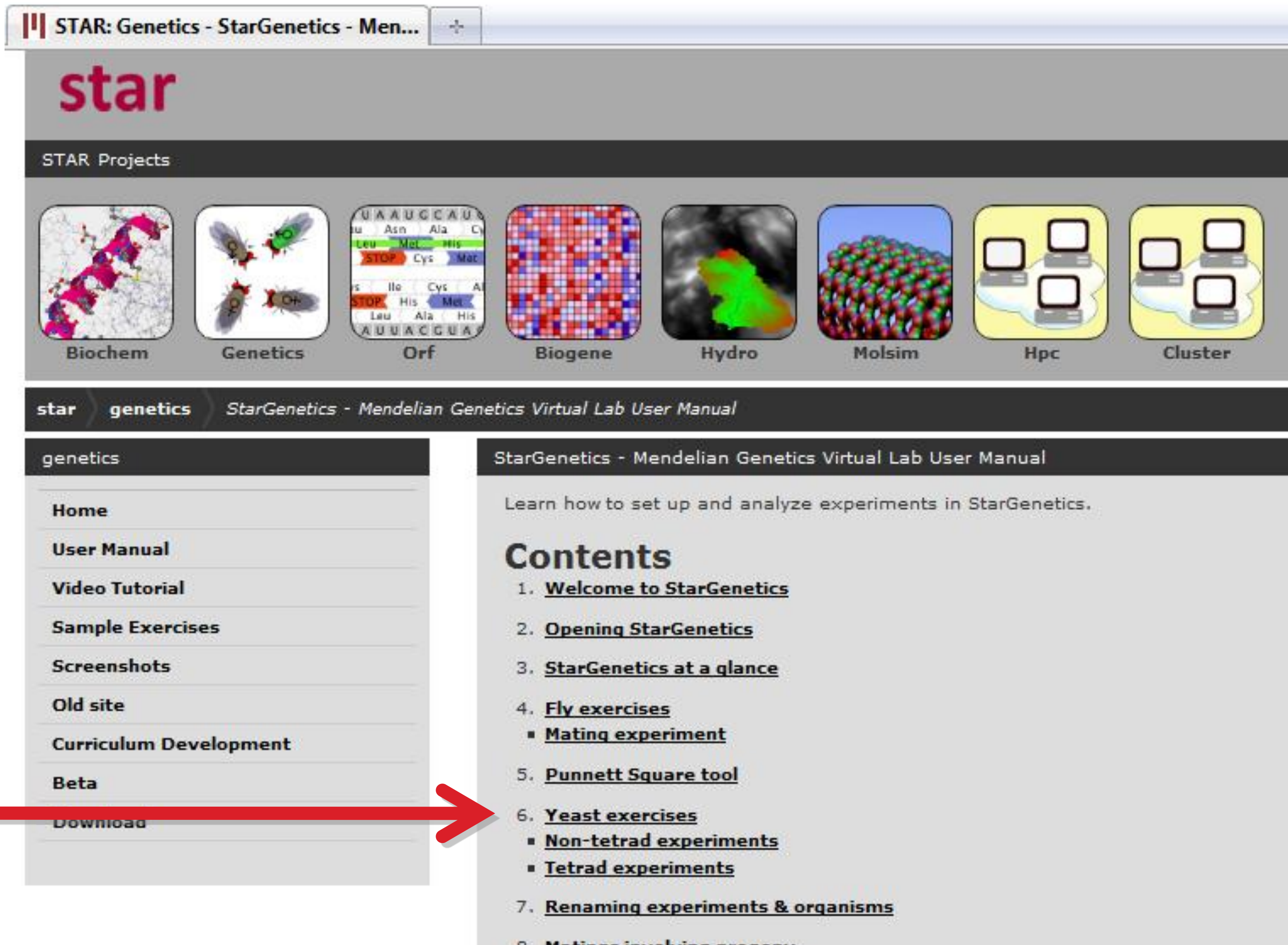
StarGenetics genetic cross simulator: Yeast



See Movie6: StarGenetics Yeast Tour

Further development

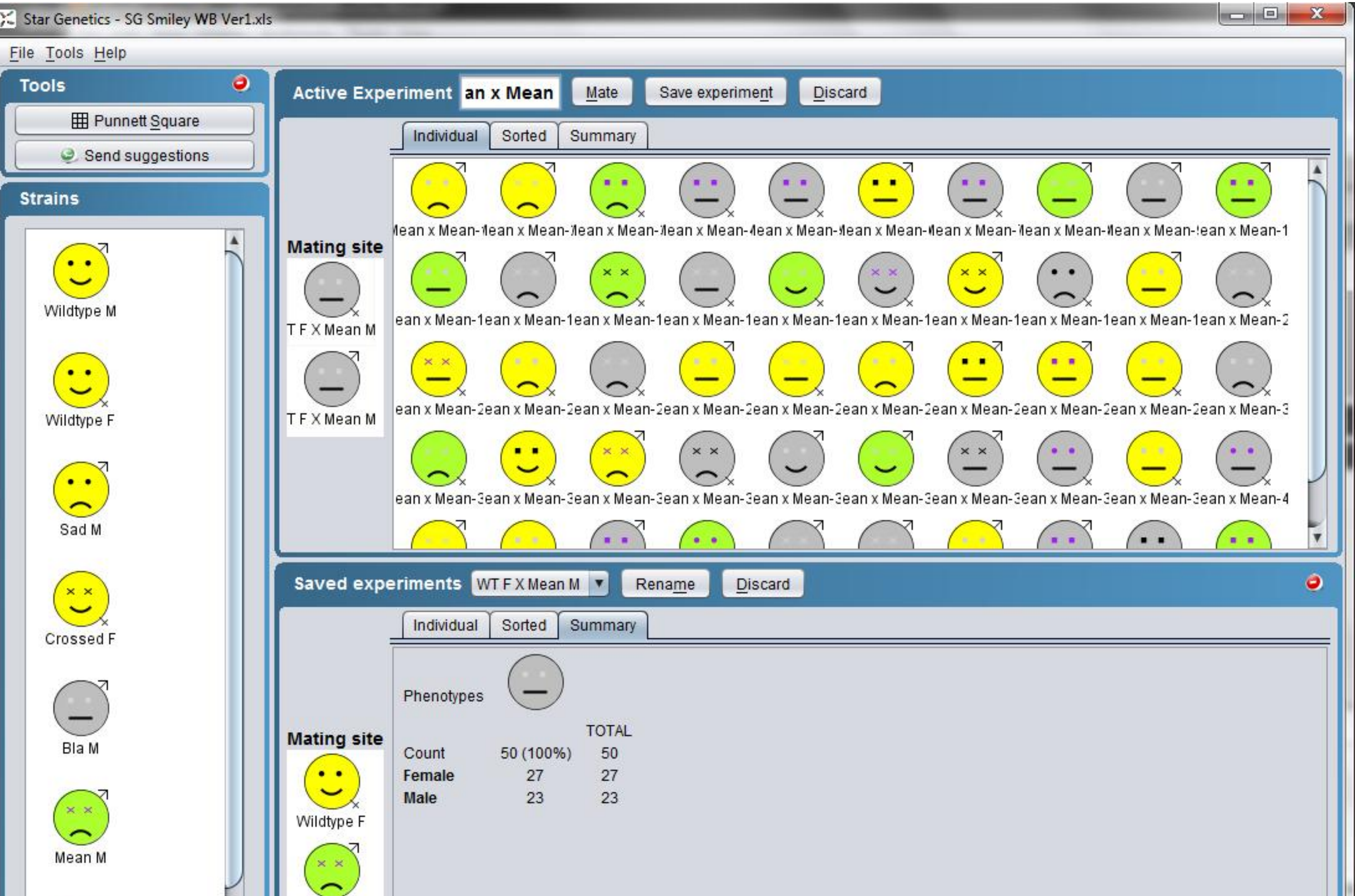
http://web.mit.edu/star/genetics/documentation/index.html



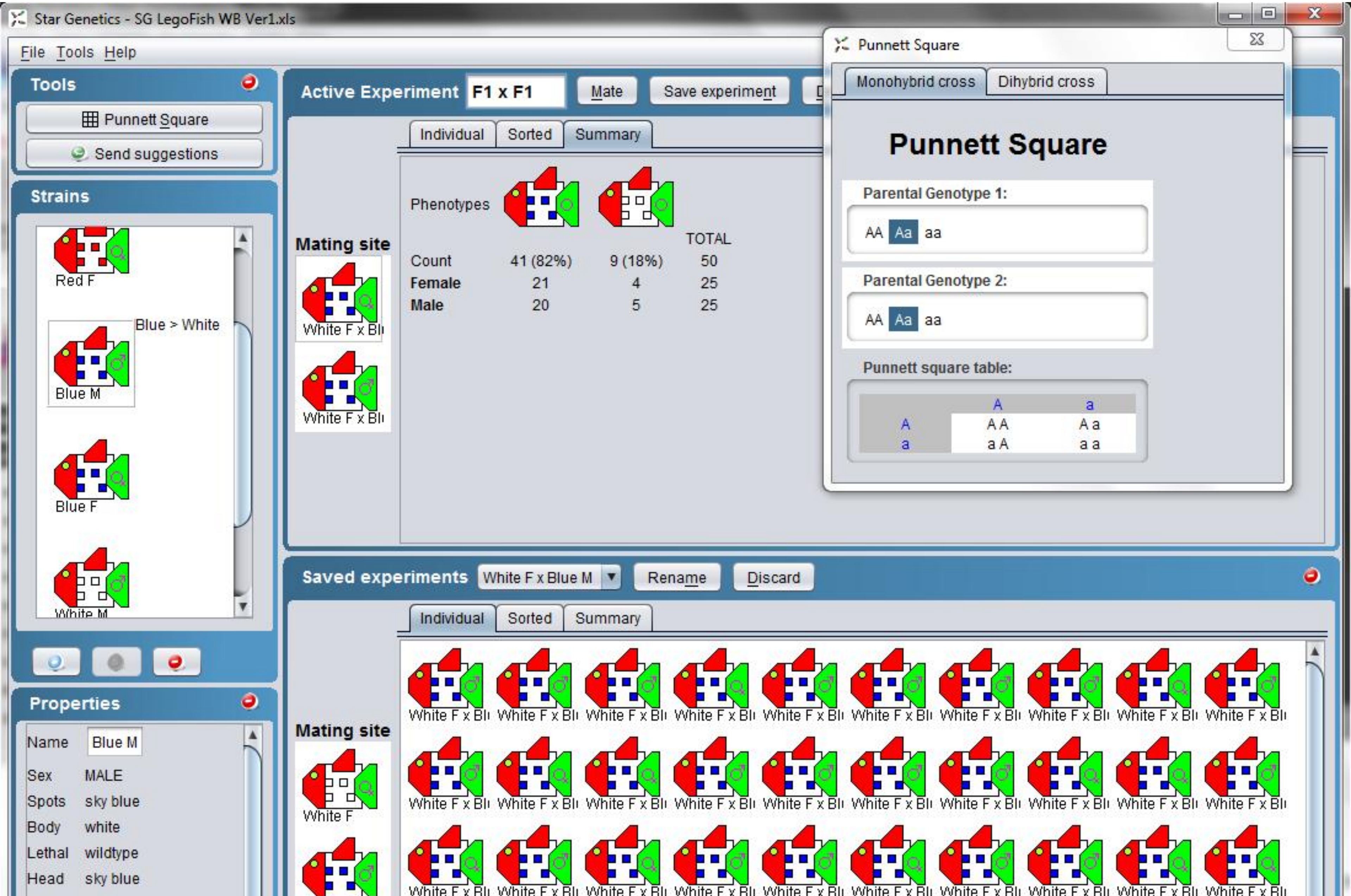
User Manual:

Learn more about StarGenetics Yeast!

StarGenetics genetic cross simulator: Smileys



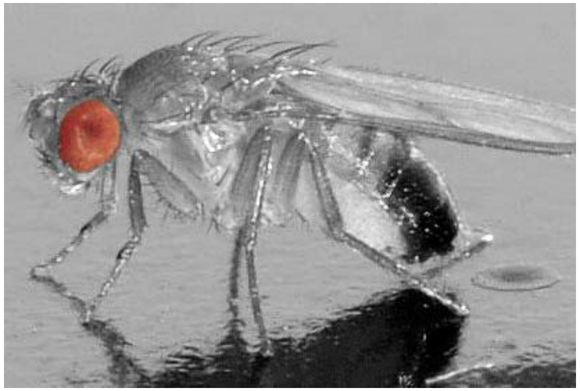
StarGenetics genetic cross simulator: Lego Fish



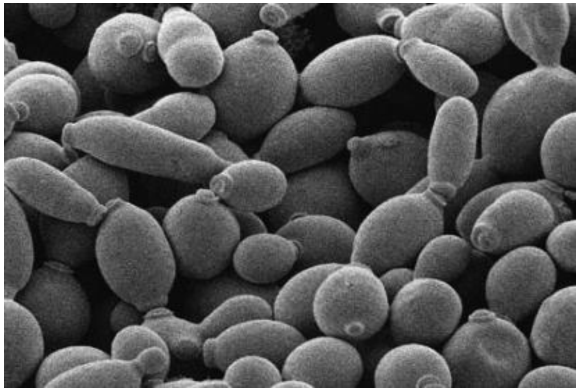
StarGenetics visualizers

Currently Available:

Flies



Yeast



plus:
Smileys
&
Lego fish

In progress:

StarGenetics visualizers

Currently Available:

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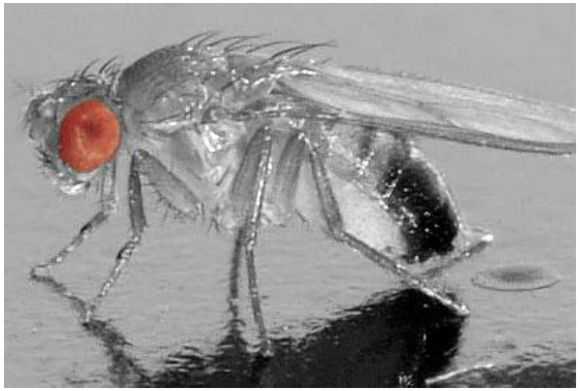

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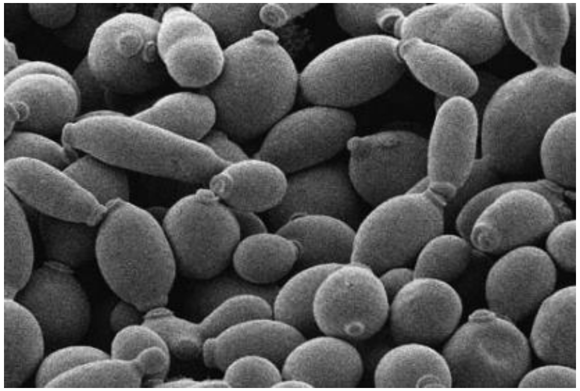


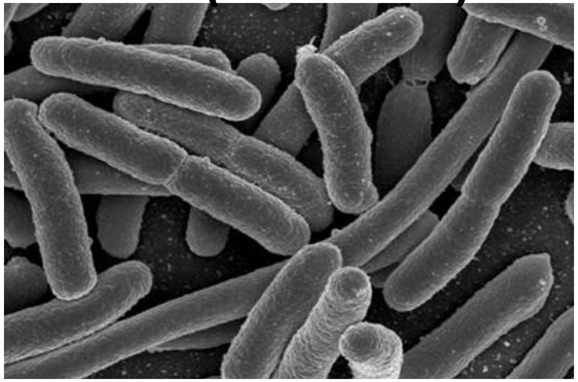
plus:

Smileys
&
Lego fish

In progress:

Mendel's Peas (Summer 2011)

Bacteria (2011-2012)



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