

Hot Science Cool Talks

UT Environmental Science Institute

58

From Silent Spring to Silent Night

**Dr. Tyrone Hayes
January 30, 2009**

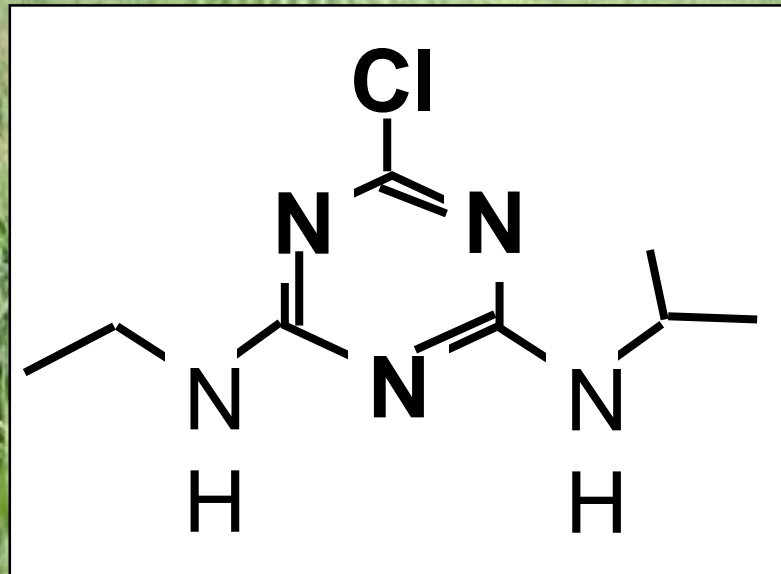
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From Silent Spring to **Silent Night**

Dr. Tyrone Hayes
University of California at Berkeley
January 30th, 2009



ATRAZINE



ATRAZINE

**IS AN HERBICIDE
USED WITH
MONOCOT CROPS
(CORN, SORGHUM)
AND STONE FRUITS**

ATRAZINE

A wide-angle photograph of a vast agricultural field, likely corn, stretching to the horizon. The plants are in various stages of growth, with some appearing as dense green rows in the foreground and others as a lighter green expanse in the distance. The sky is a pale, clear blue, and the overall scene is bright and open.

**HAS BEEN USED
FOR 48 YEARS**

ATRAZINE

A wide-angle photograph of a cornfield. The rows of green corn plants are very straight and extend far into the distance, creating a strong sense of perspective. The sky is a pale, clear blue, and the overall scene is bright and open.

**80 MILLION POUNDS
USED ANNUALLY
IN THE U.S.**

ATRAZINE

A wide-angle photograph of a vast agricultural field, likely corn, stretching to the horizon. The plants are in various stages of growth, with some appearing taller and greener in the foreground, and others shorter and more yellowish-green further back. The sky is a pale, clear blue, and the overall scene is bright and open.

**IS USED IN
MORE THAN
80 COUNTRIES**

ATRAZINE

A wide-angle photograph of a lush green cornfield. The rows of corn plants are perfectly straight and recede into the distance, creating a strong sense of perspective. The sky is a pale, clear blue, and the overall scene is bright and open.

**BUT NOW OUTLAWED
IN ALL OF EUROPE**



**SOUTHERN
SAG**

ATRAZINE

St. Augustine Weed Killer

Active Ingredients:
Atrazine (3-chloro-4-cyanopyridin-2-amine) 4.00%
Inert Ingredients 96.00%

**KEEP OUT OF REACH
OF CHILDREN
CAUTION**

SHAKE WELL BEFORE USING

See Section of Label for First Aid,
Precautionary Statements, and Directions
for Use

Read and understand the
entire directions on this label to users.



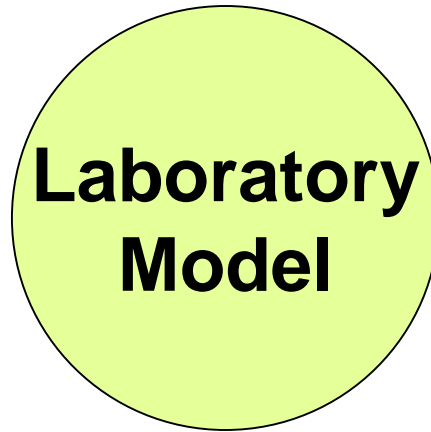
FOR THE CONTROL OF BOTH
EMERGED WEEDS AND
WEEDS FROM SEEDS
OF ST. AUGUSTINE GRASS AND
CENTROPHEGUS AND
1.1 INCHES DEEP IN THE
SOIL FOR 60 DAYS POST

ONE GALLON
COVERS
14,874 sq. ft.

Southern Agricultural Insecticides, Inc.

Net Contents: 1 Gallon (3.785 liters)

1



Testes



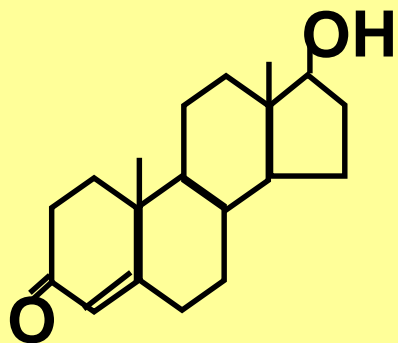
Ovaries

Uterus

Vagina



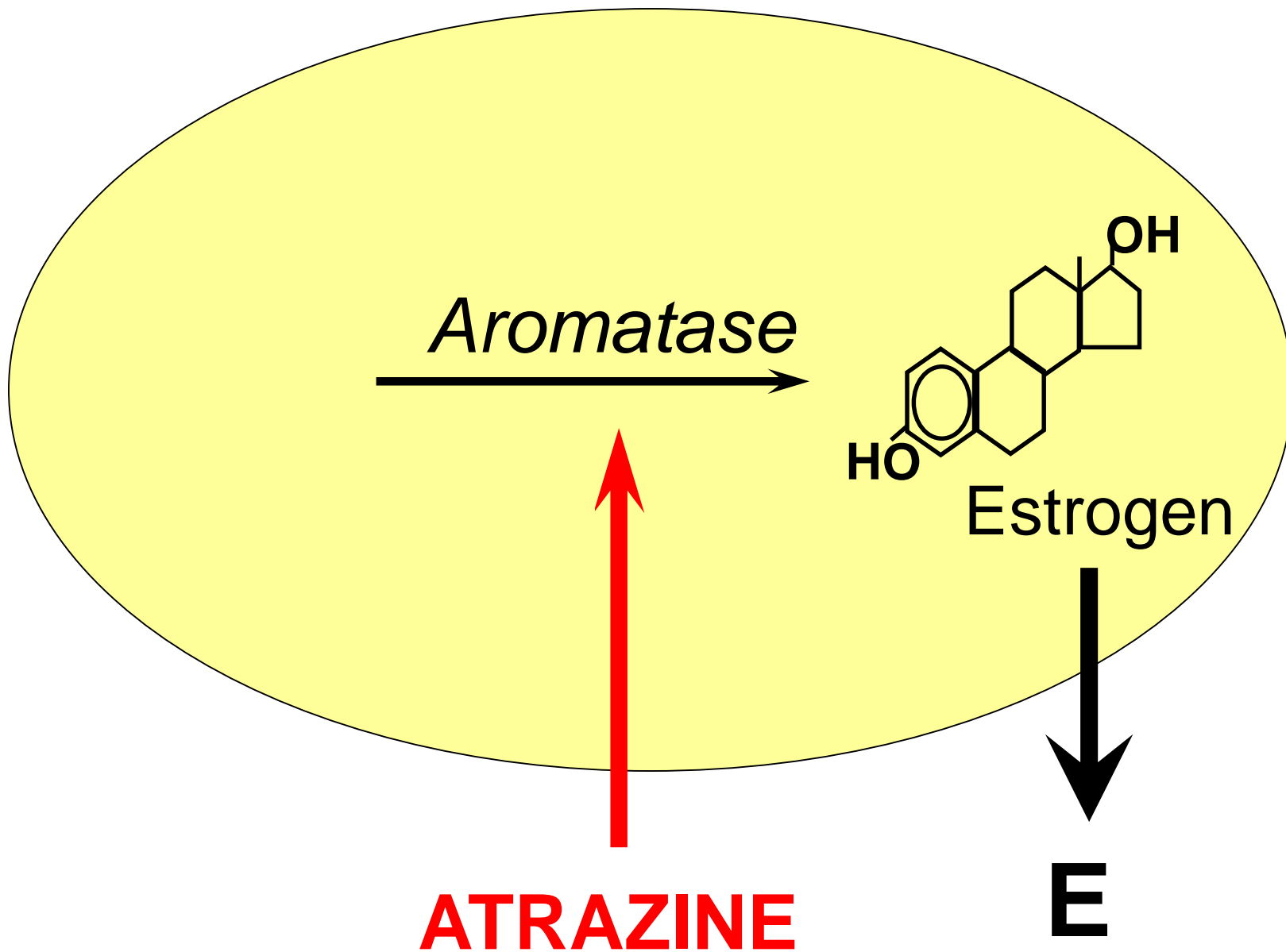
NOT NORMAL

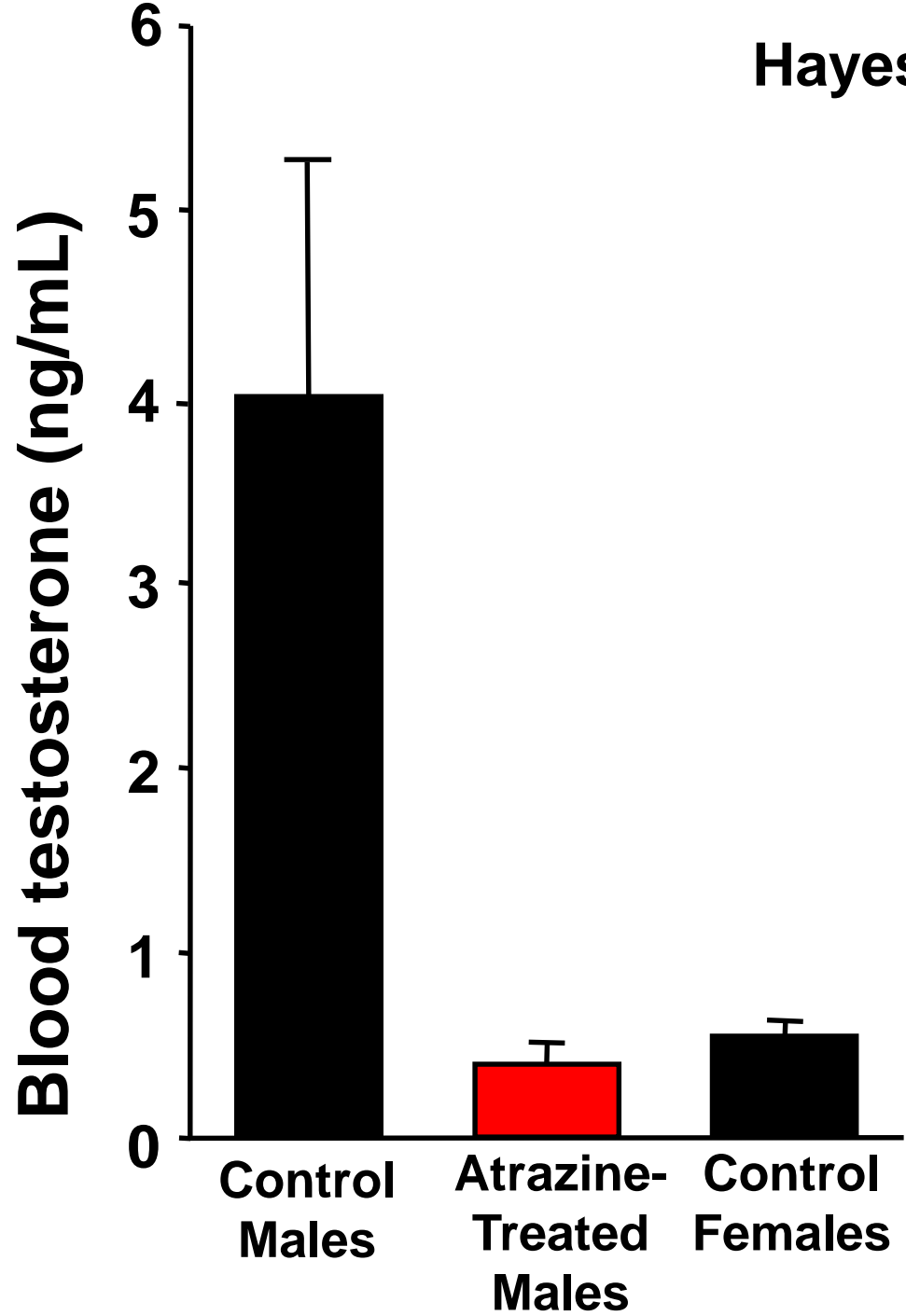


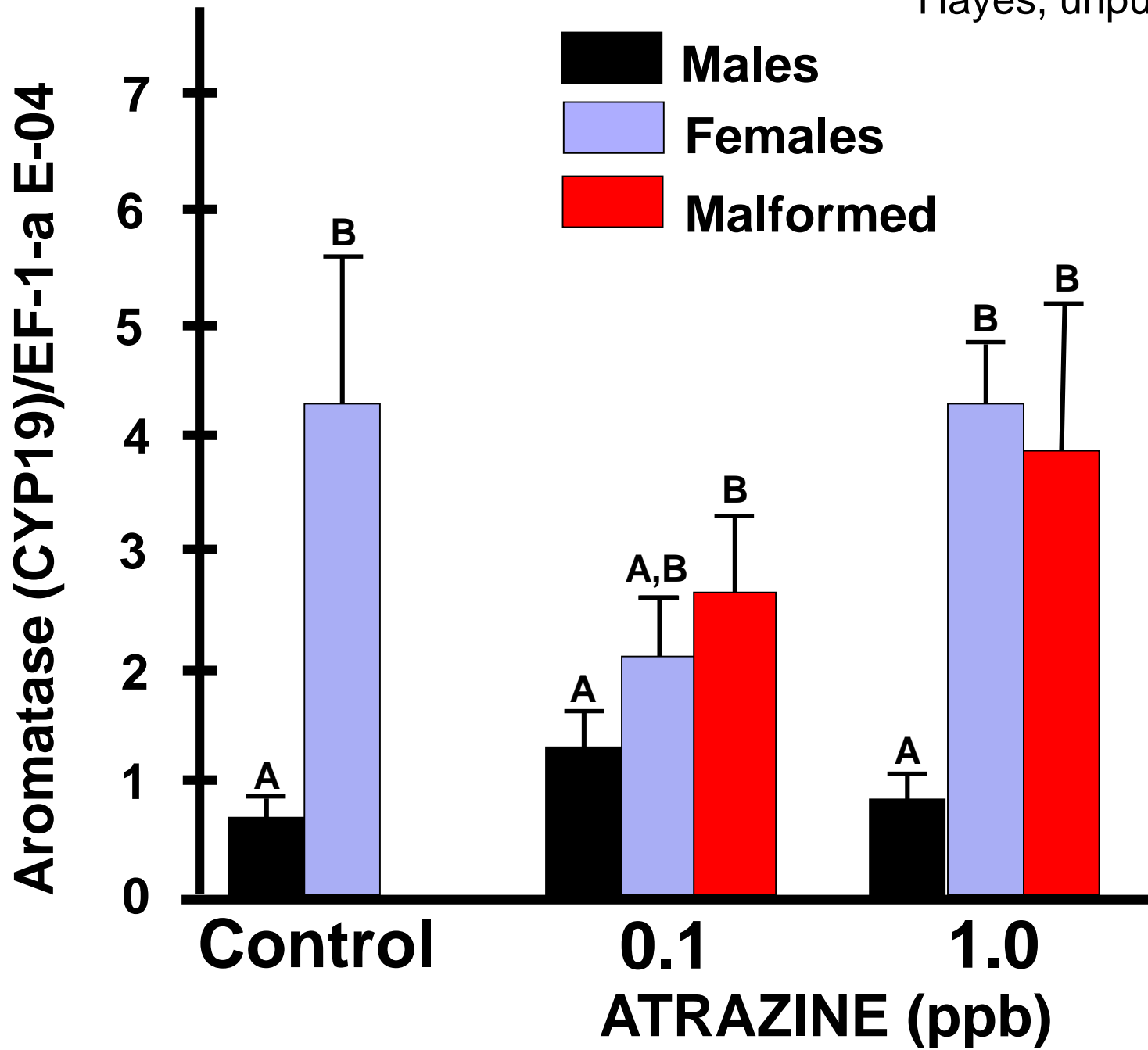
Testosterone



T





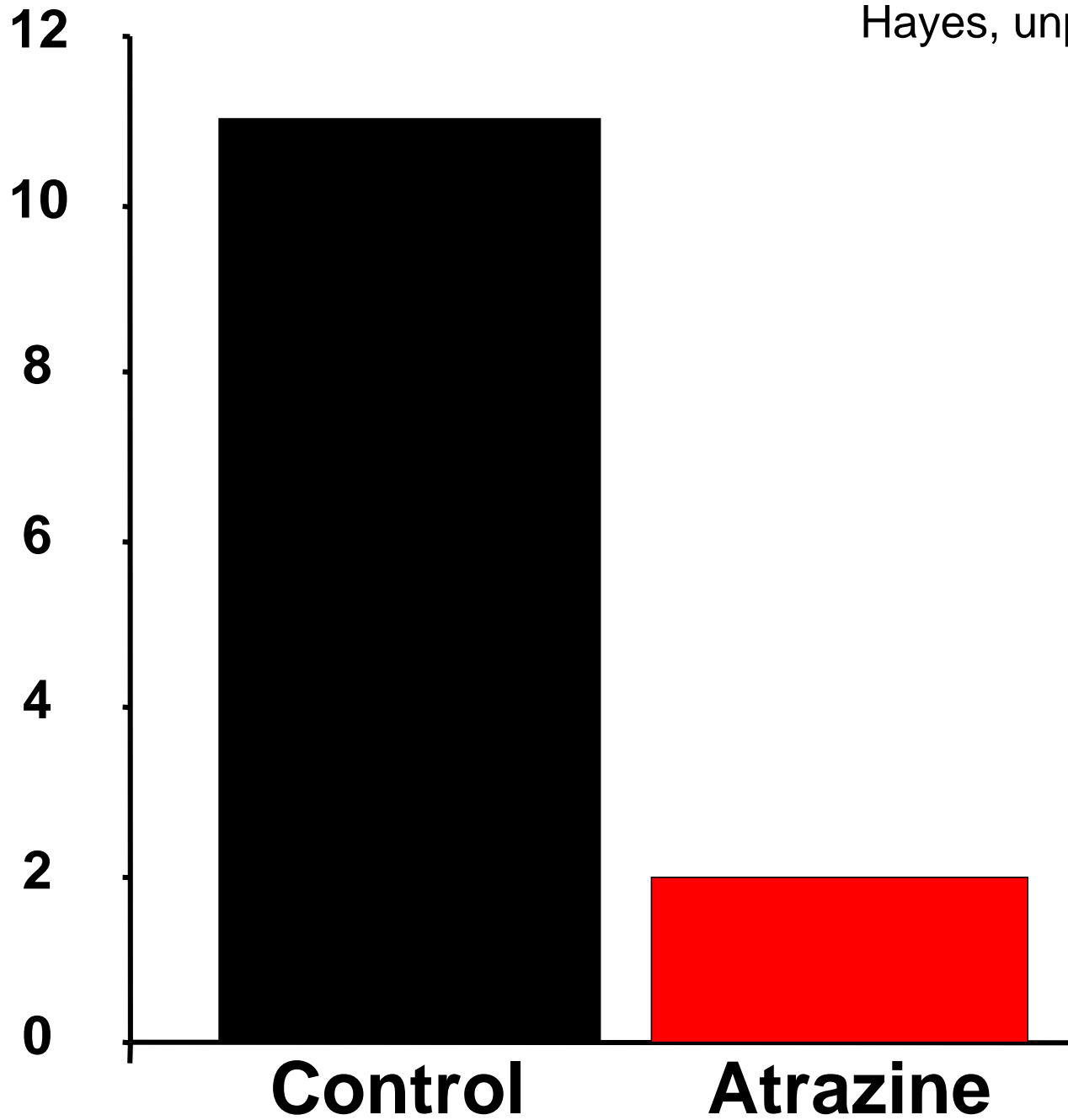


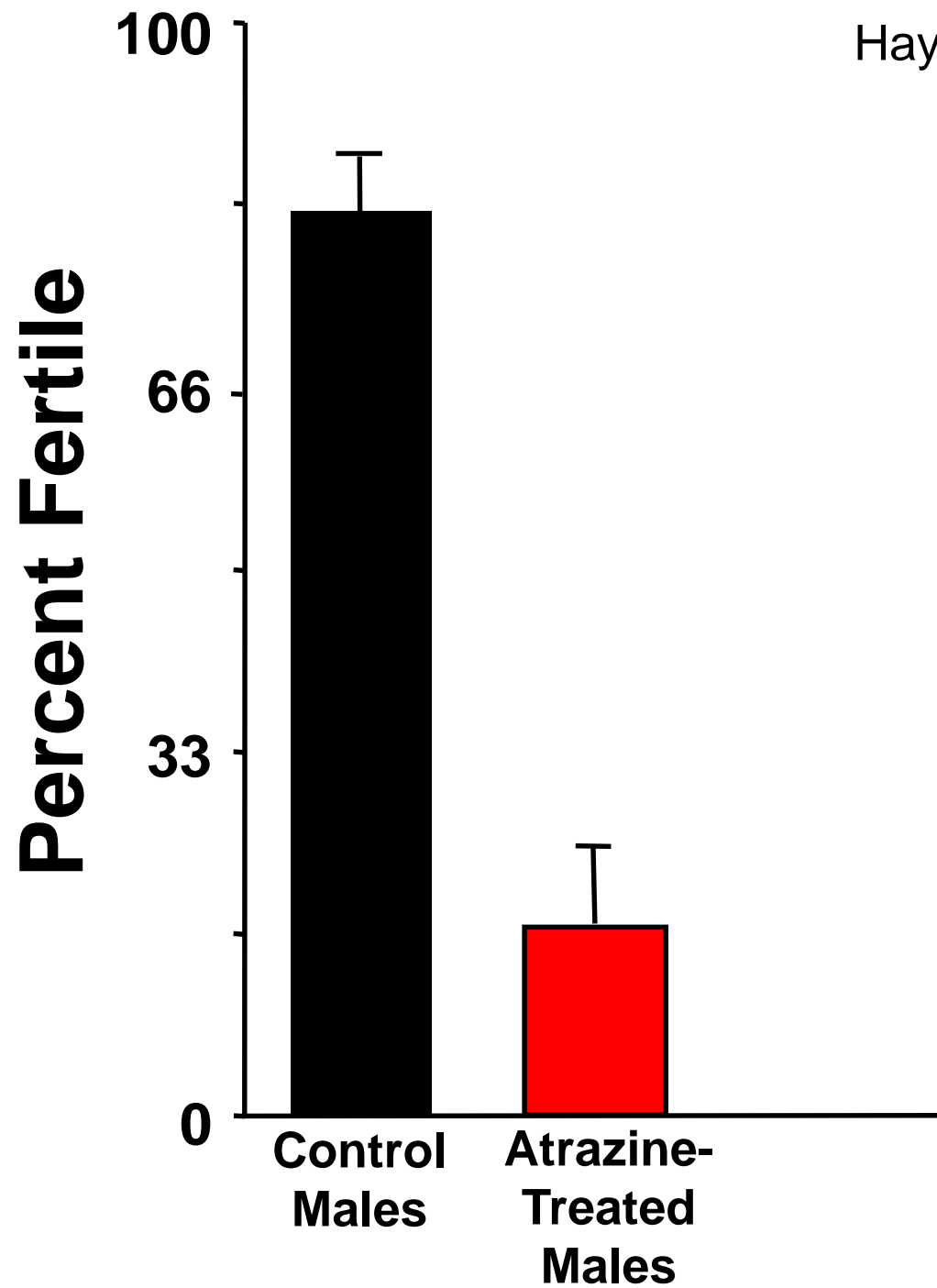




Hayes, unpubl. data

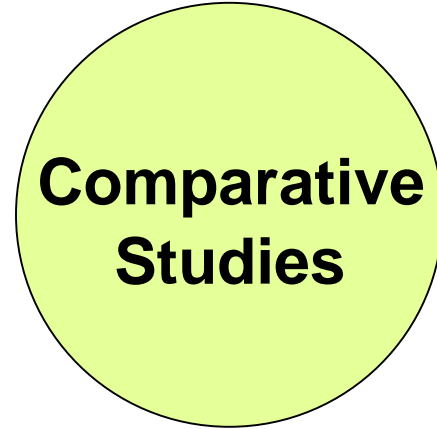
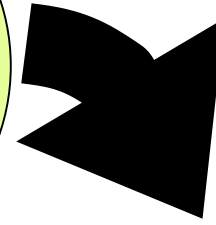
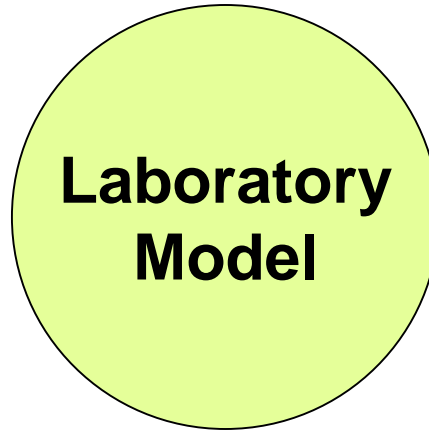
Successful Pairings







1

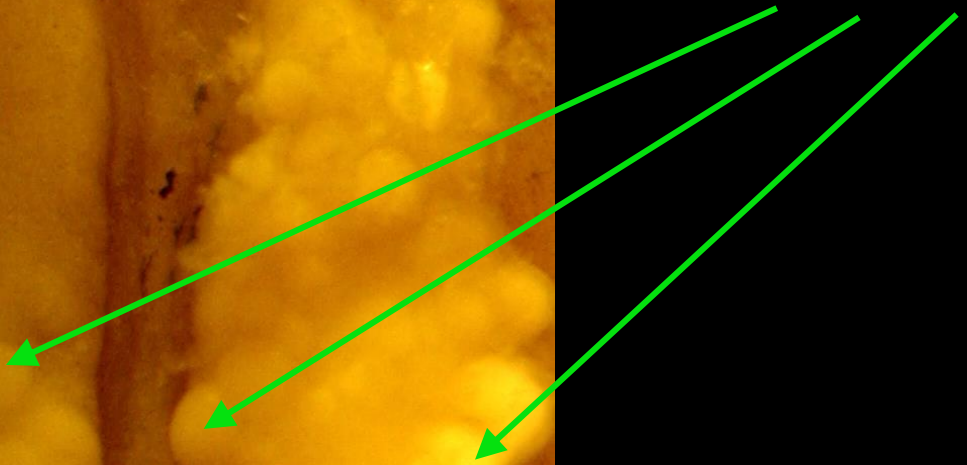


2

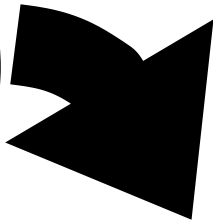
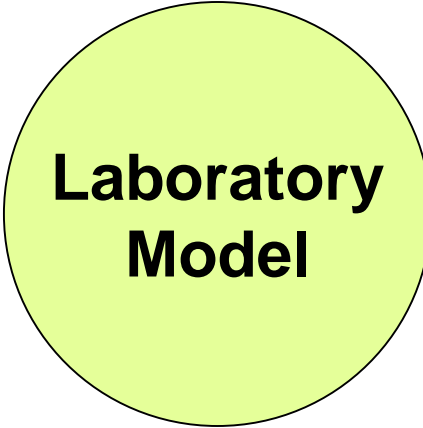
**Leopard
Frog
Testes**



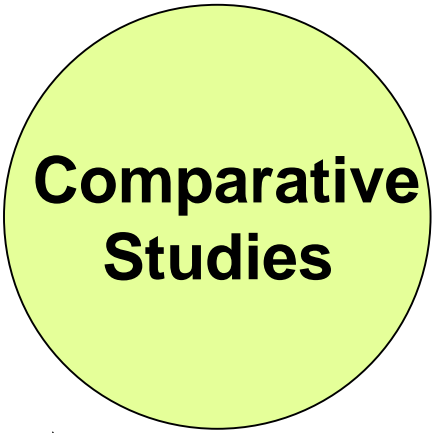
eggs



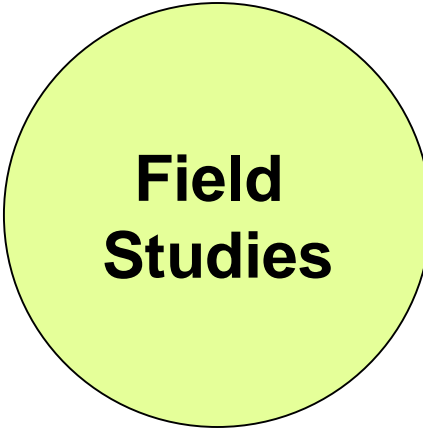
1



2

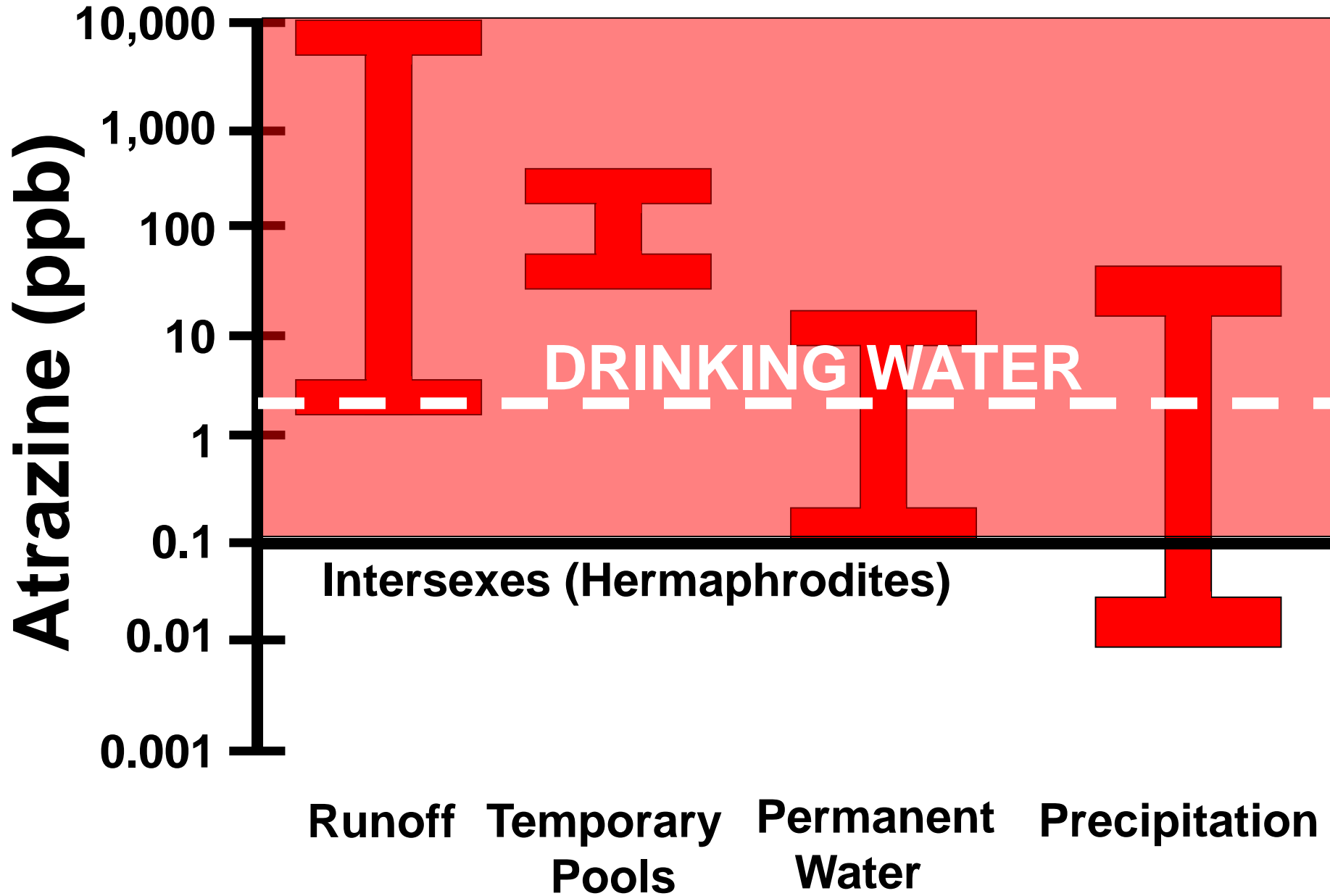


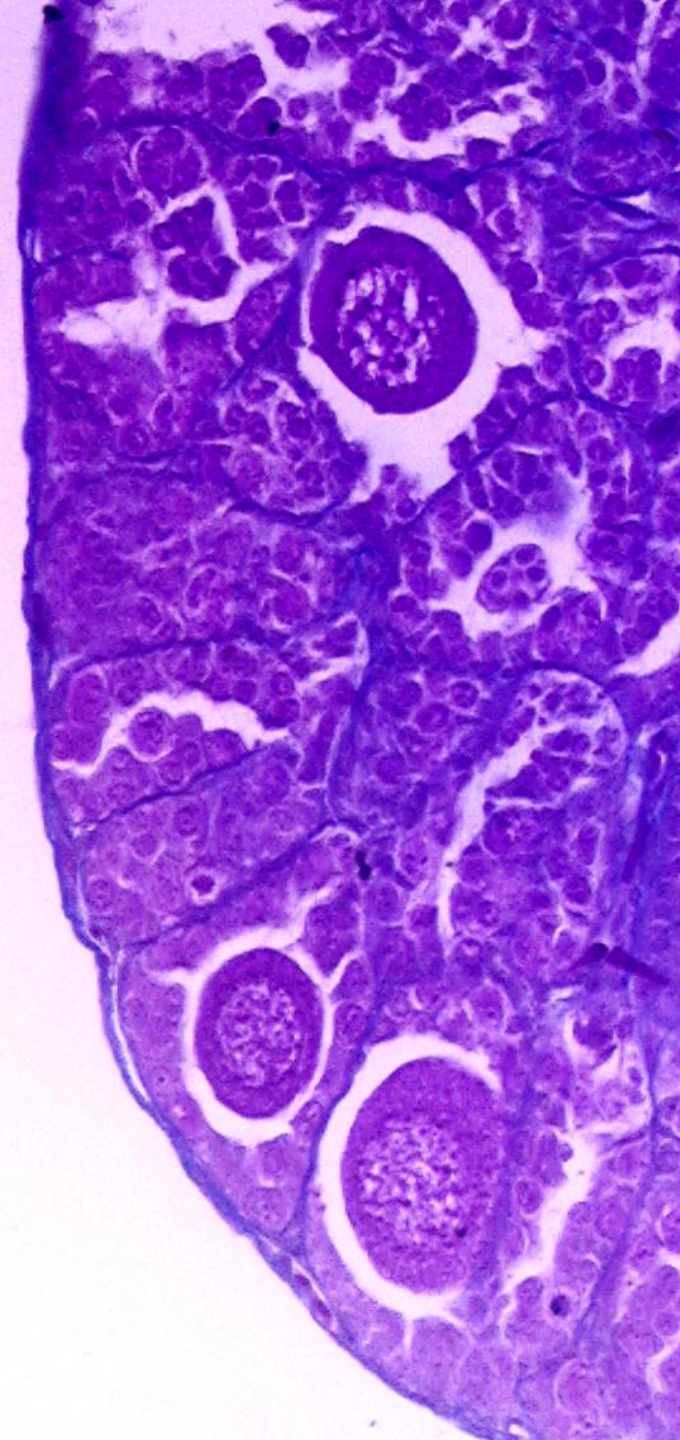
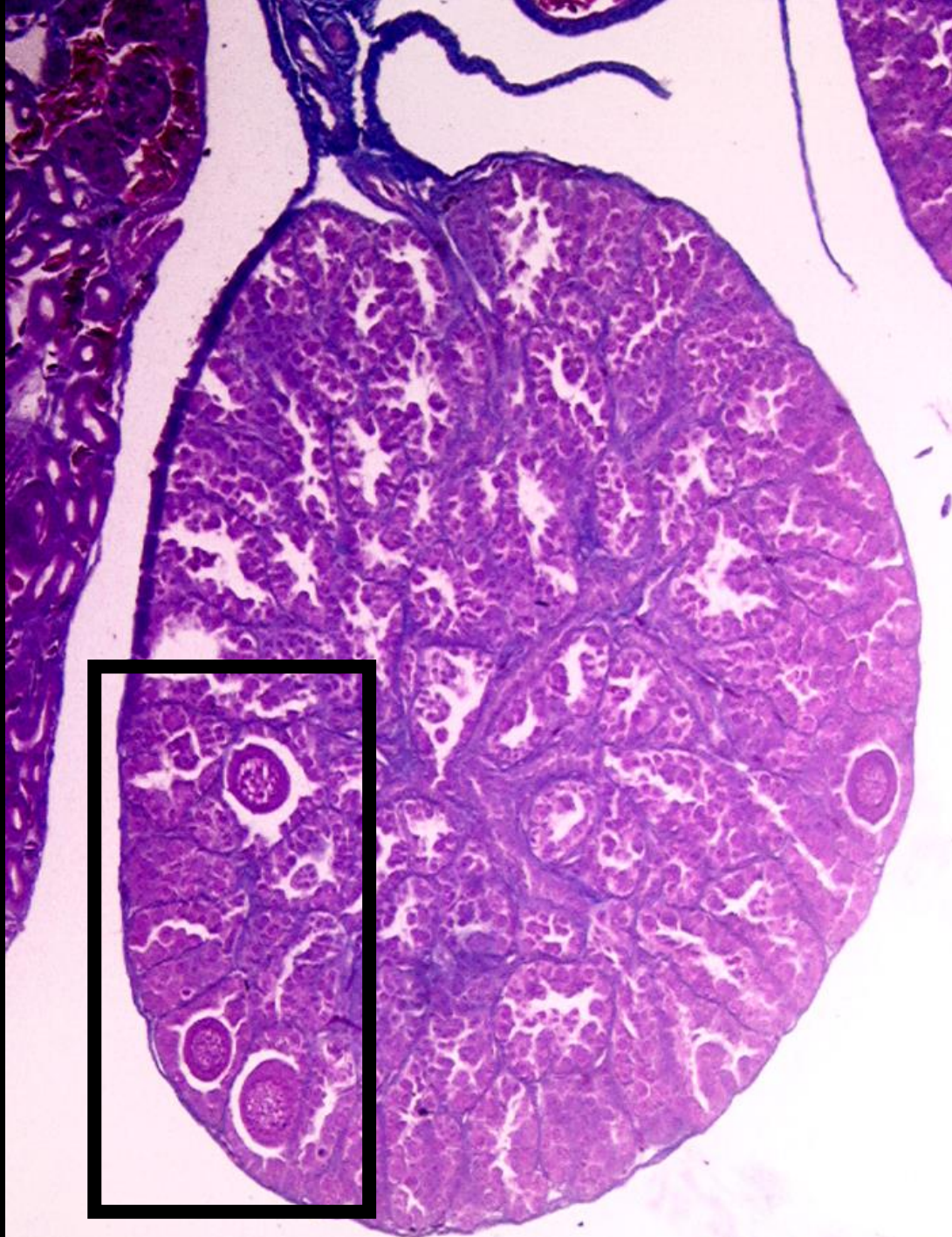
3

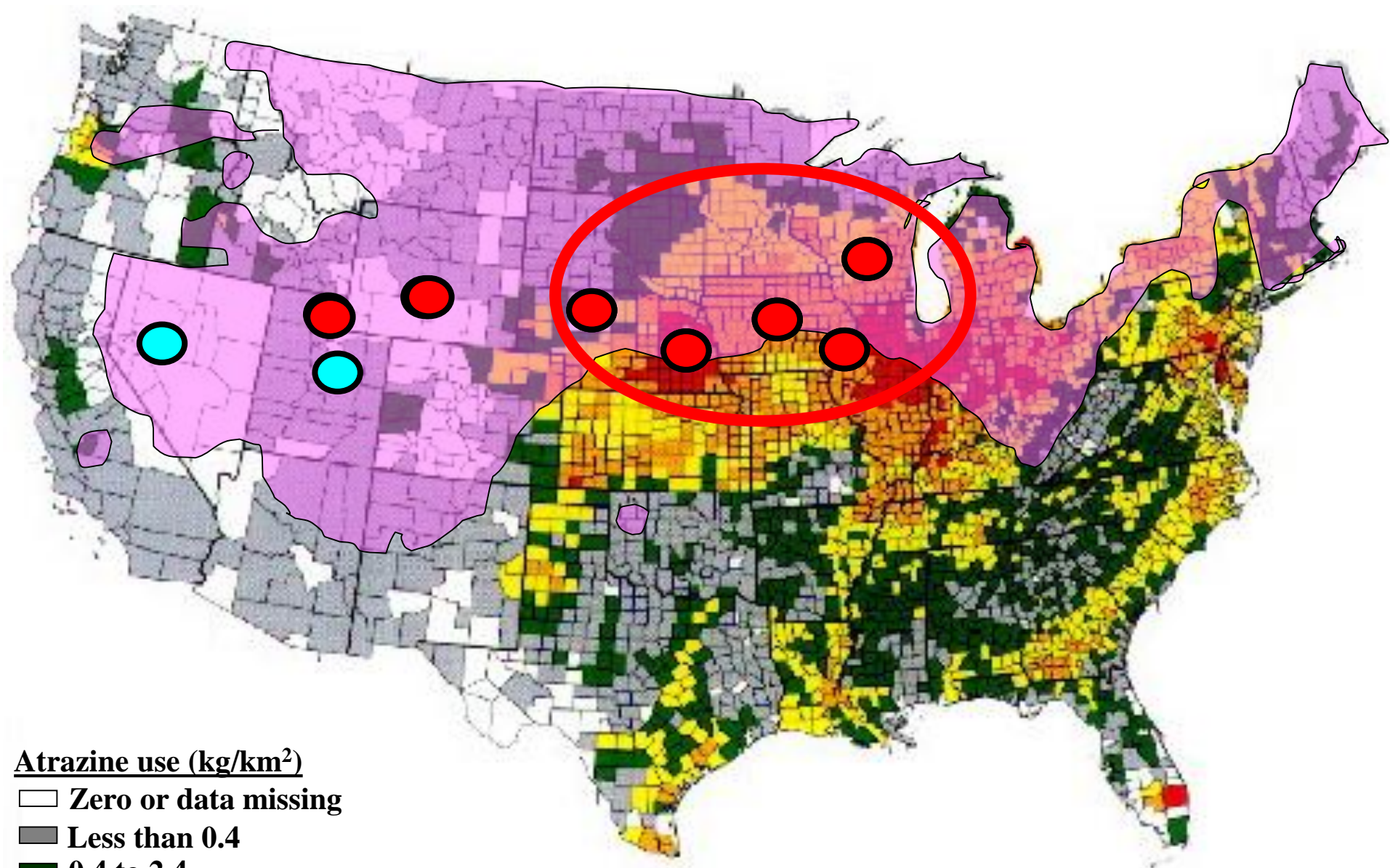


**ARE THE EFFECTIVE DOSES (≥ 0.1 PPB)
ECOLOGICALLY RELEVANT?**

2.9 – 29 million

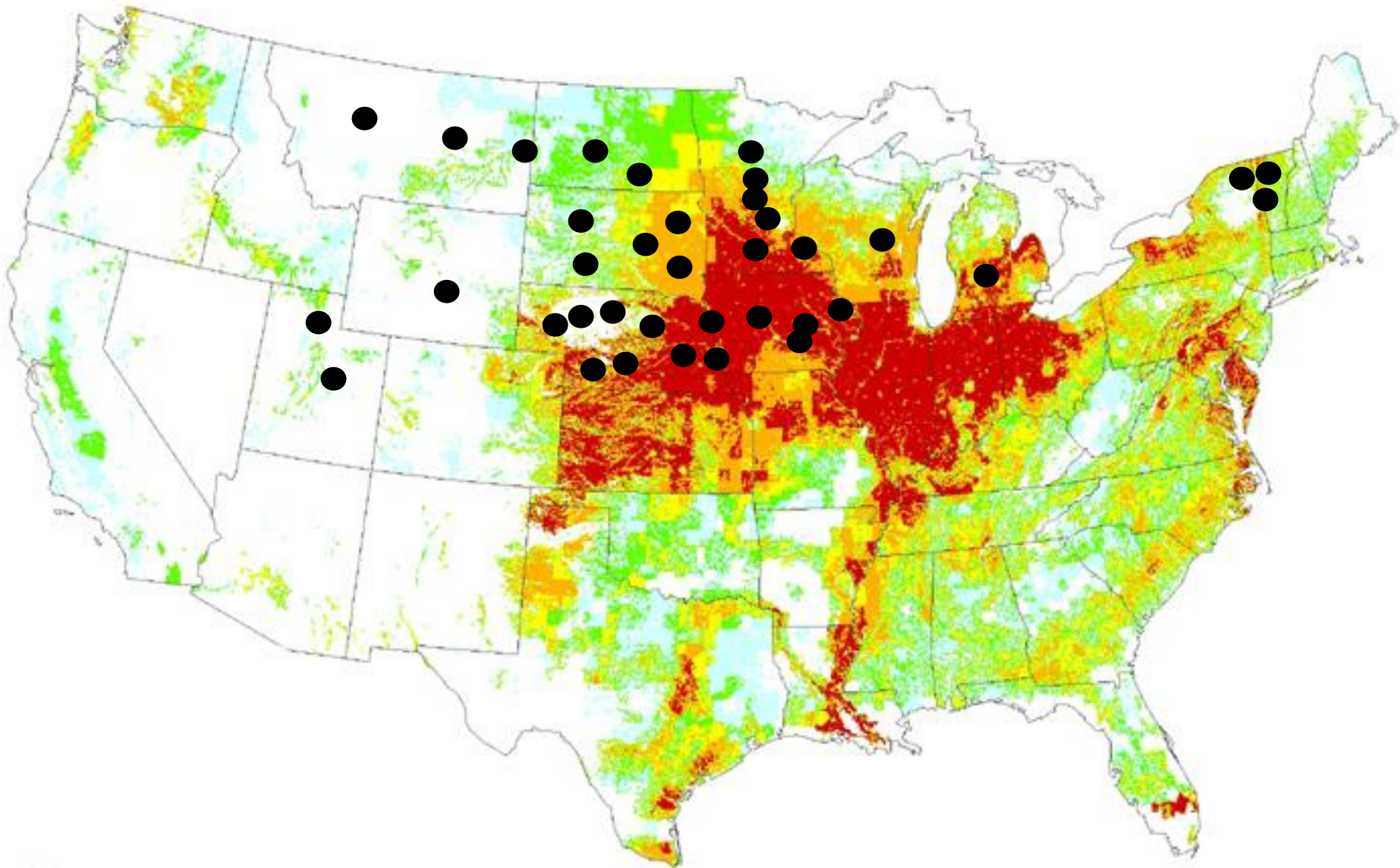






Atrazine use (kg/km²)

- Zero or data missing
- Less than 0.4
- 0.4 to 2.4
- 2.5 to 9.2
- 9.3 to 28.7
- More than 28.7

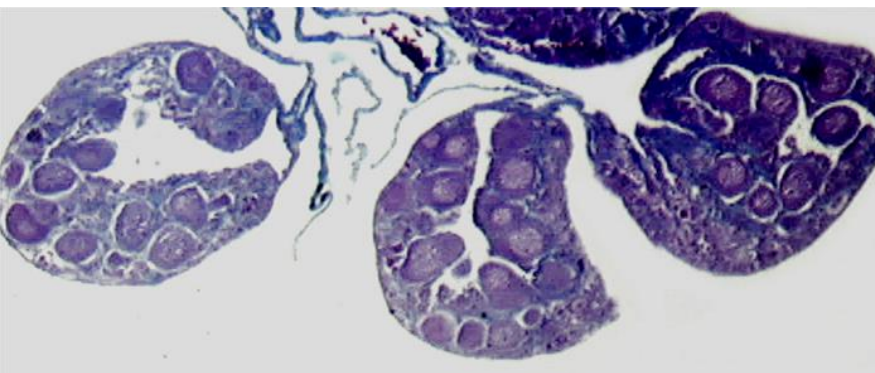




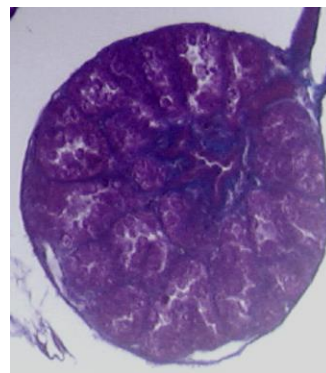
Atrazine



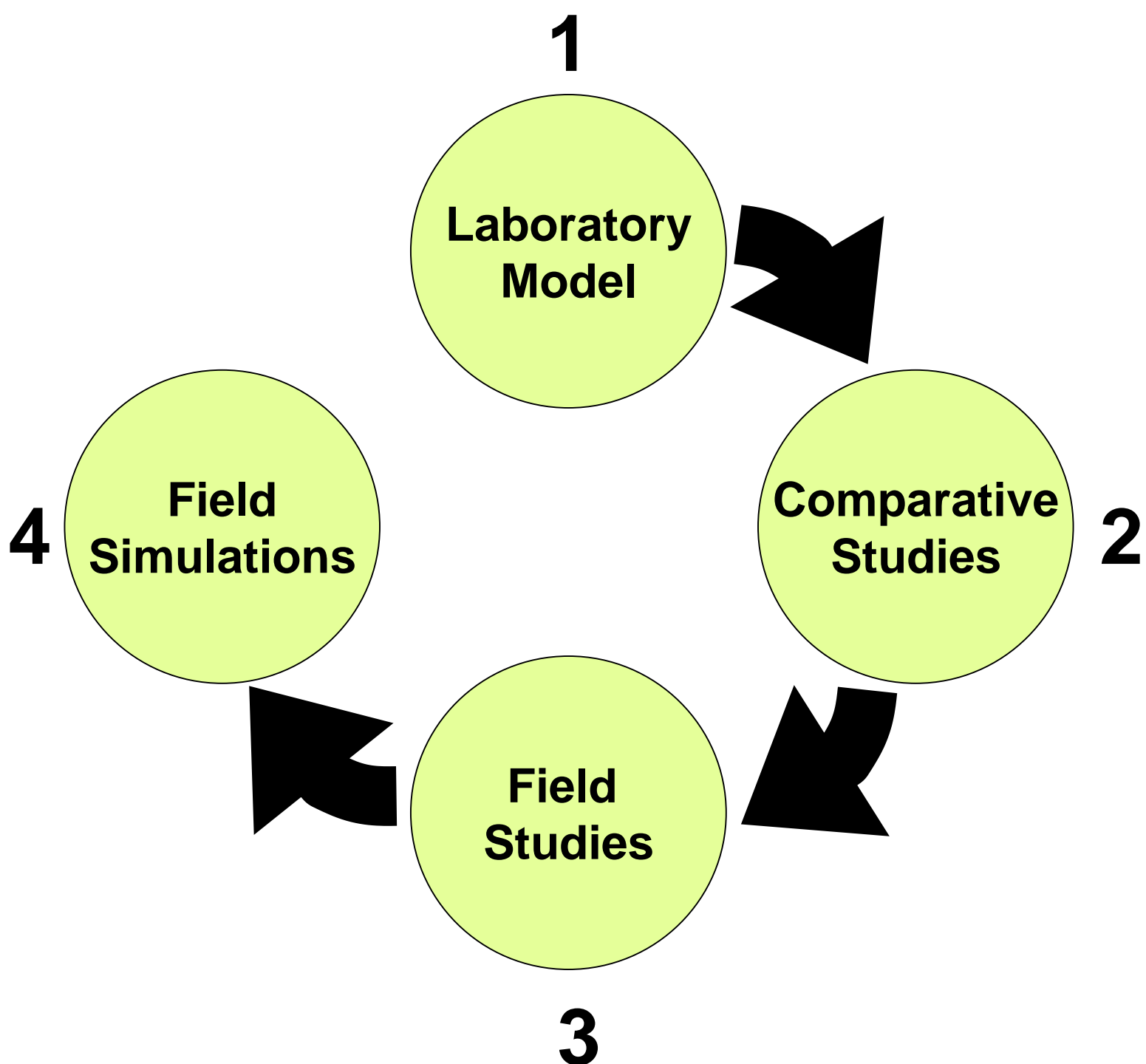
No Atrazine



92% Hermaphrodites



0% Hermaphrodites





CSI:

CRIME SCENE INVESTIGATION™



AS VEGA
VADA



SPRING

Atrazine

Metolachlor

Alachlor

Nicosulfuron

Methoxyacetyl

Propiconazole

Tebupirimphos

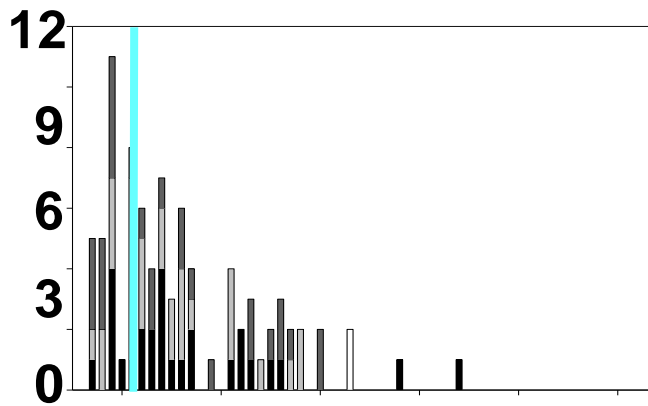
Cyfluthrin

Cyhalothrin

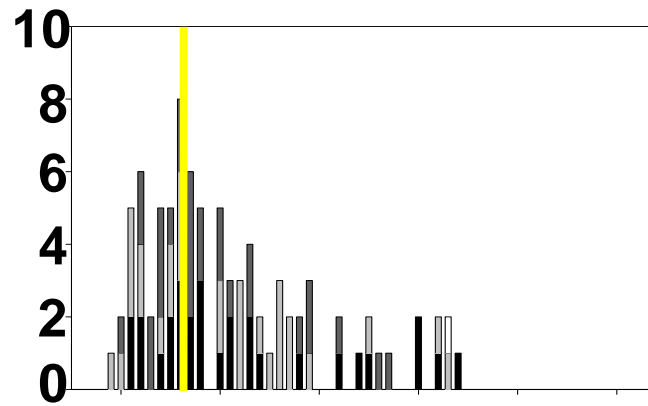




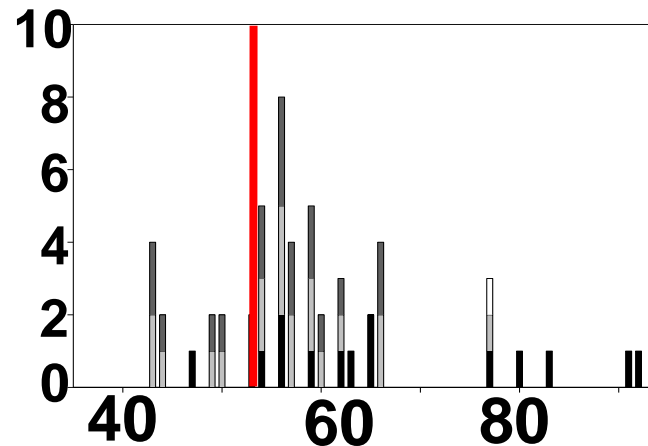
Number at Metamorphosis



Control

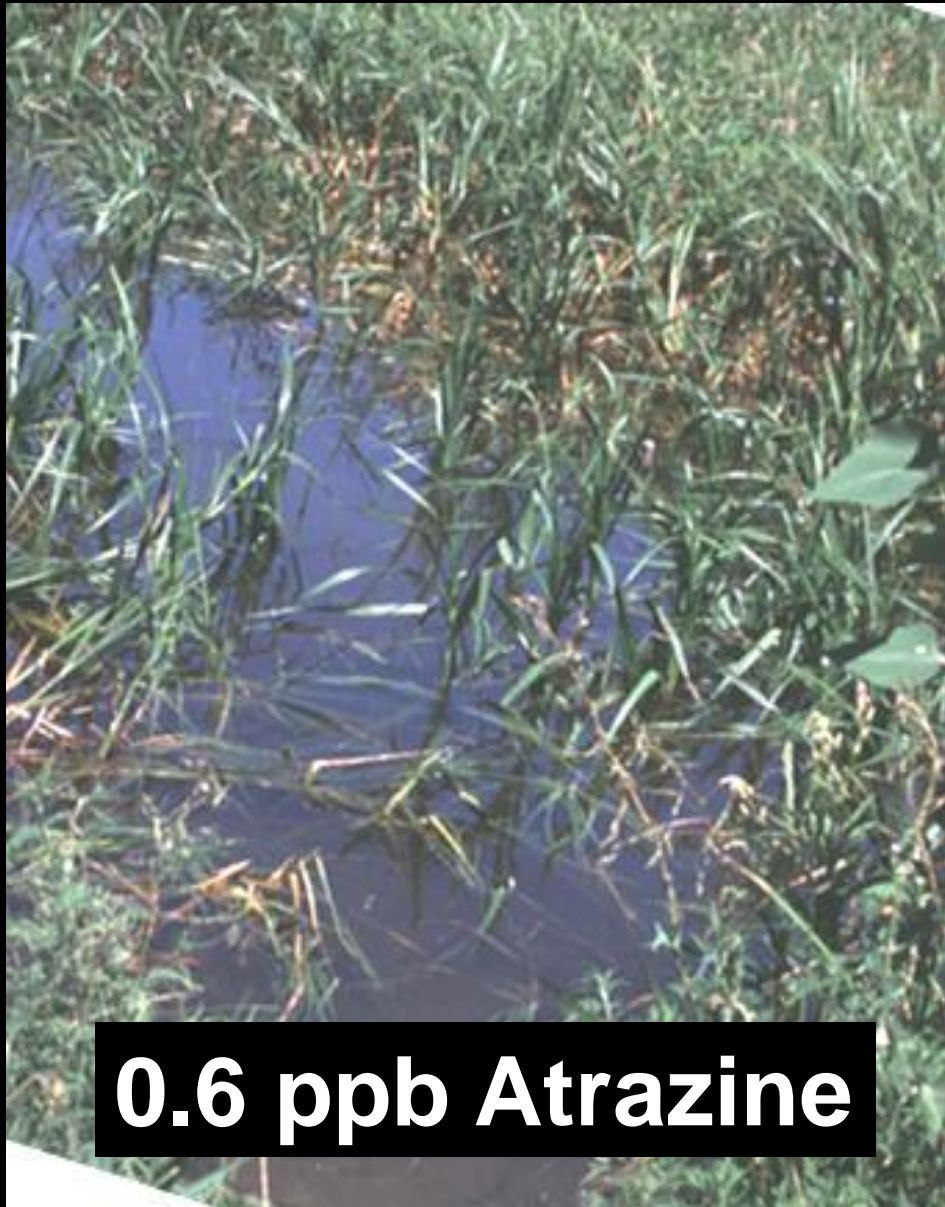


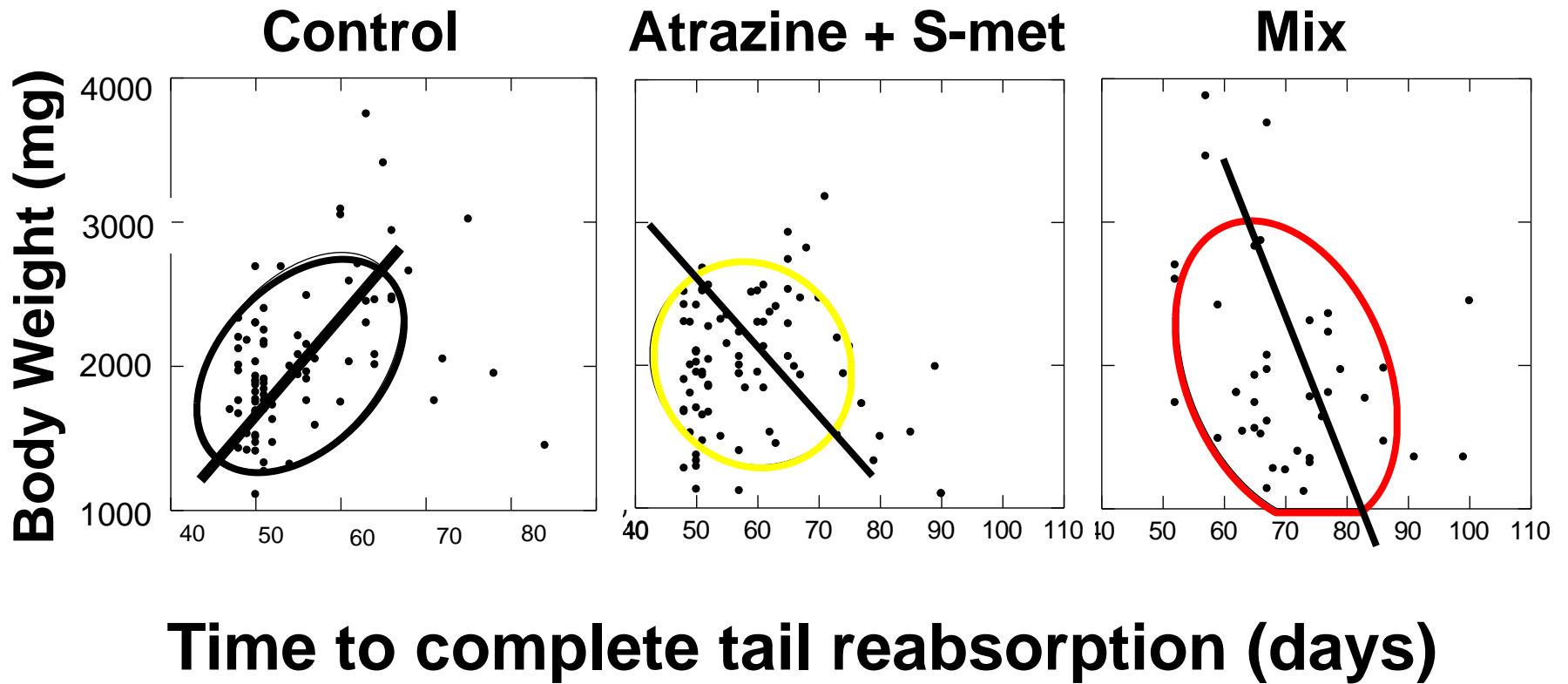
**Atrazine and
S-metolachlor**



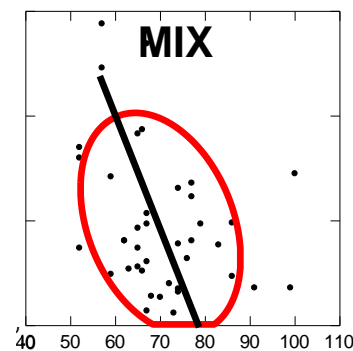
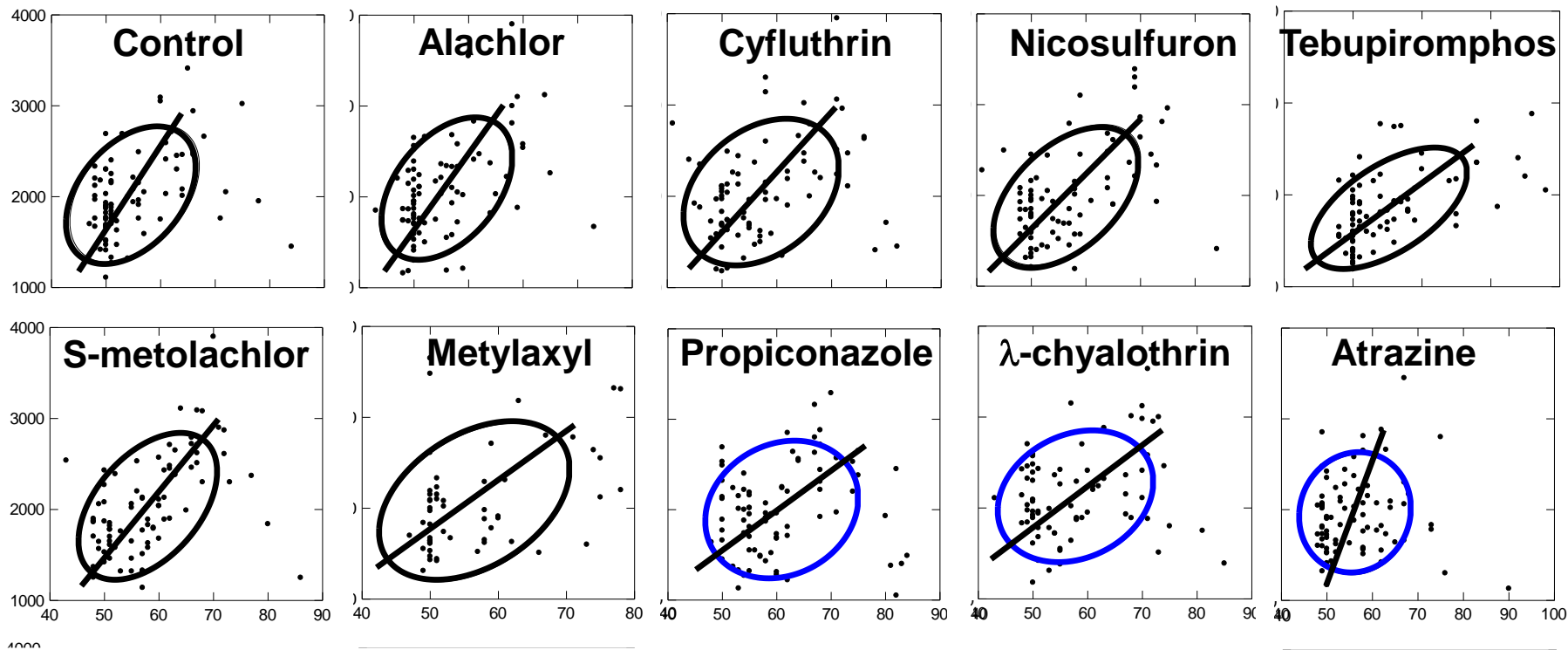
**Mixture of
9 compounds**

Time (days)





Body weight (mg)

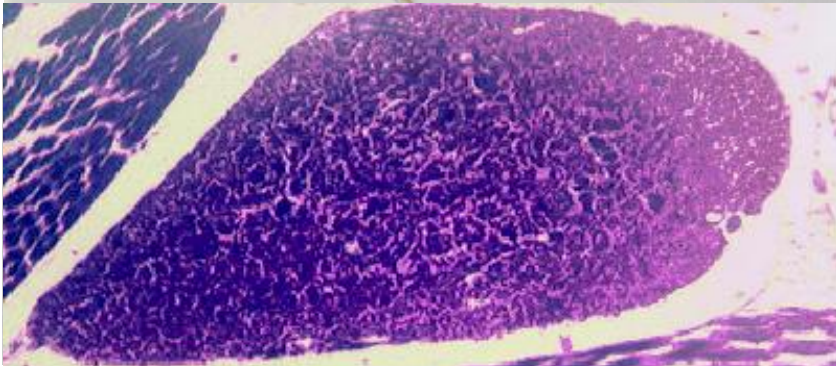


Time to complete tail reabsorption (days)

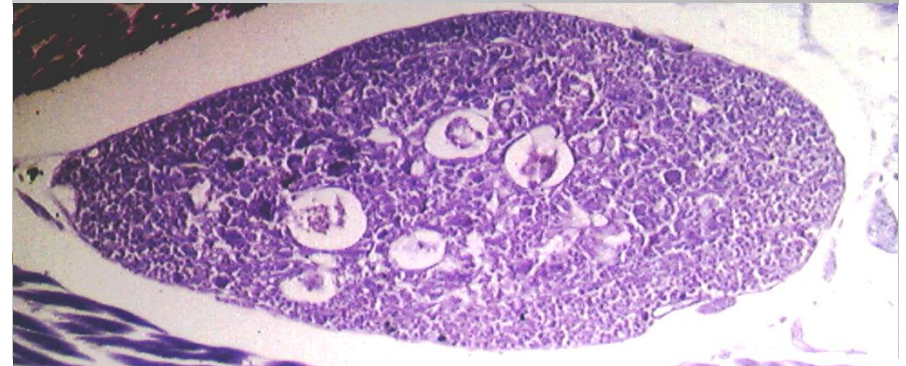




CONTROL



MIX



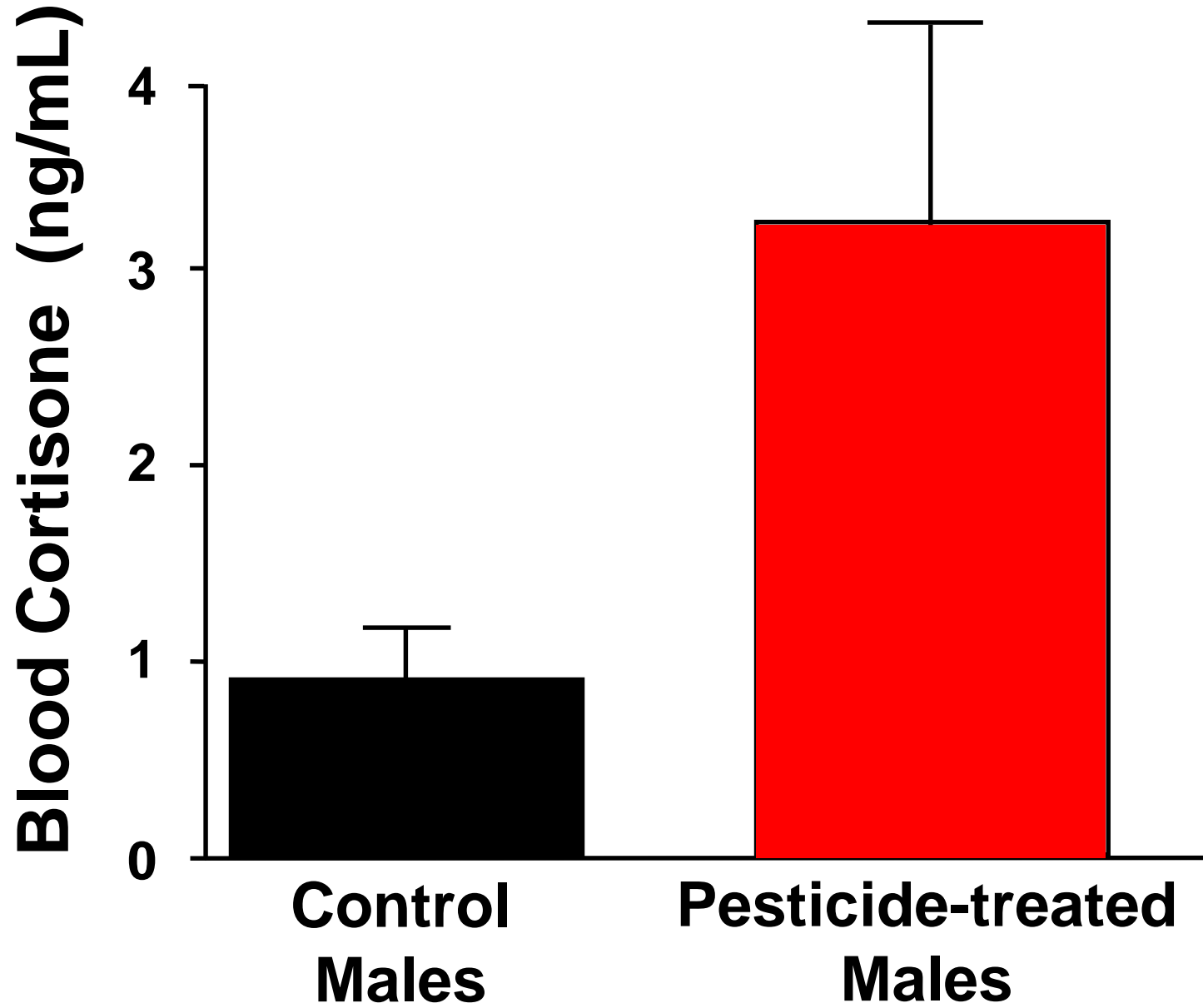
pesticides

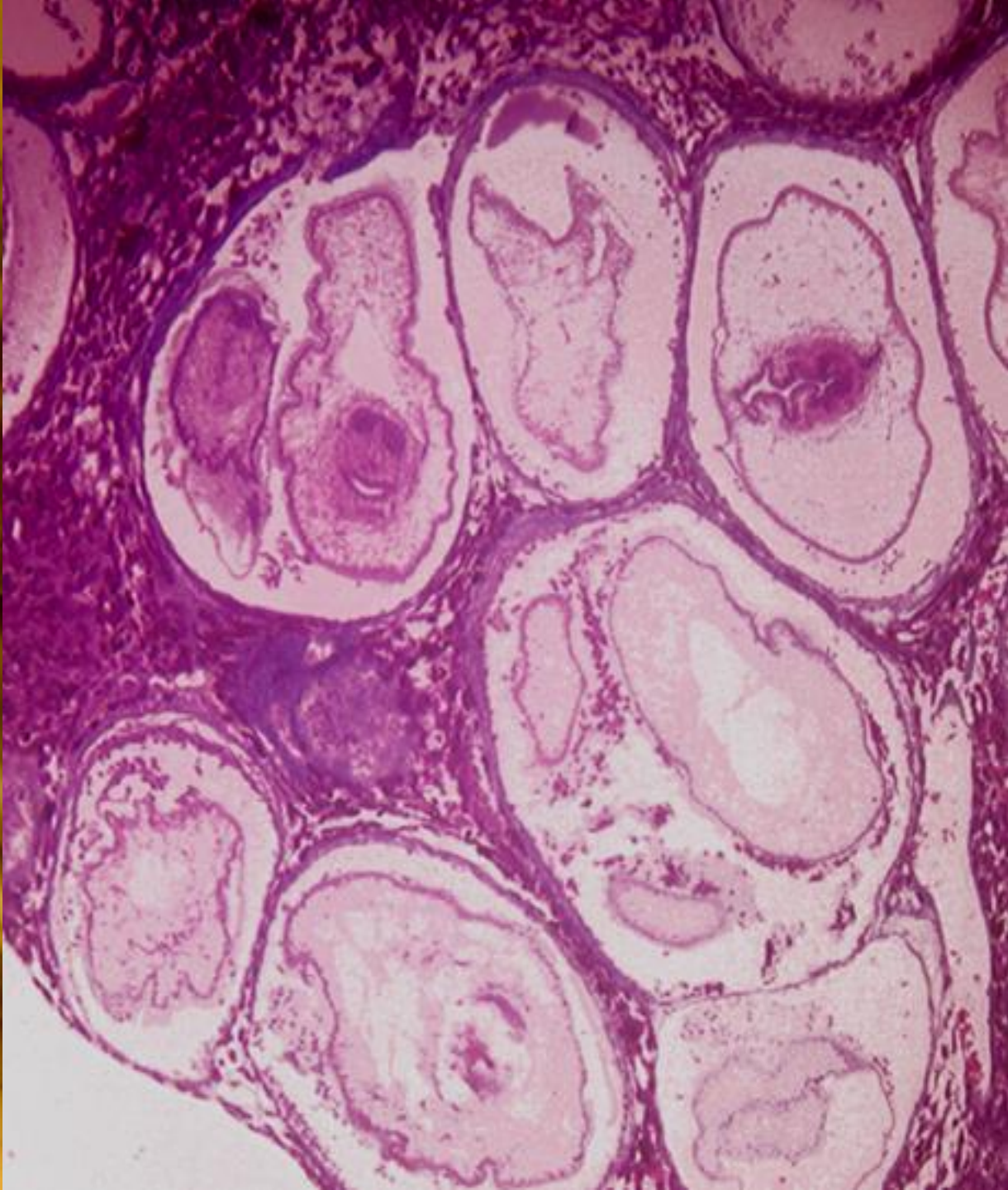


**Stress hormone
(Corticoids)**



**Immunosuppression,
Decreased growth,
Retarded development,
Inhibited metamorphosis**





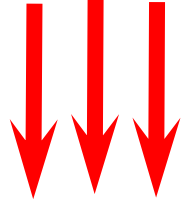
temperature



desiccation



pesticides



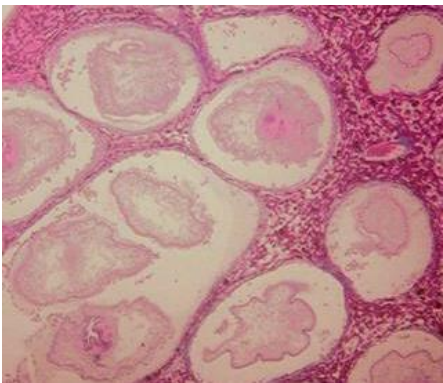
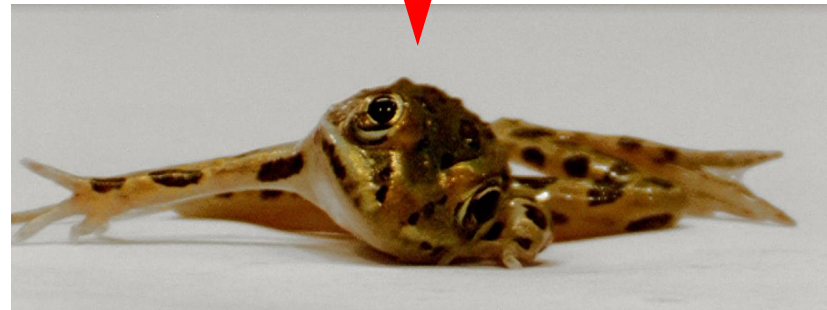
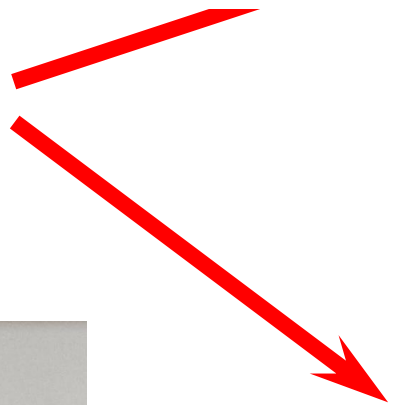
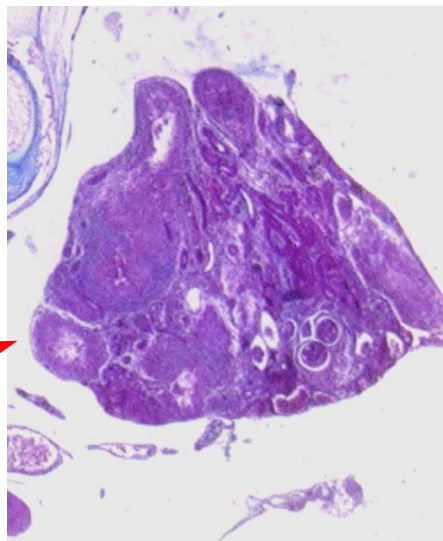
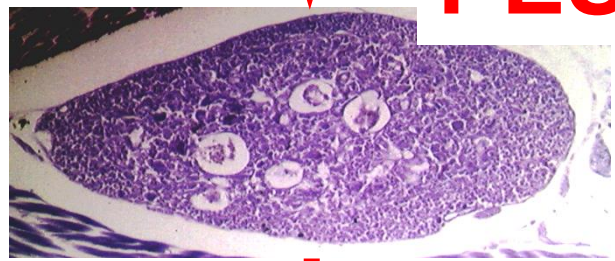
density



**Stress hormone
(Corticoids)**

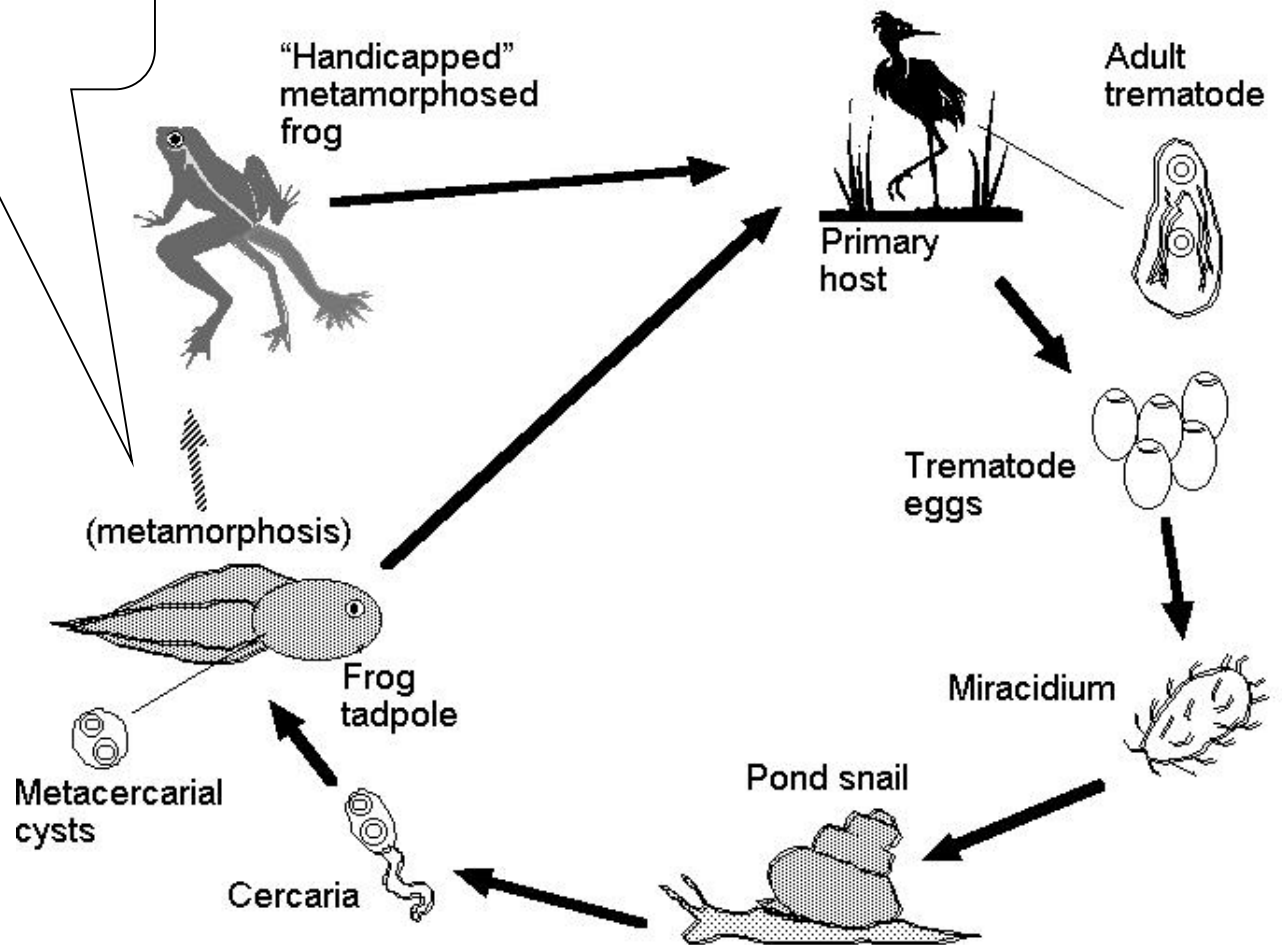


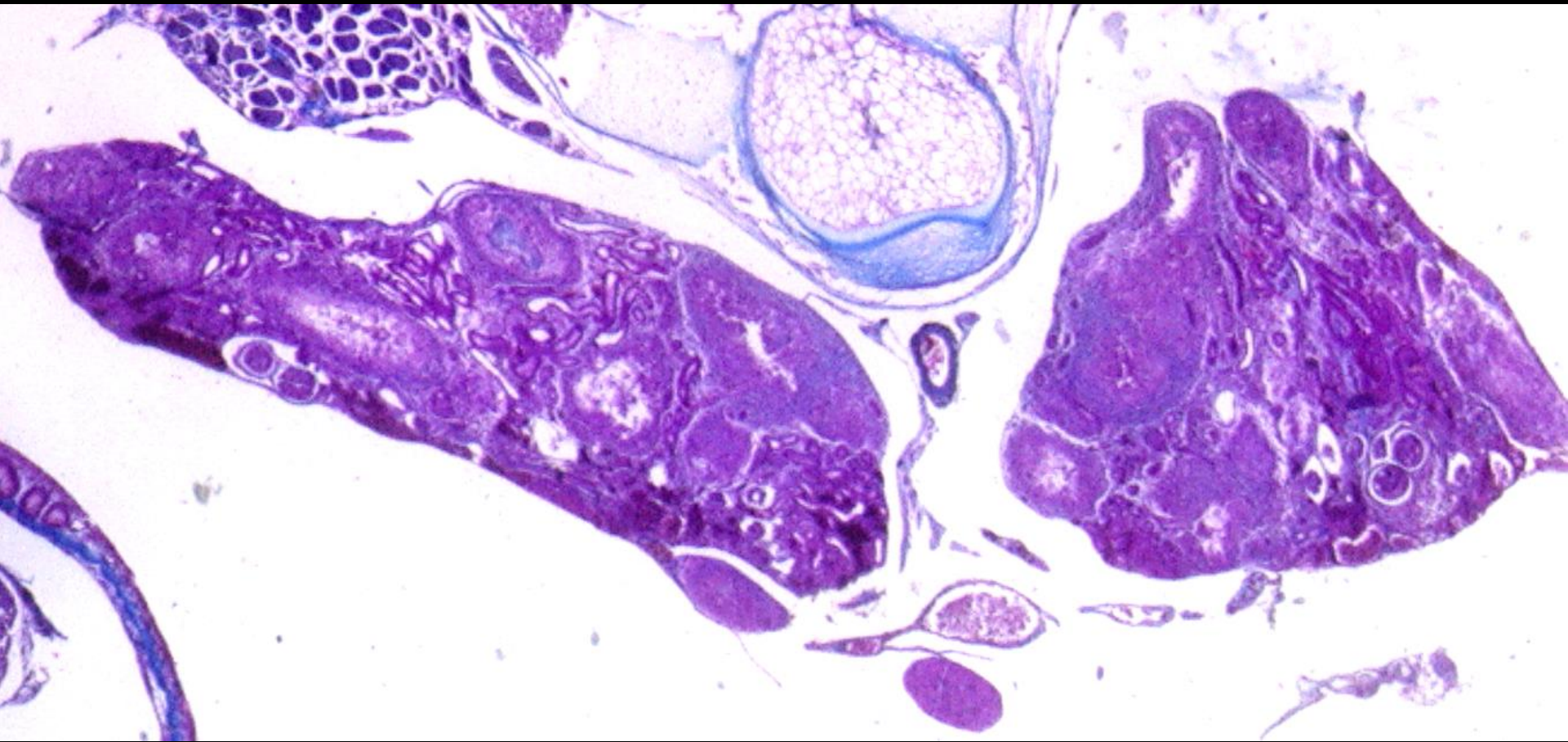
PESTICIDES



**Kesieker,
2002**

Ribeiroia sp. life cycle

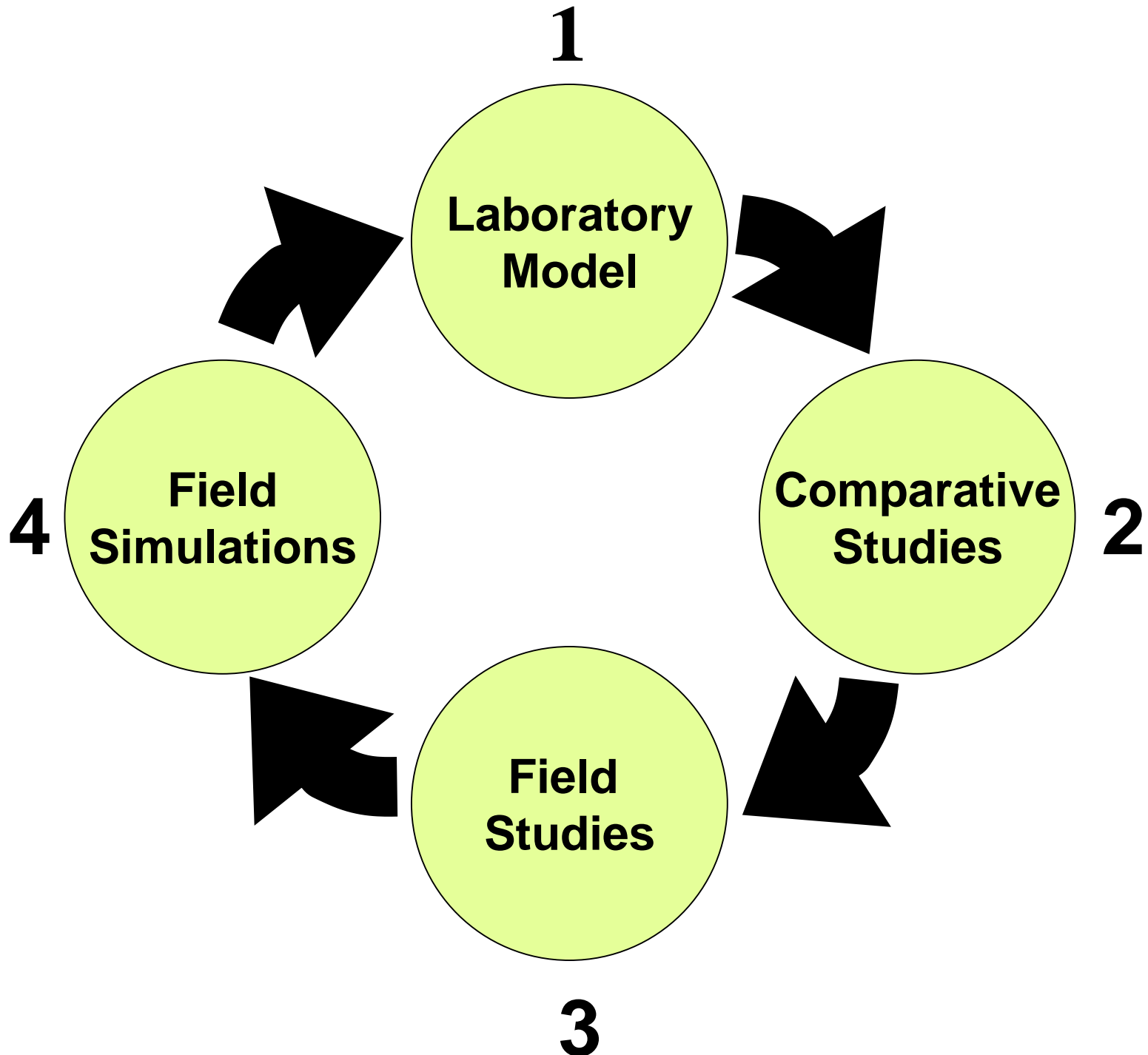




Atrazine increases rana virus susceptibility
in the tiger salamander, *Ambystoma Tigrinum*

-- Forson and Storfer, 2006



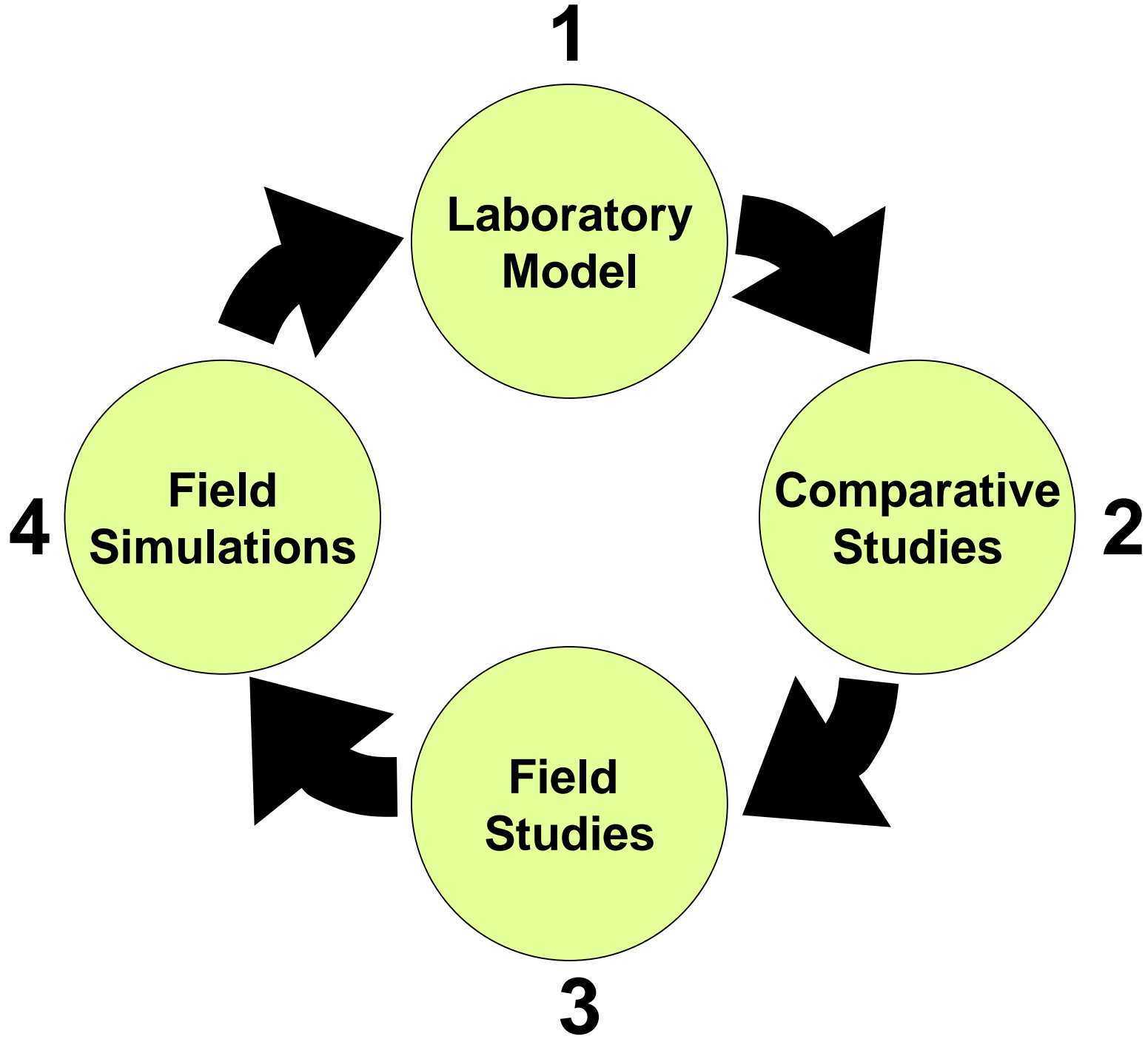


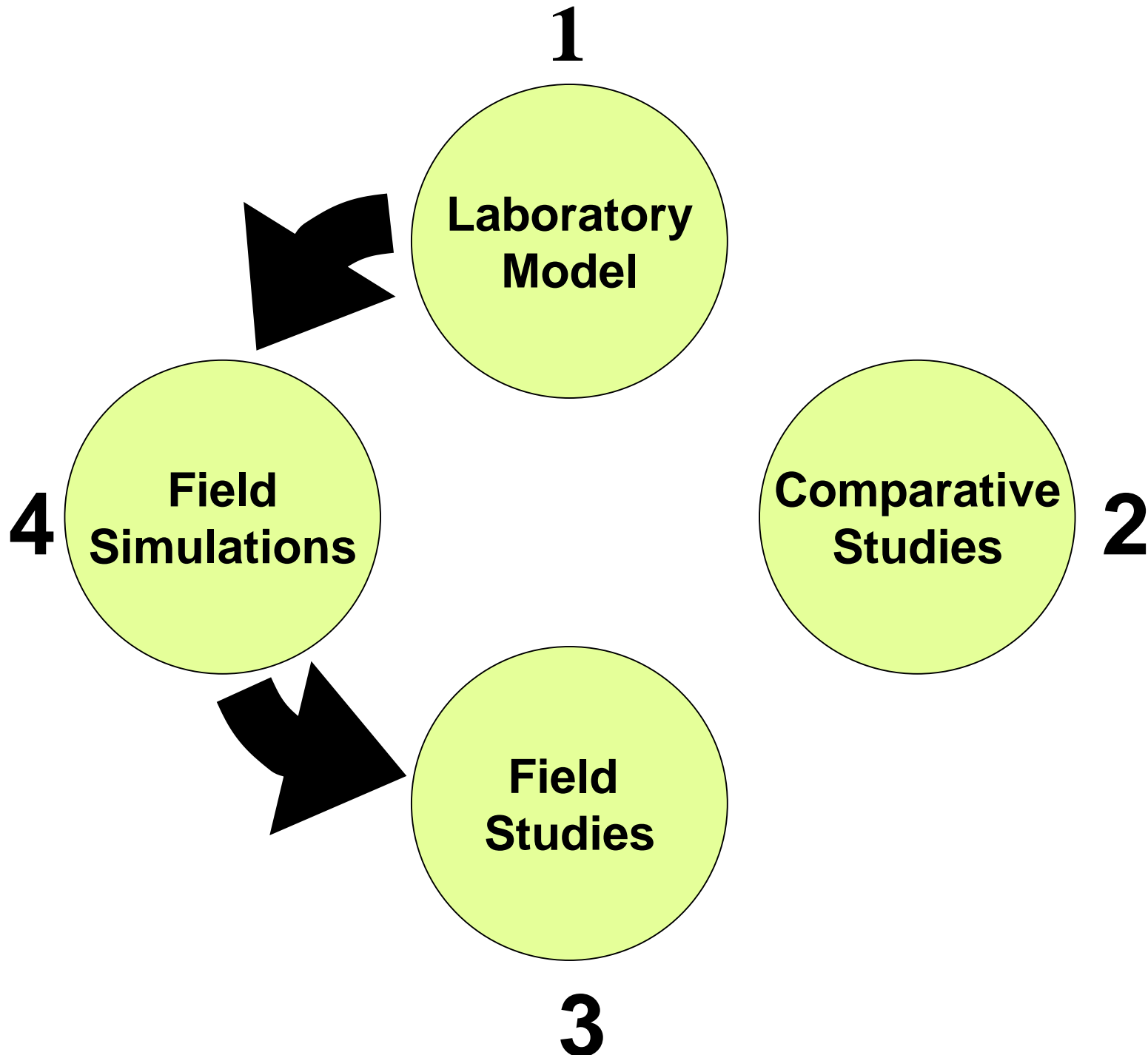
2001

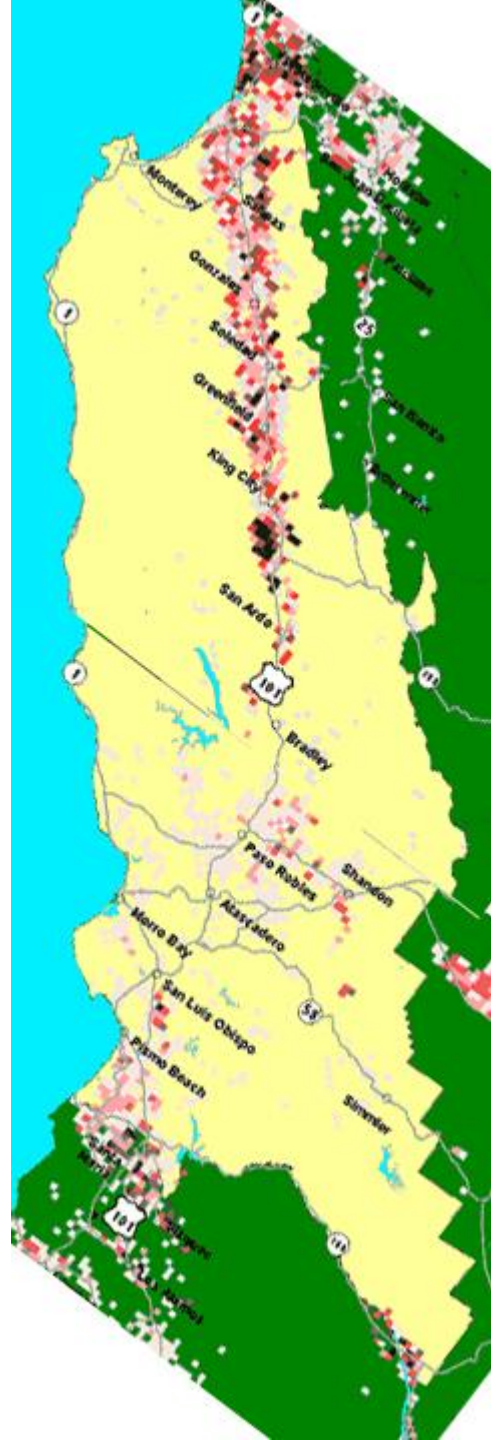


2003













Monterey Bay

Moss Landing

Elkhorn Slough

Old Salinas River

Castroville

Marina

Monterey

101

Carmel

Salinas

Carmel River

Salinas River

Chualar

16

Gonzales

Soledad

Los Padres National Forest

Arroyo Seco River

Greenfield

King City

Salinas River

101

San Lucas

San Ardo

San Antonio Reservoir

Bradley

Lake Nacimiento

San River

Santa Margarita Lake





© 2007 Navteq

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Pointer 35°19'05.29" N 120°25'12.38" W

Streaming ||||| 100%

Eye alt 10.43 mi





Atascadero, CA

Image © 2008 DigitalGlobe

© 2007 Google

Pointer 35°29'57.67" N 120°39'00.08" W elev 856 ft

Streaming ||||| 100%

Eye alt 10.93 mi





Salinas, Monterey, California, United States

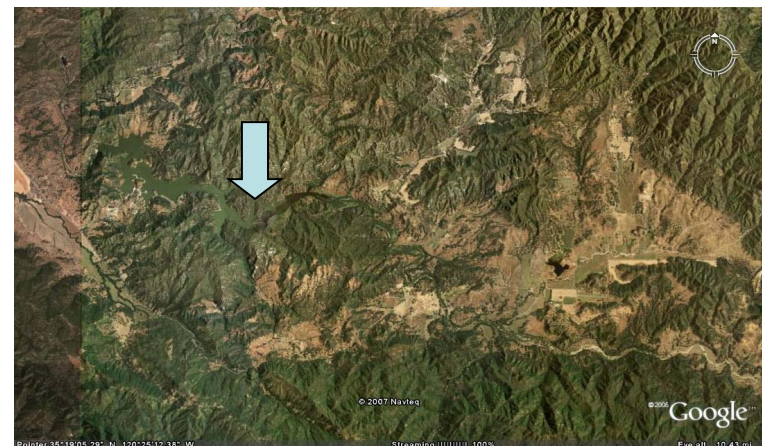
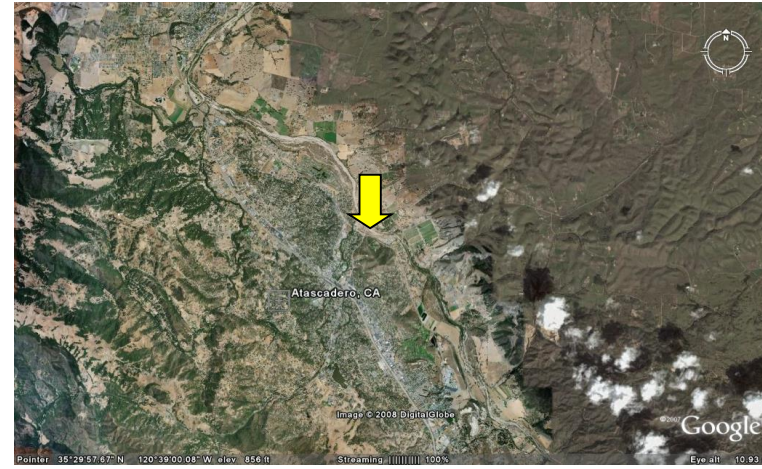
Image NASA
Image © 2007 DigitalGlobe

© 2006 Google™

Pointer 36°39'08.34" N 121°38'14.12" W

Streaming ||||| 100%

Eye alt 10.51 mi



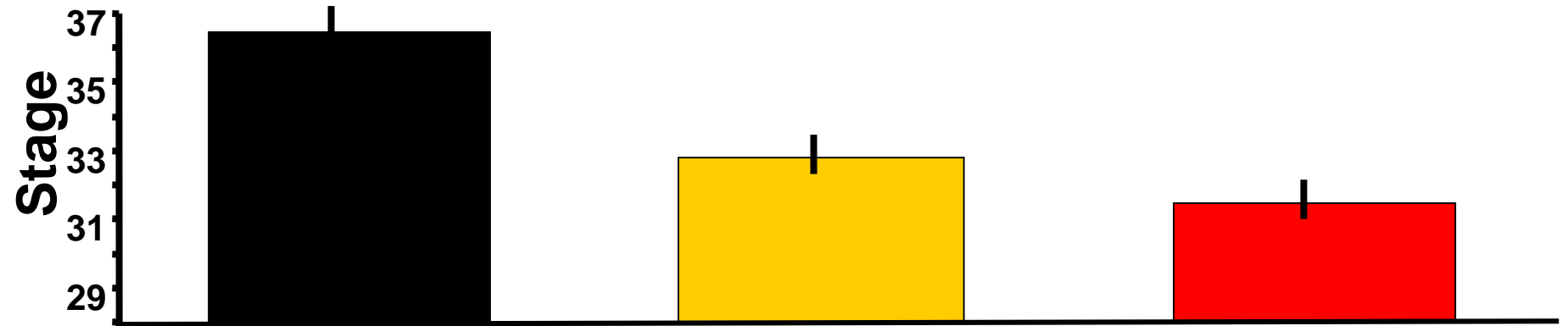
Santa Margarita



Atascadera



Salinas



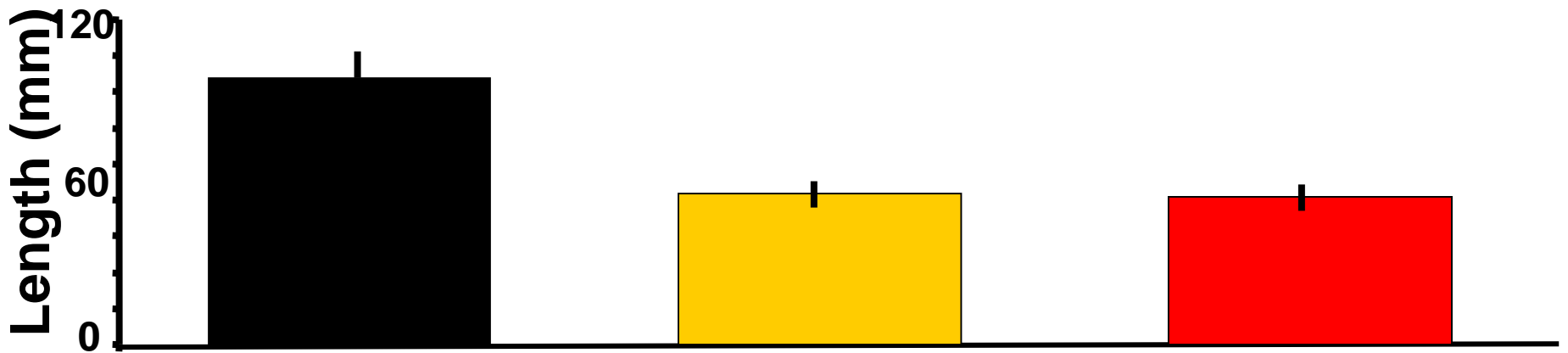
Santa Margarita



Atascadera



Salinas



Margarita Atascadera Salinas



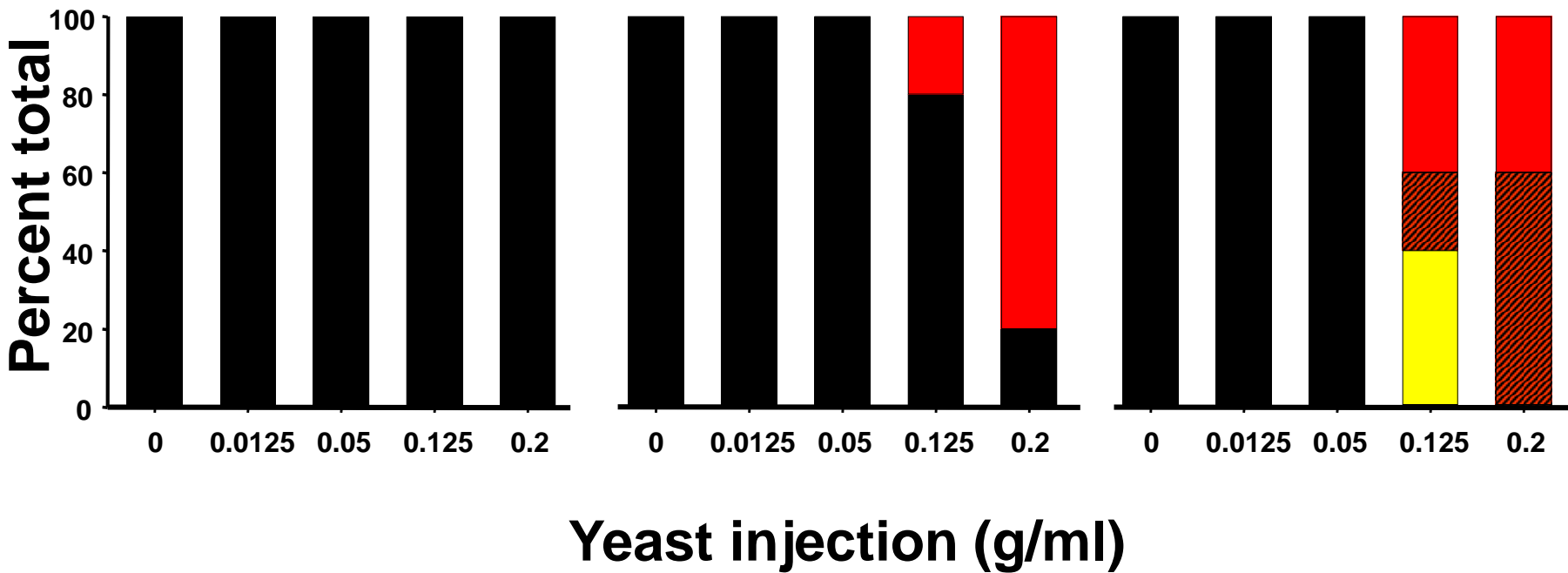
Santa Margarita

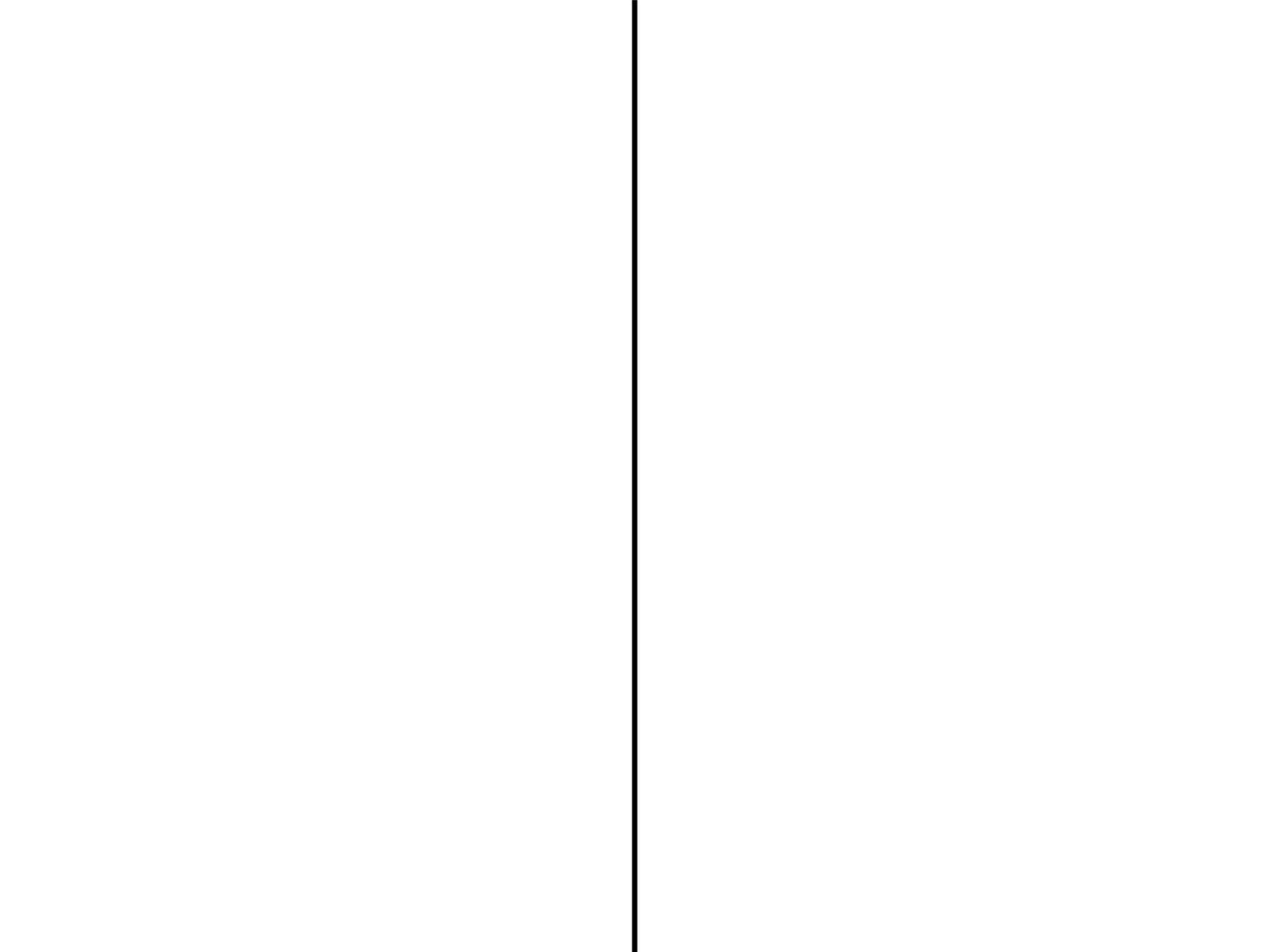


Atascadera

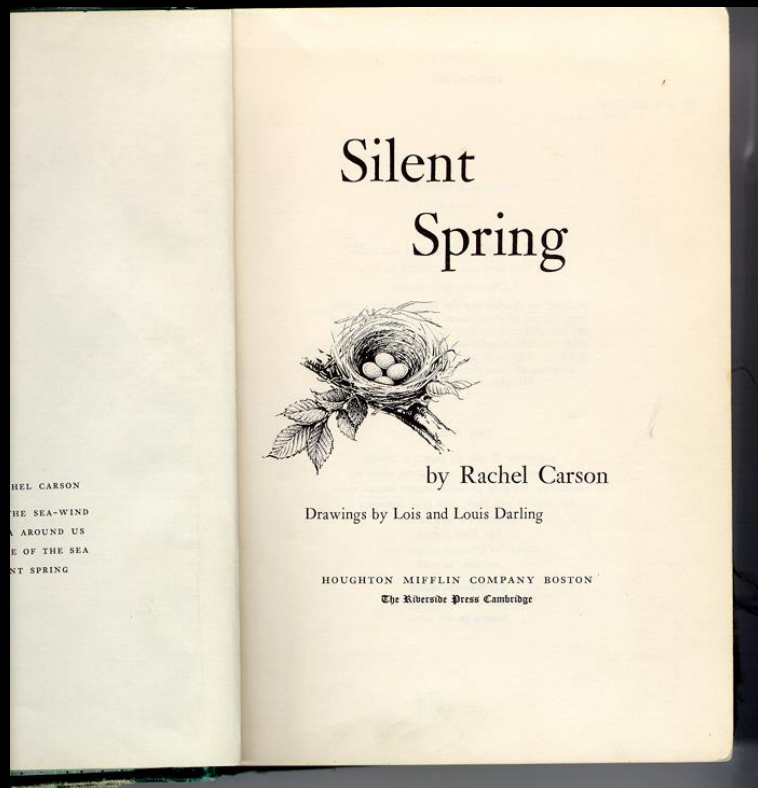


Salinas





FROM



TO



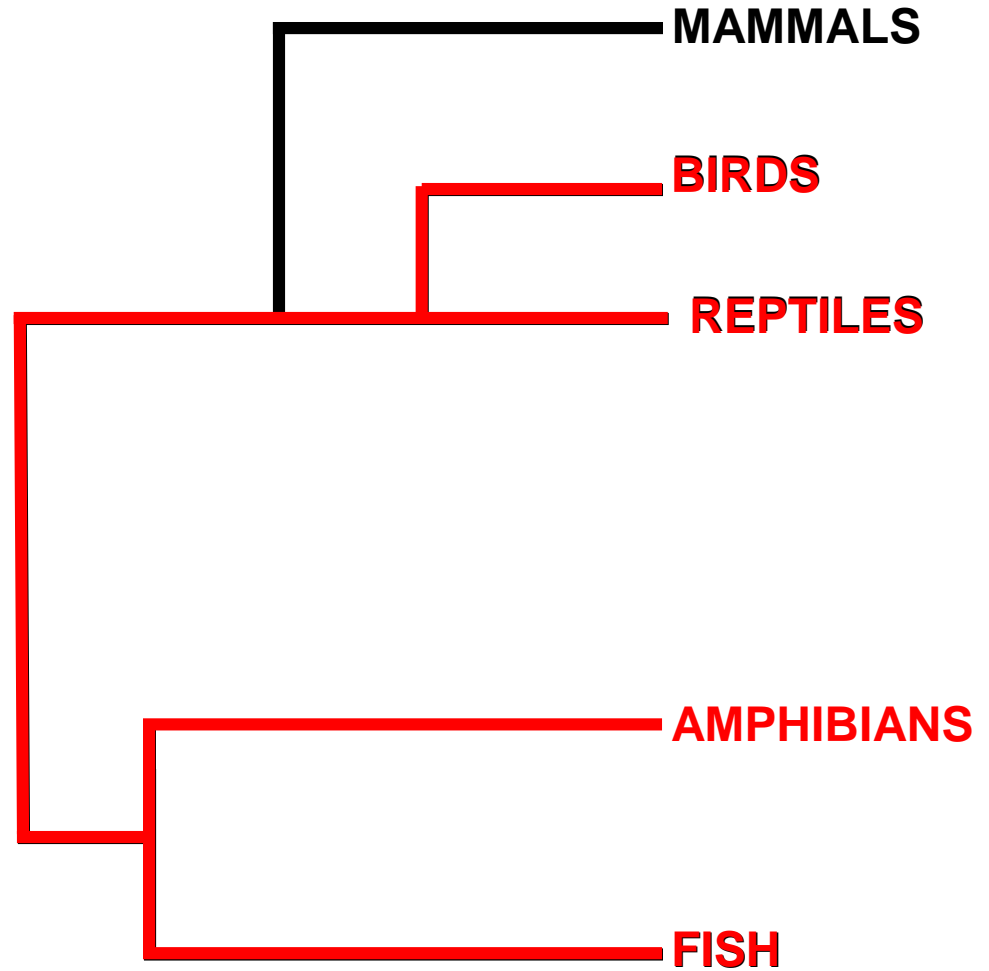
**SILENT
NIGHT**

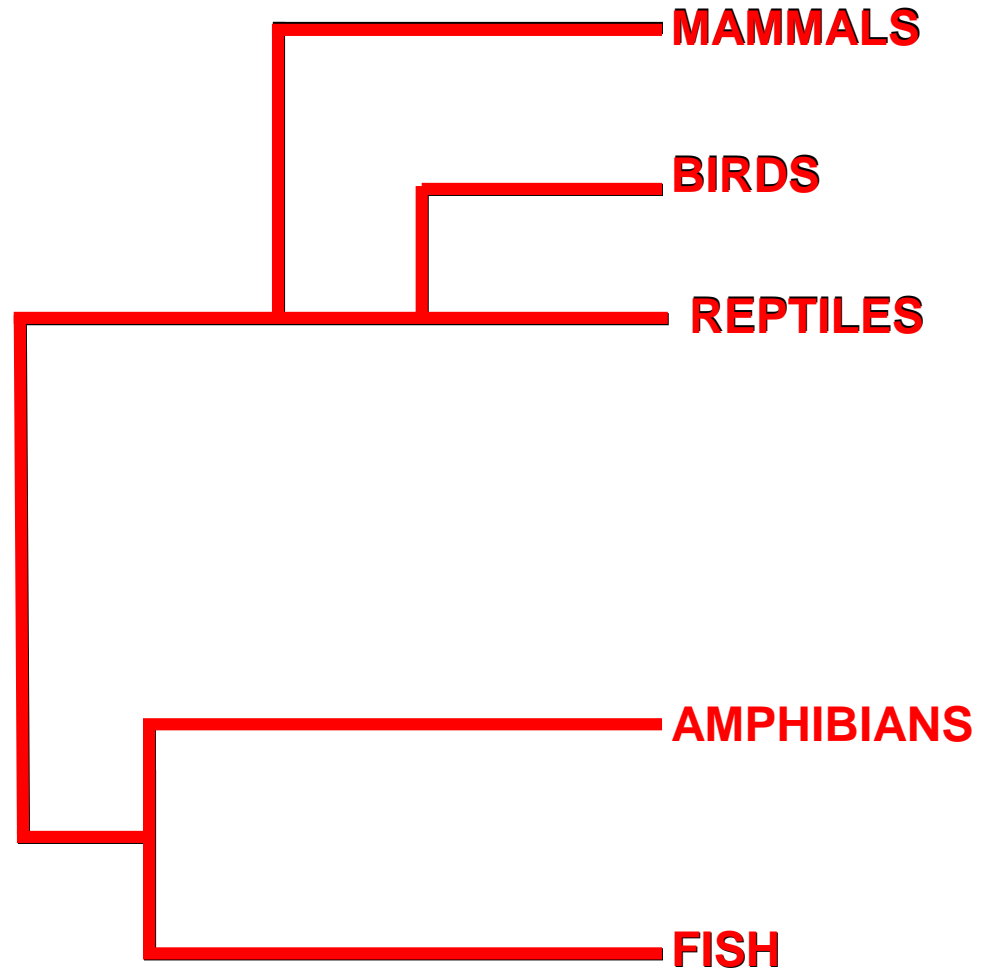






“In ecoepidemiology, the occurrence of an association in more than one species and species population is *very strong* evidence for causation.” (Fox, ref. 10, page 368).





“There is no direct scientific information to assess this hypothesis.”

from EPA, Statement of Anne Lindsay, page 10

Atrazine

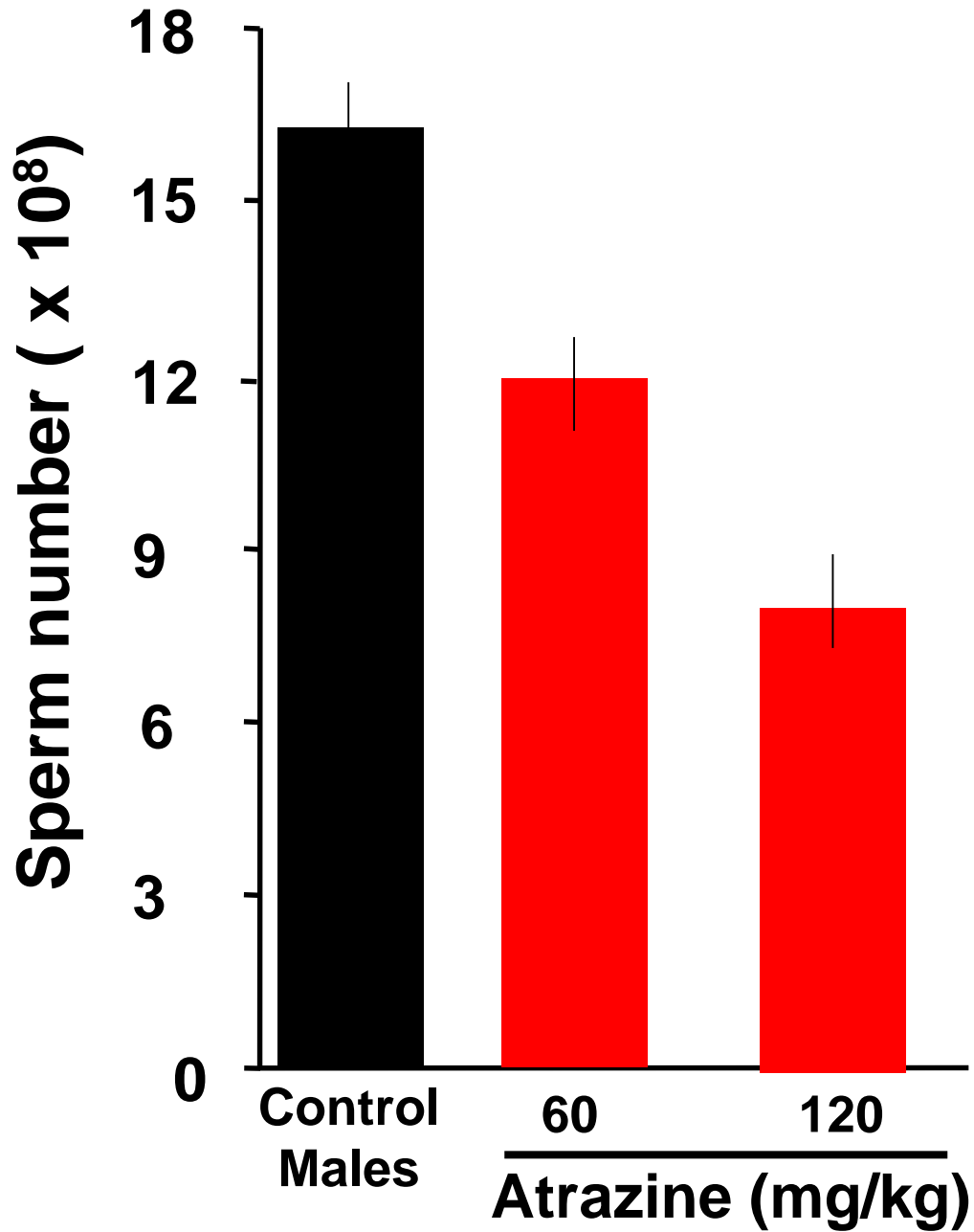
Testosterone



Sperm production

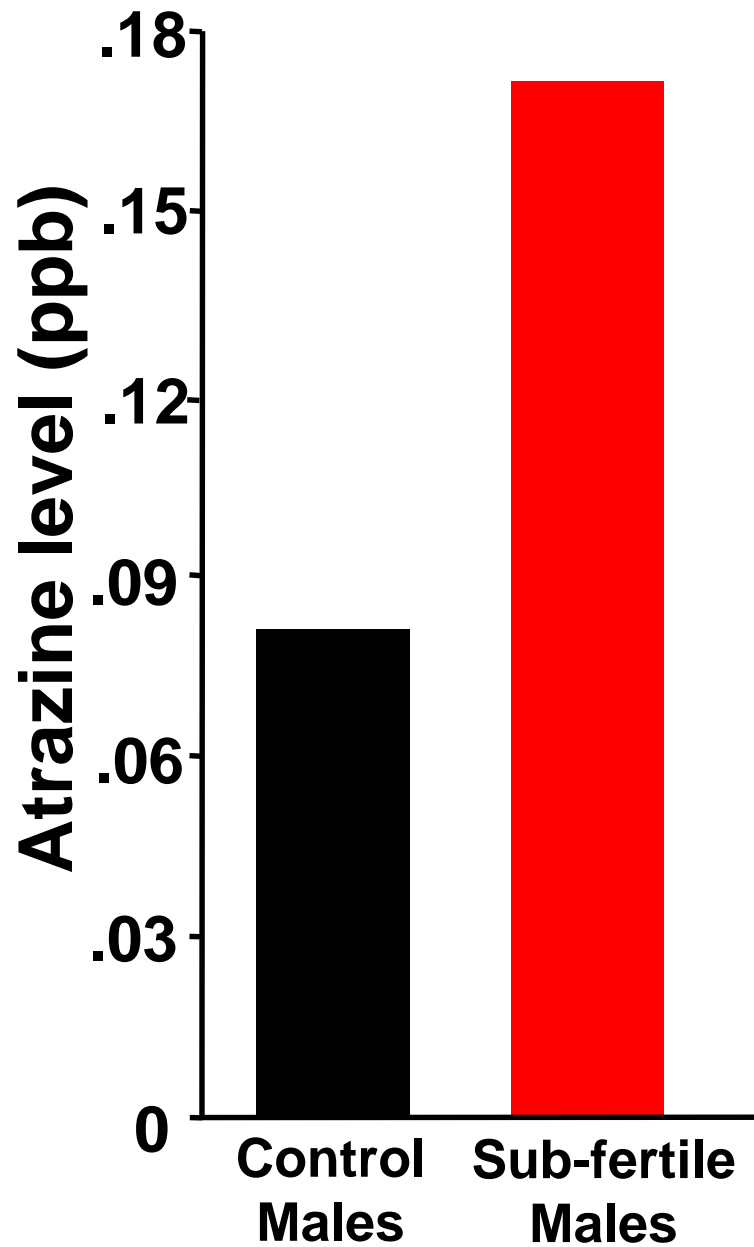
In rats
(Kniewald *et al.* 2000)

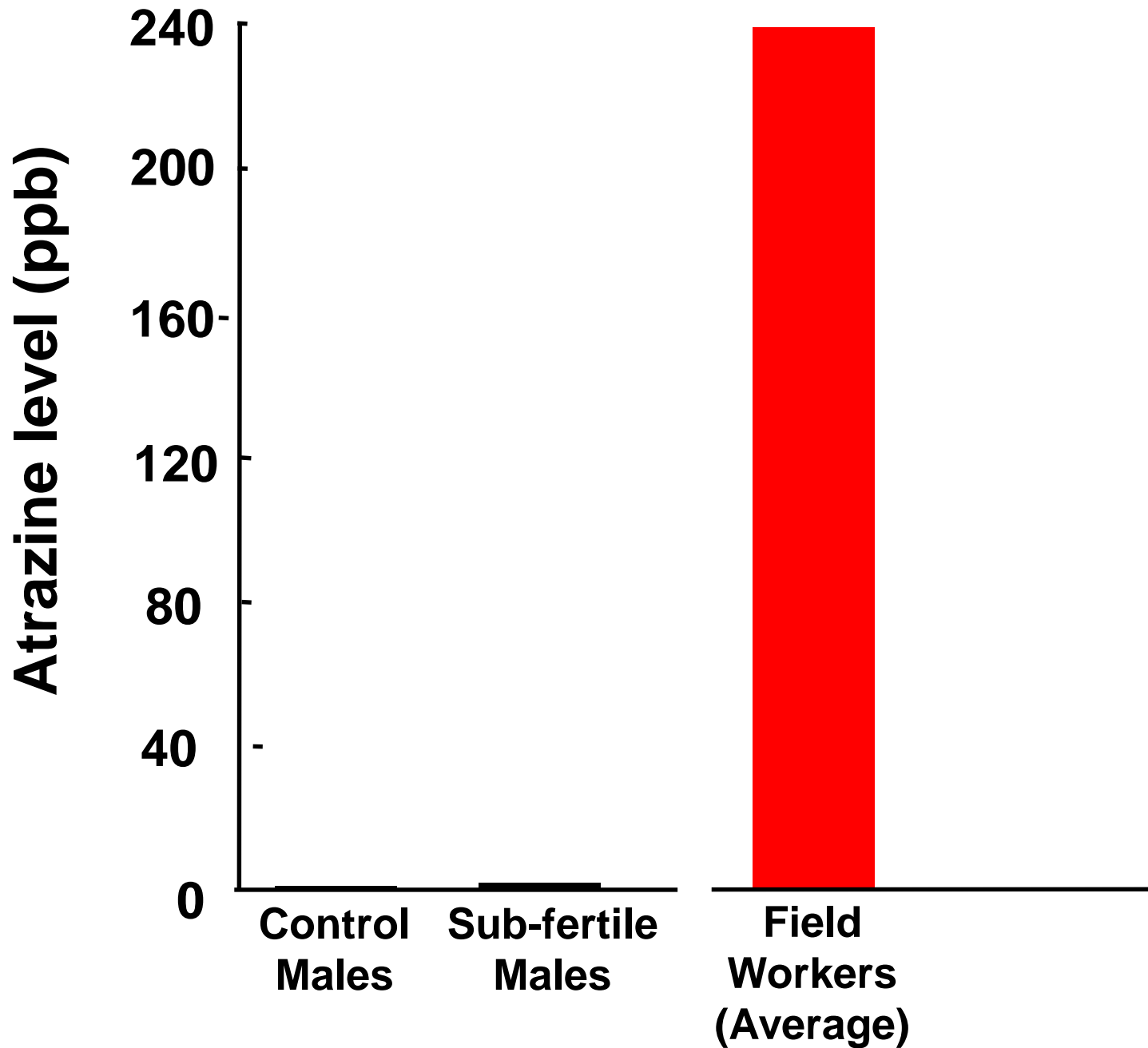
P < 0.001

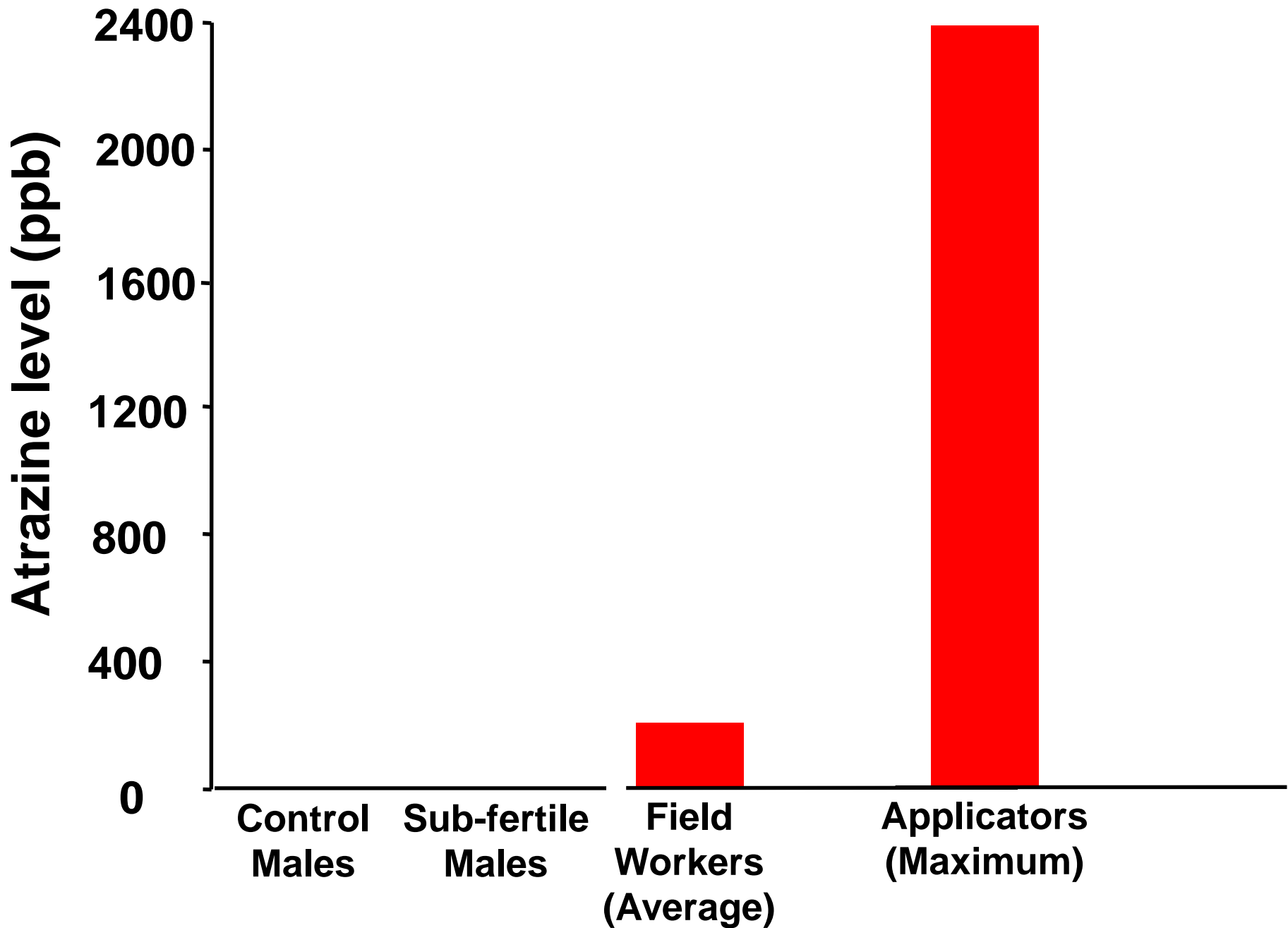


In humans
Swan *et al.* 2003

P < 0.009







**“Atrazine has been a
vital tool for US farmers
for nearly 50 years.”**

**--Tim Pastoor, Letter to the editor
Terra Haute Tribune Star
Jan 3, 2008**

Atrazine



aromatase

Testosterone



Estrogen



Vitellogenesis

Oogenesis

Mammary tumors

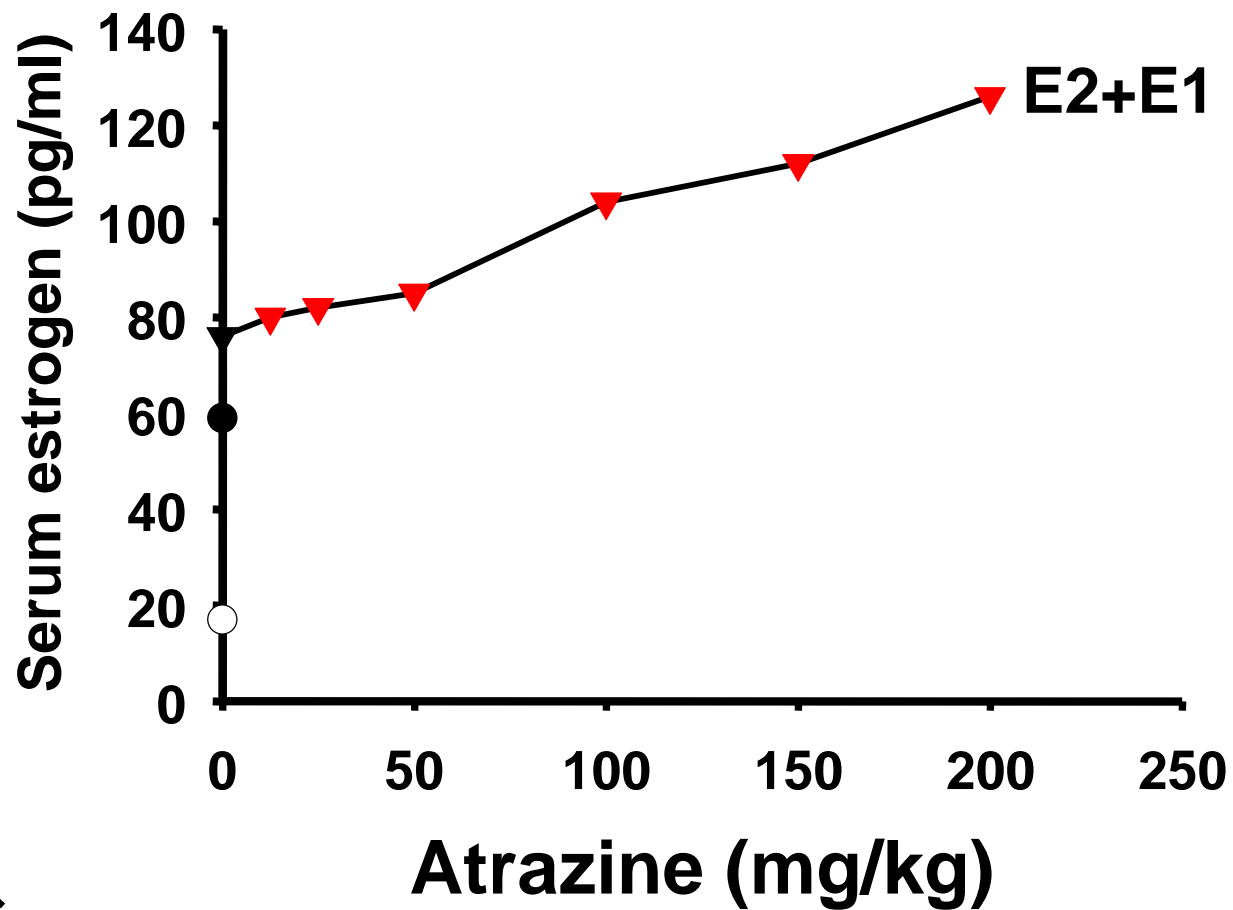
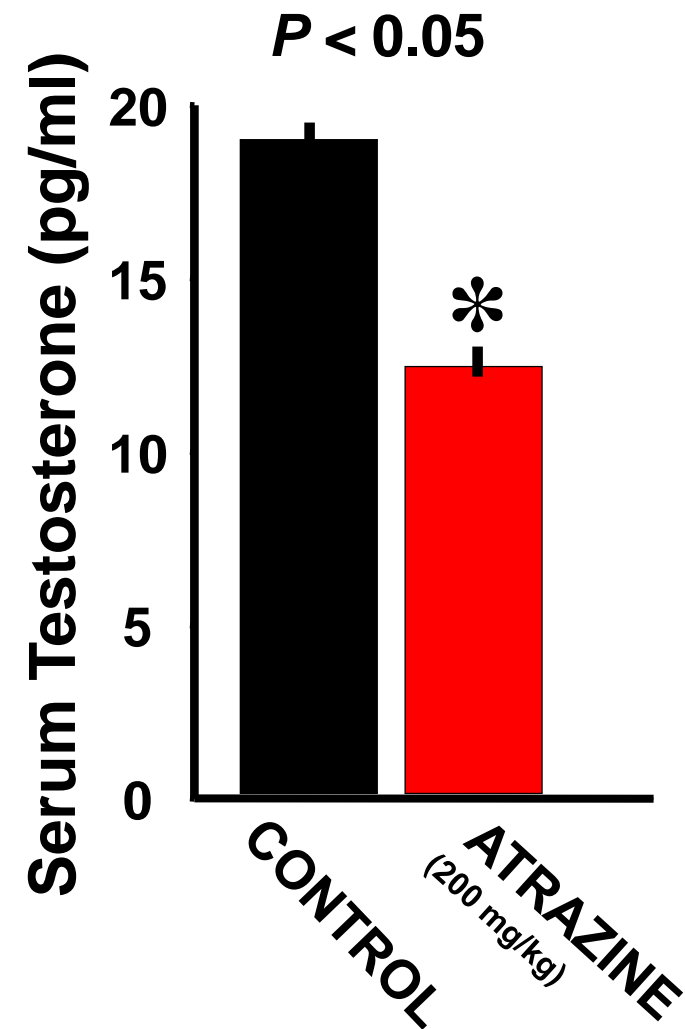
Prostate cancer



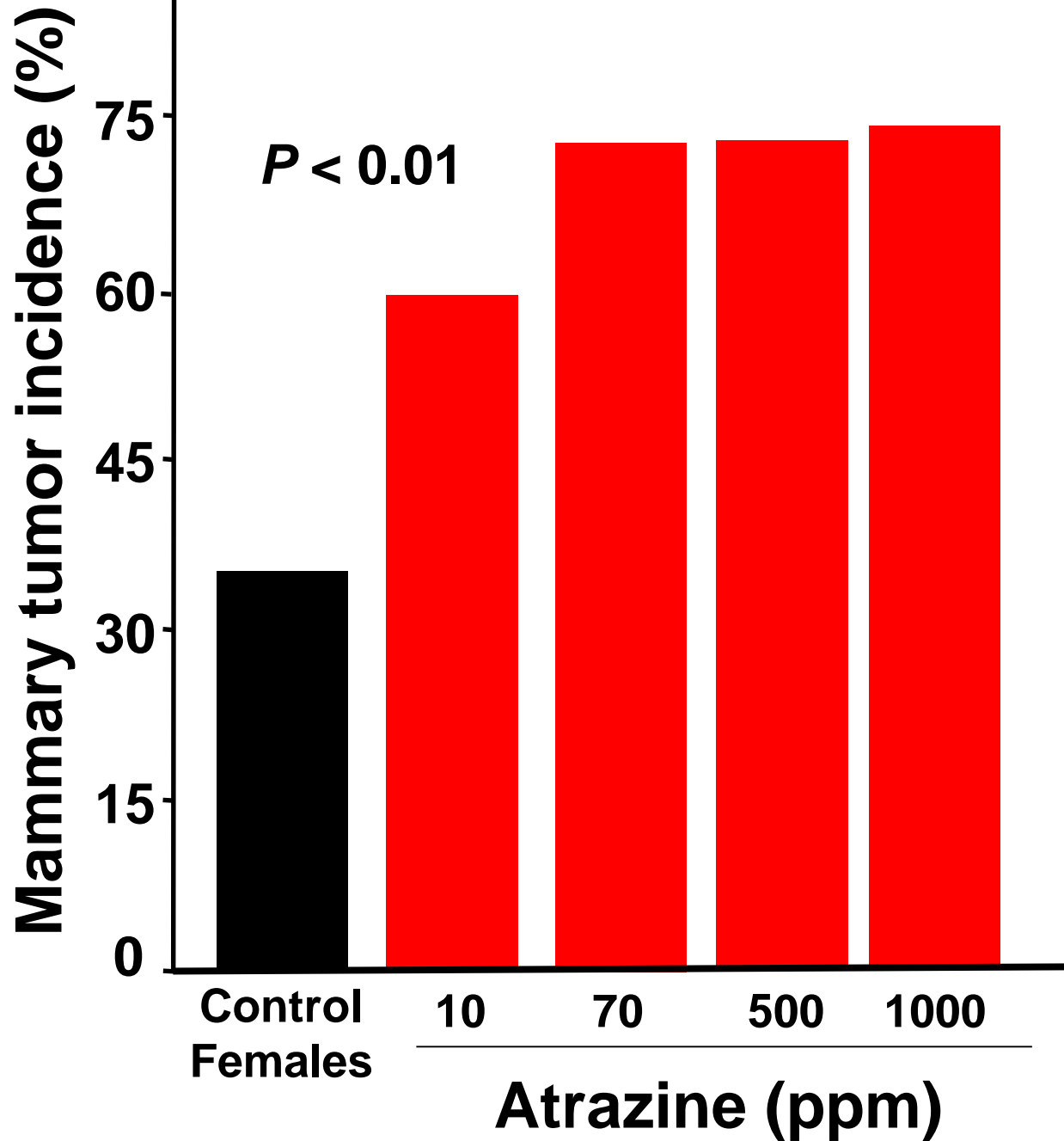
Sperm production

Stoker 2000

Rodents

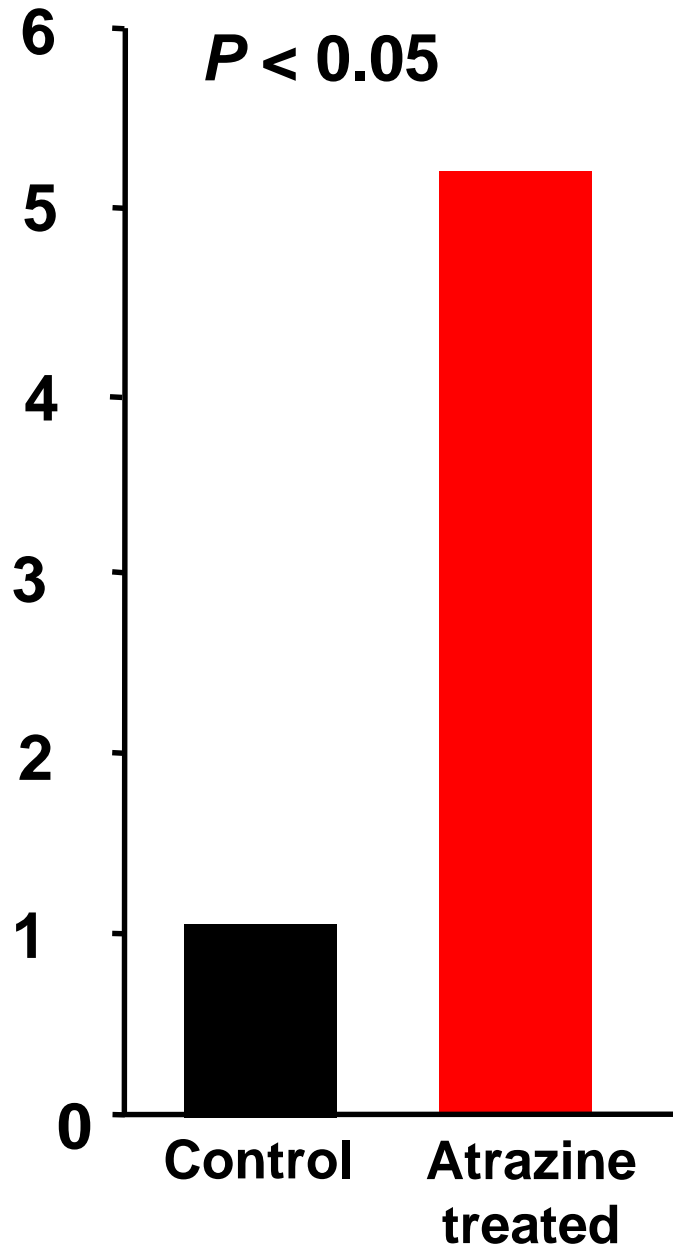


Stevens *et al.* 1994



Rodents

**Relative CYP 19 expression
Or aromatase activity**

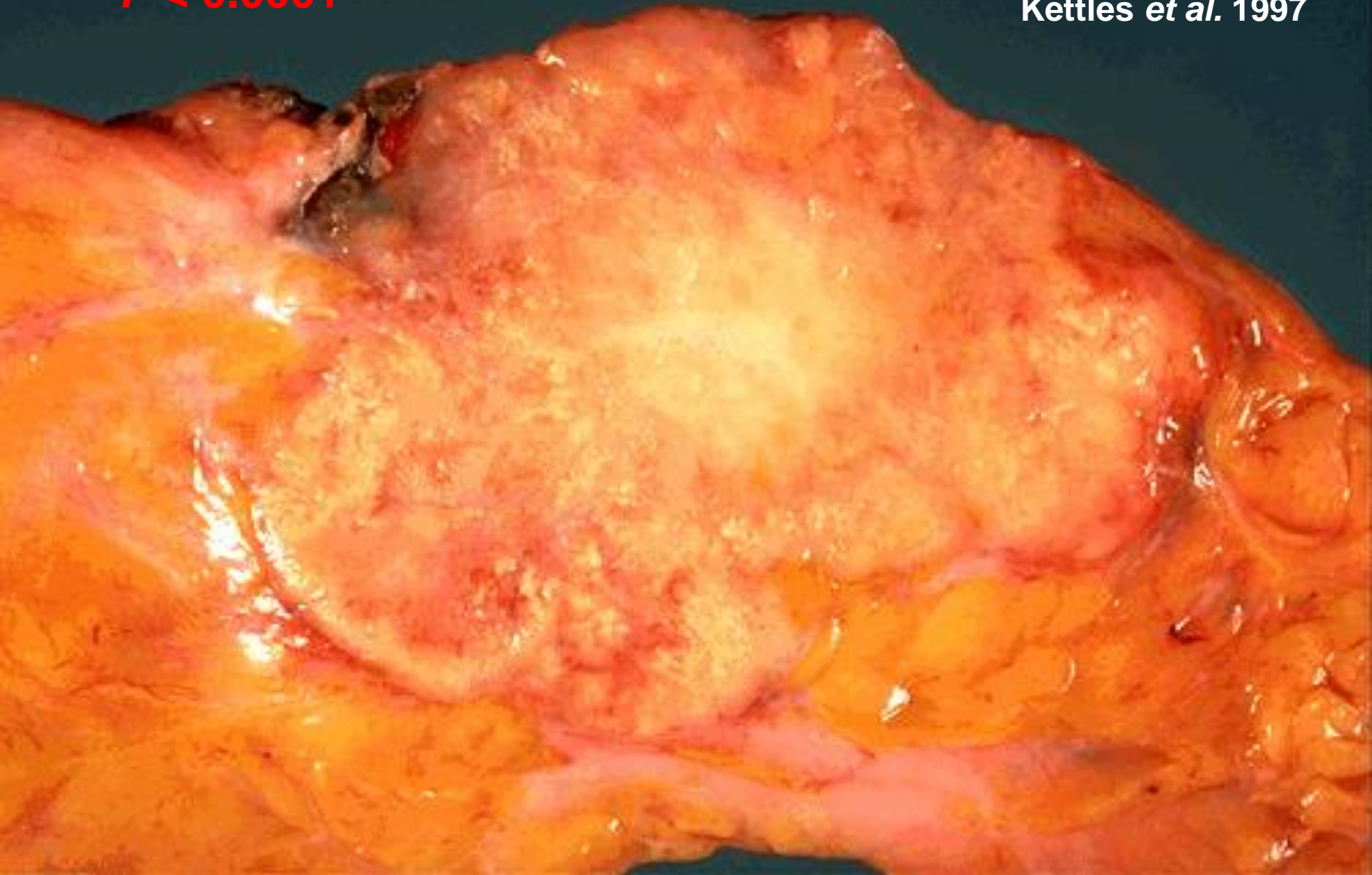


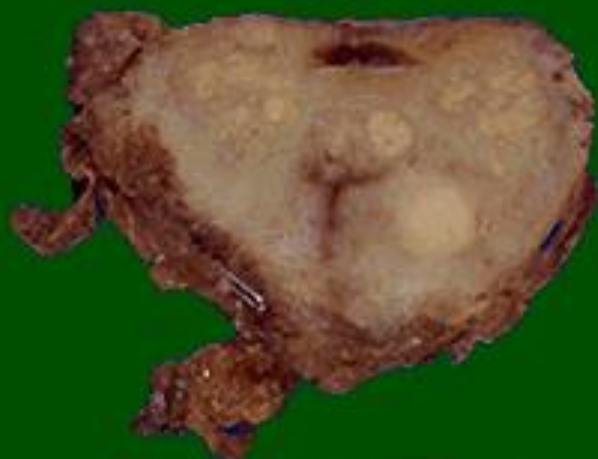
Sanderson *et al.* 2001

Human Cells

$P < 0.0001$

In humans
Kettles *et al.* 1997





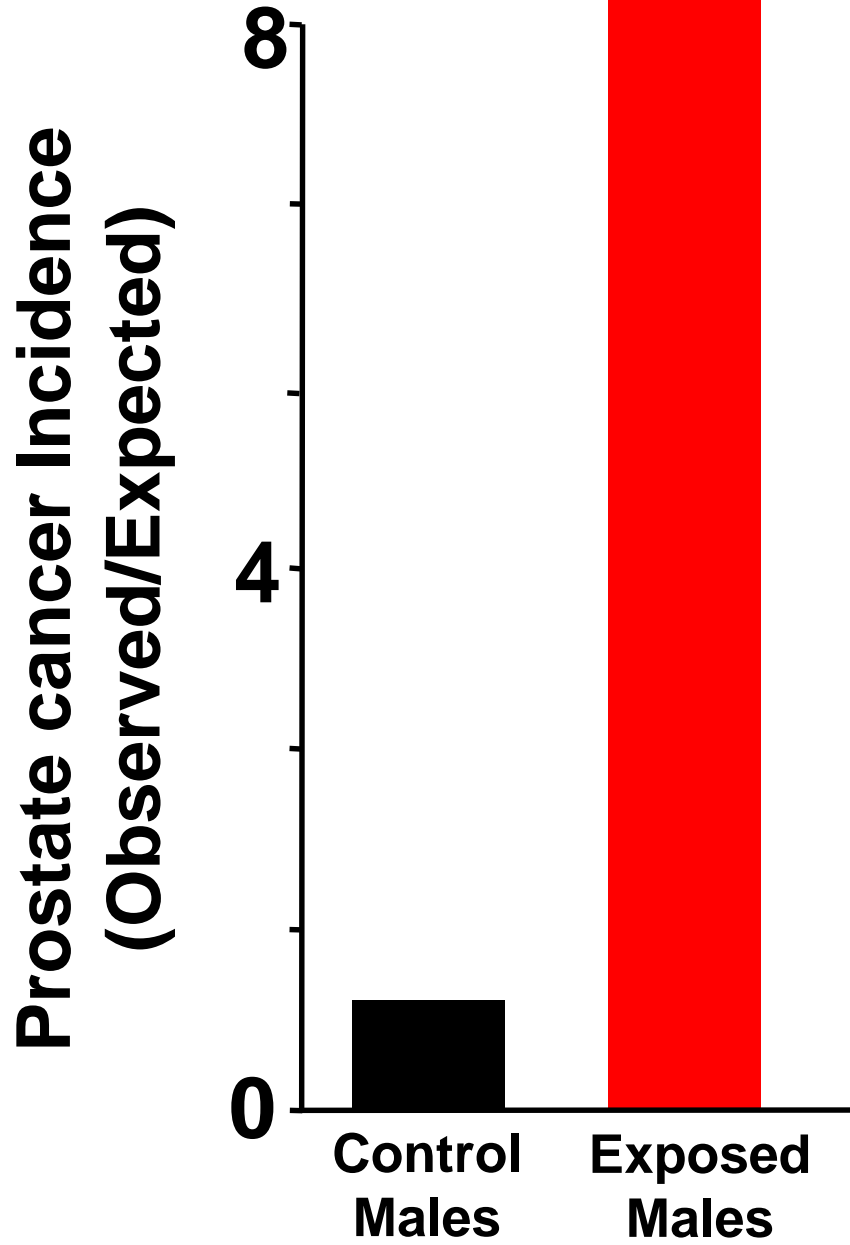
“The increase in all cancers combined seen in the overall study group was concentrated in the company employee group.” (page 1052)

“The increase in prostate cancer in male subjects was concentrated in company employees.” (page 1052).

“The prostate cancer increase was further concentrated in actively working company employees.” (page 1053)

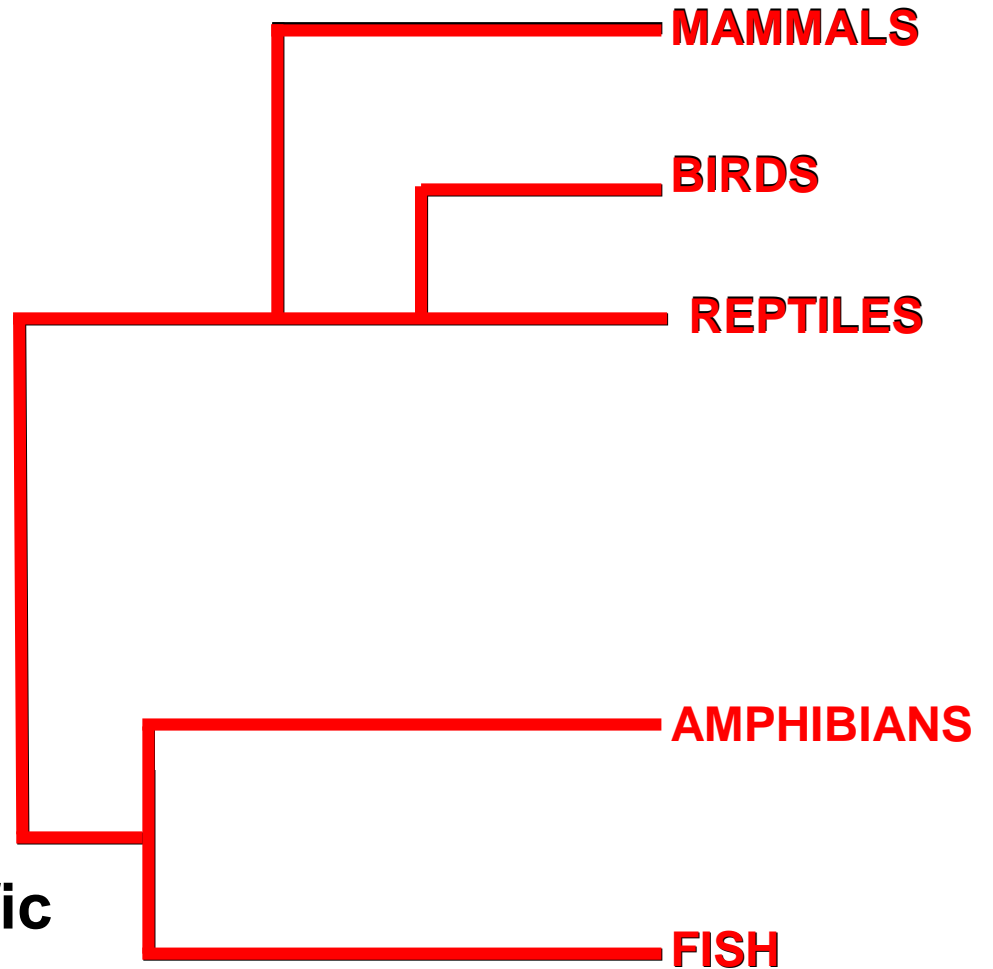
“all but one of the cases occurred in men with 10 or more years since hire”. (page 1052)

“Analyses restricted to company employees also found that the prostate cancer increase was limited to men under 60 years of age.” (page 1053).



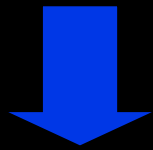
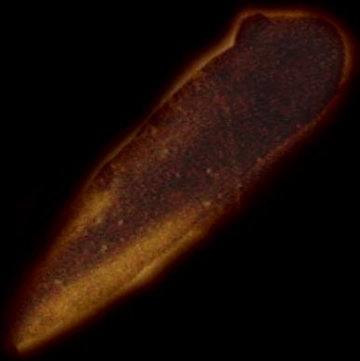
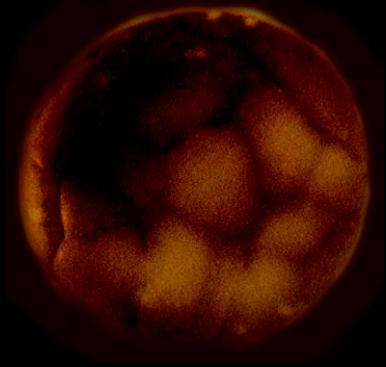
**“Atrazine has been used safely
for more than 47 years.”**

**-- Tim Pastoor
Syngenta Crop Protection**



“There is no direct scientific information to assess this hypothesis.”

(EPA, page 10)



DMSO

100M

100M

GATA4

DMSO

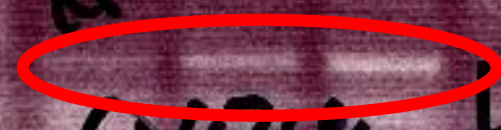
100M

100M

DMSO

100M

100M



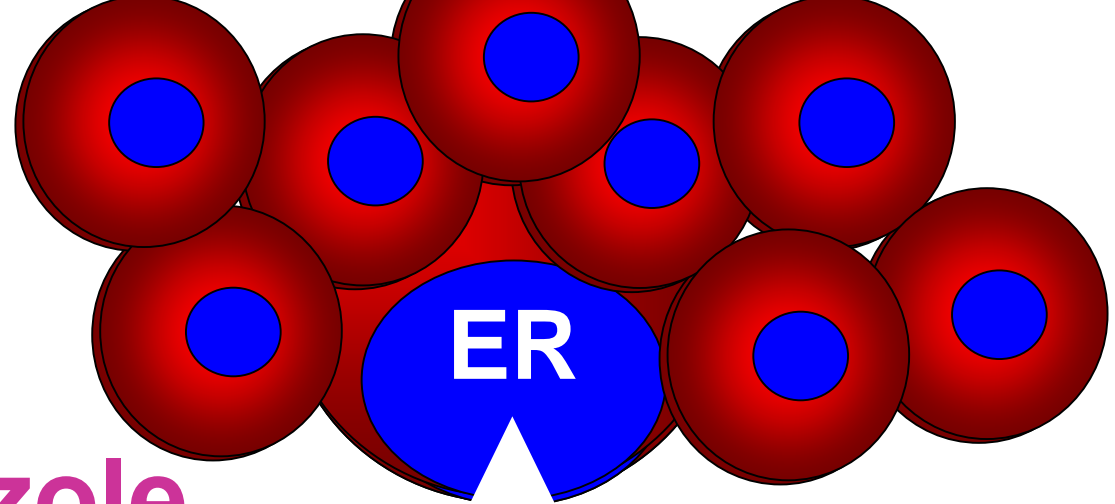
CYP19

LRH-1

DMSO

100M

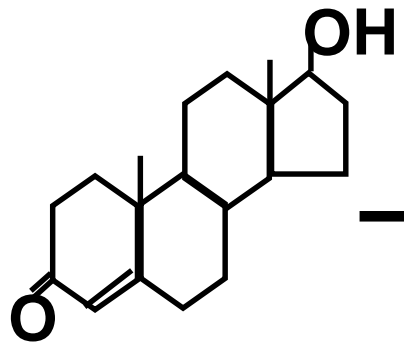
ERα



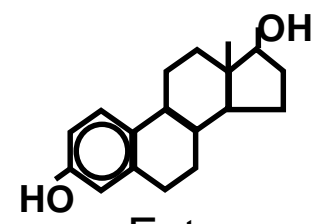
Letrozole



Aromatase

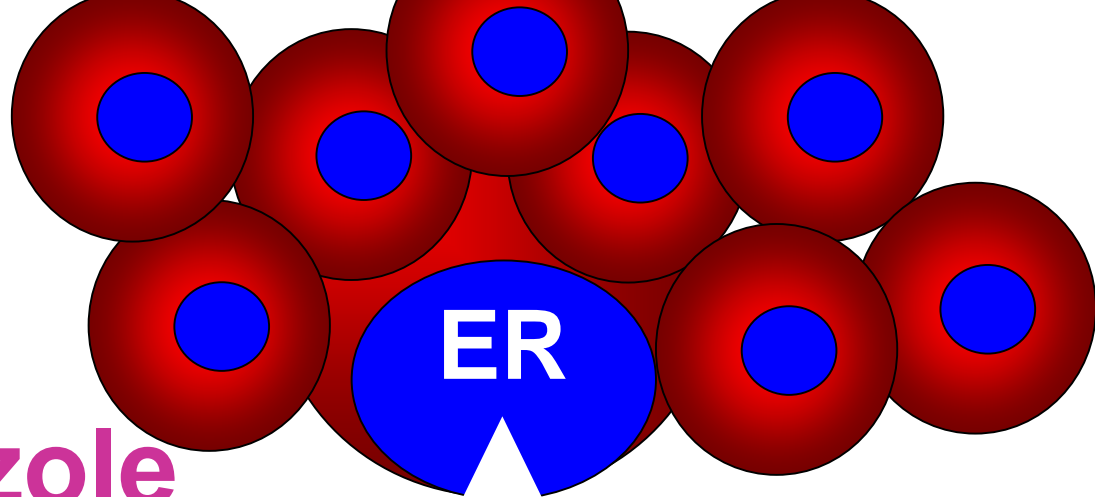


Testosterone



Estrogen

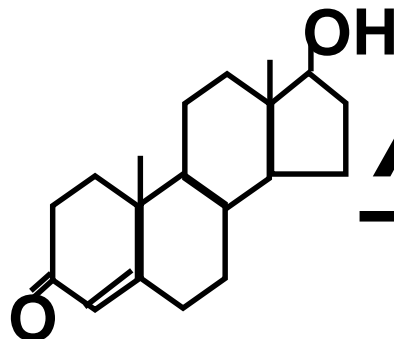




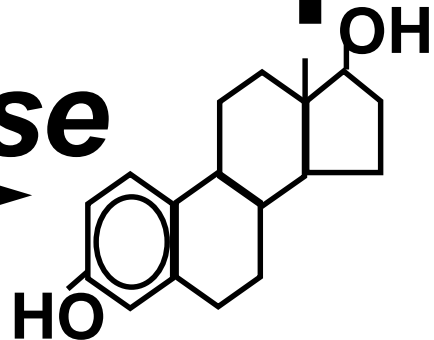
Letrozole



Aromatase



Testosterone



Estrogen



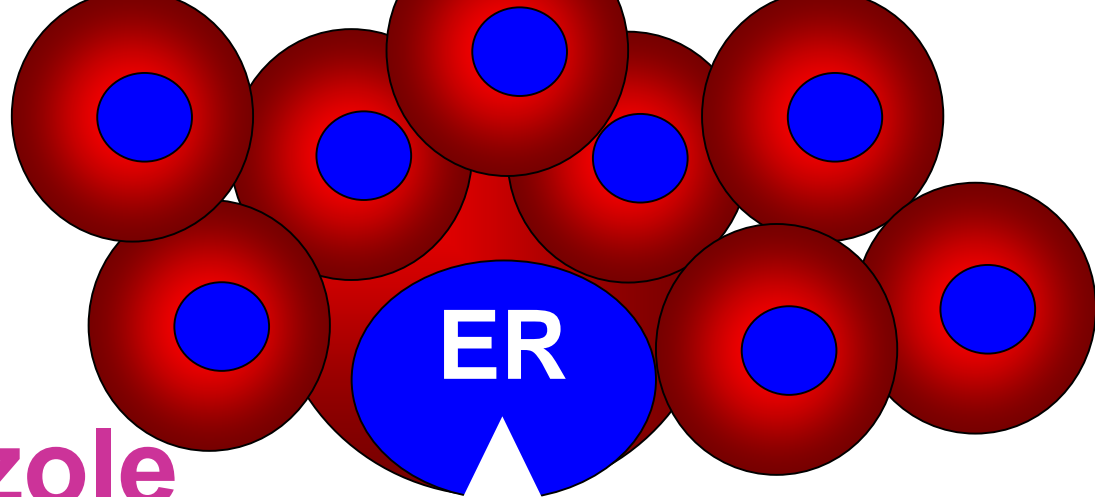
ATRAZINE



Clinical Trials of drugs in development...



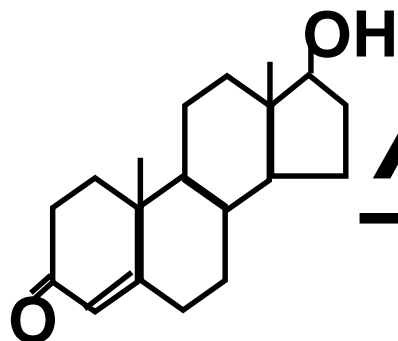
“Novartis Oncology offers treatments for cancers that range from breast cancer to leukemia to bone cancer to carcinoid tumors.” – novartis.com



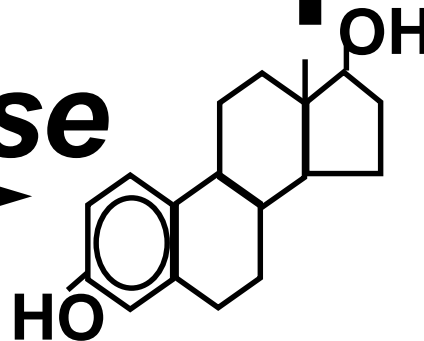
Letrozole



Aromatase



Testosterone

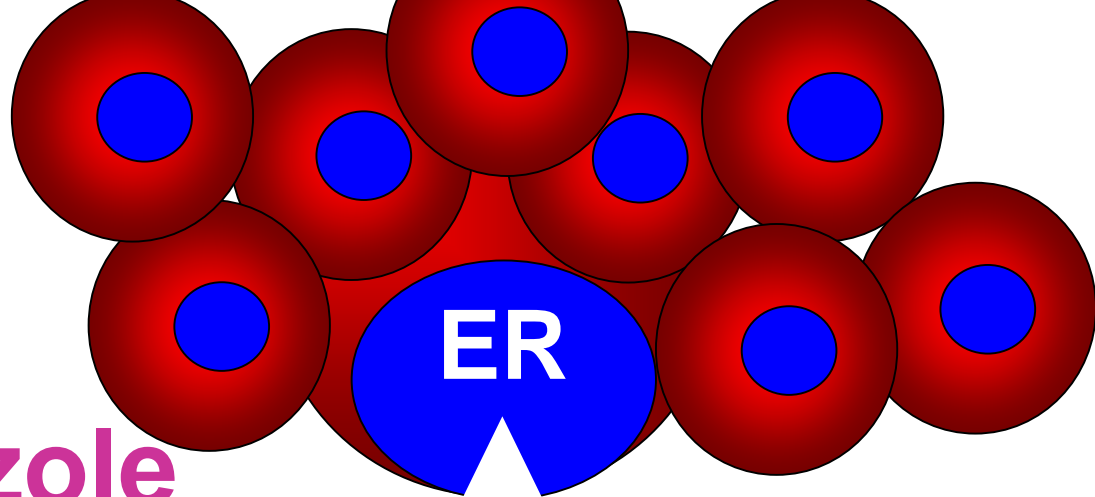


Estrogen



ATRAZINE

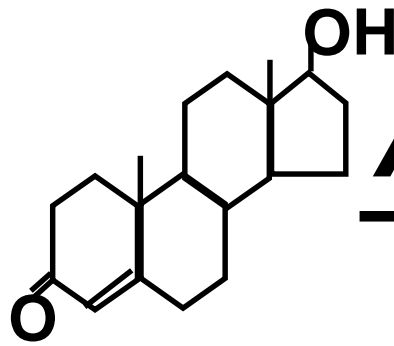




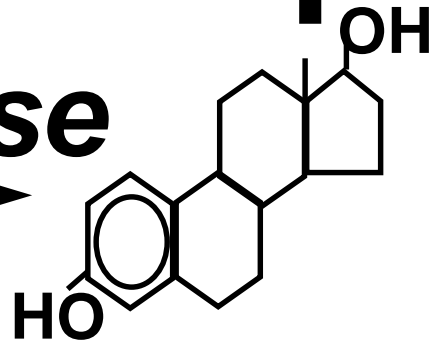
Letrozole



Aromatase



Testosterone



Estrogen



ATRAZINE



“...use of atrazine according to the label instructions will not likely result in harm to human health or the environment.”

**-- Office of Pesticide Programs
US EPA, 2008**

Working Hypothesis

1

Apical Effects

NO

STOP

YES

Ecological
Relevance

2

Sex Steroid
Measurements

NO

Test for
Alternative Effects

YES

3

Aromatase
Activity ?

NO

Test for
Alternative Effects

YES

4

Aromatase
Inhibitor
Study

Mechanism



Working Hypothesis

1

Apical Effects

NO

STOP

YES

Ecological
Relevance

2

Sex Steroid
Measurements

NO

Test for
Alternative Effects

YES

3

Aromatase
Activity ?

NO

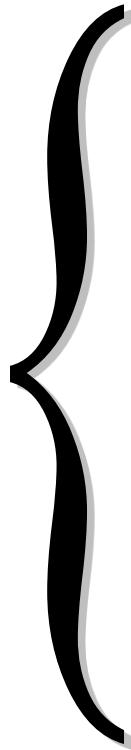
Test for
Alternative Effects

YES

4

Aromatase
Inhibitor
Study

Mechanism





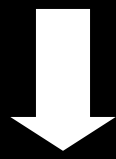
**Prostate
And
Mammary
Cancer**



**Immune
Failure**



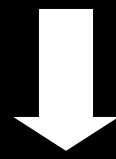
Abortion



**Impaired
Mammary
Development**



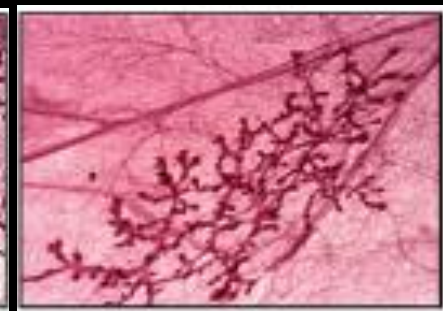
**Prostate
Disease**



**Neural
Damage**



Control



Atrazine



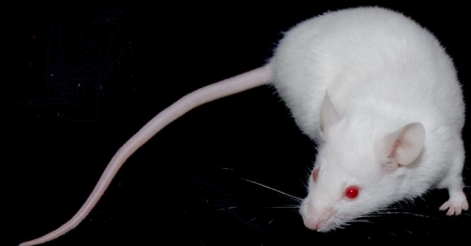
**Prostate
And
Mammary
Cancer**



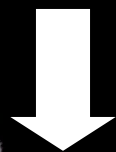
**Immune
Failure**



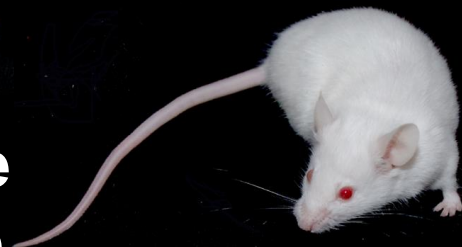
Abortion



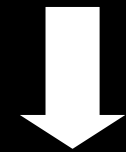
**Impaired
Mammary
Development**



**Prostate
Disease**



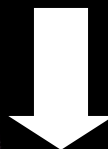
**Neural
Damage**



**Impaired
Growth and Development**



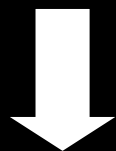
Abortion



**Impaired
Mammary
Development**



**Prostate
Disease**



**Impaired
Growth and Development**



**“The ultimate decision
is much bigger than science...
...it weighs in public opinion.”**

**-- Stephen Bradbury
US EPA, Dec 3, 2006**

Thank you

**Dr. Tyrone Hayes
University of California – Berkeley**

tyrone@berkeley.edu

Dr. Tyrone B. Hayes



Dr. Tyrone B. Hayes's work is transforming biology one battle at a time. From a very early age, he knew that he was interested in biology, amphibians in particular. Always fascinated by frogs and toads, this fascination turned into reality and a career. Dr. Hayes's work paves the way for an integrative approach to understanding how an organism reacts to changes in its environment.

Recently his work has gained international recognition for demonstrating how atrazine, a widely used pesticide which is now found in many water sources, has been shown to alter reproductive development (act as an endocrine disruptor) in frogs even at extremely low levels. Beyond his integrative work in conservation, he has won numerous teaching awards, conservation awards, and recognition as a leader in the scientific community.