Environmental Sex Determination

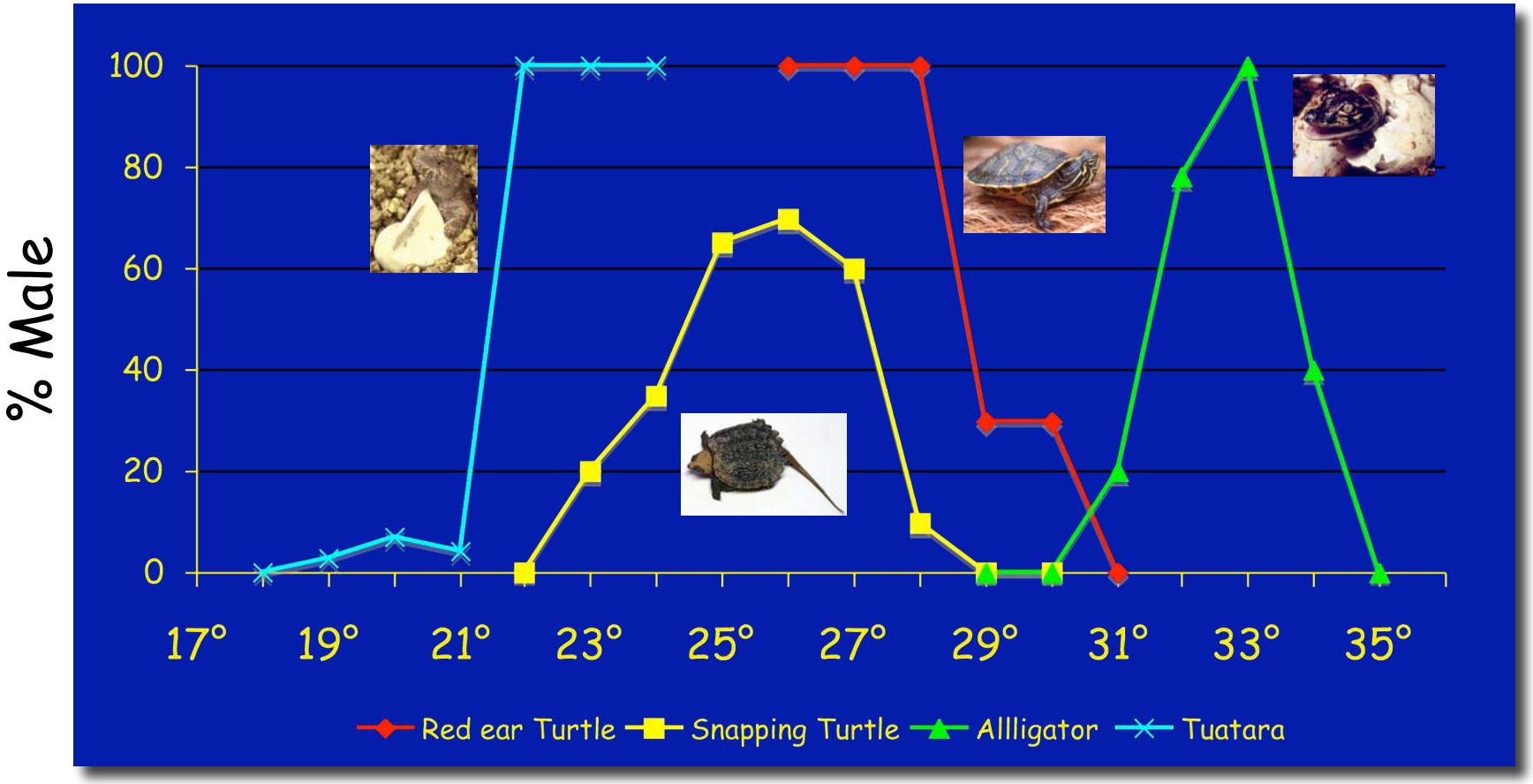
Temperature Sex Determination

- Common in many vertebrate species
  - Some fish
    - cool males/ warm females
  - Some anurans and salamanders
    - cool females/warm males
  - Many turtles
    - generally cool males/warm females
    - Exception snapping turtle
    - female warm and cool/ male at moderate temperature

TSD 2

- Some lizards
  - cool females/warm males
- All crocodilians
  - cool female/warm male
  - Also
    - cool and hot females
    - males at moderate temperatures
- Some birds? Not observed to date
- Not observed in mammals

TSD Reptiles



Mechanisms

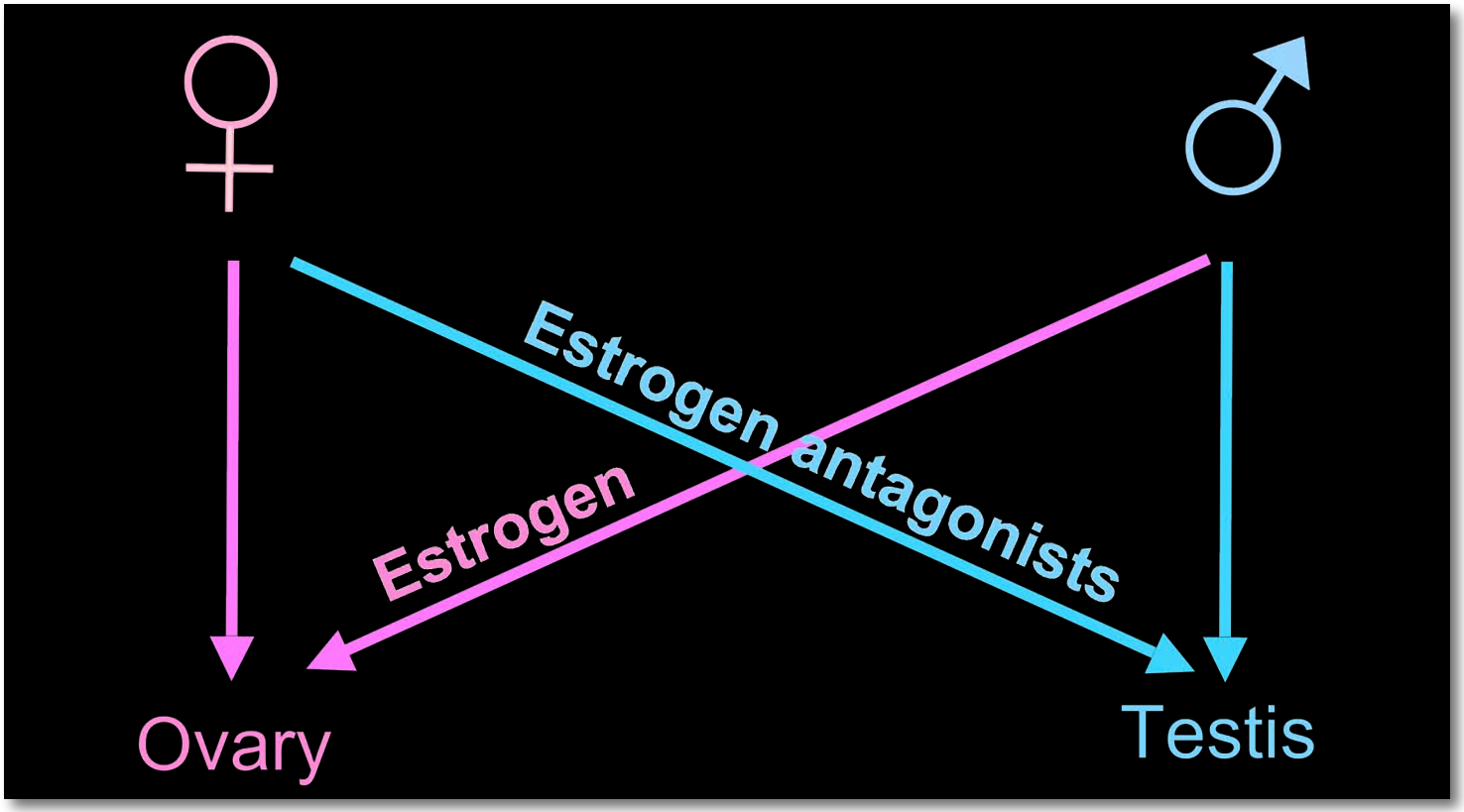
- *Hypothesis*
  - Temperature alters estrogen production by the gonad, which influences differentiation
  - Temperature-dependent aromatase actvity in European Pond turtle (*Emys obicularis*)
- Effect only on embryo early in differentiation

Sex Differentiation in Fish

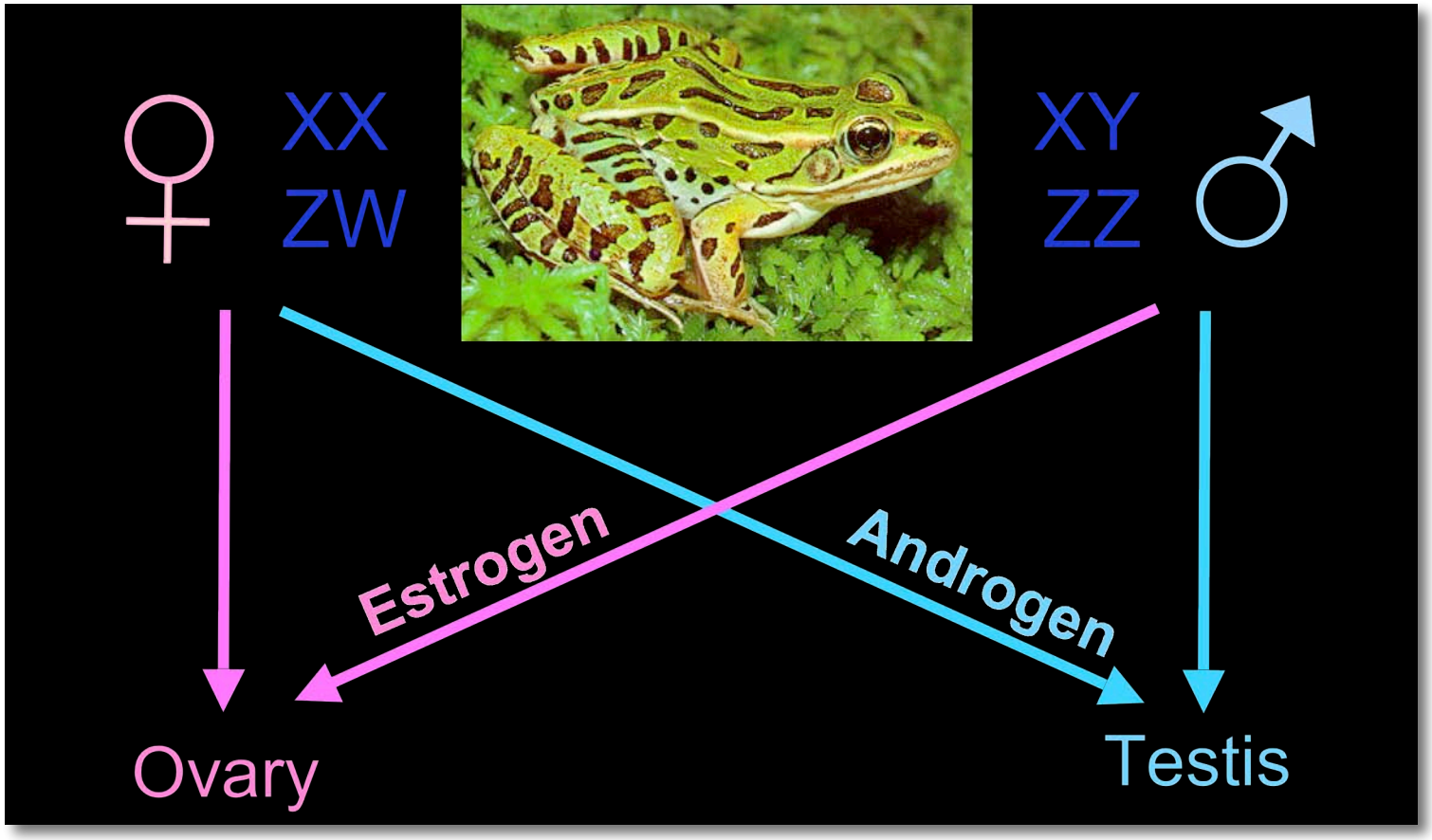
XX / XY / Temperature

(WY,WX, XX) / (YY, XY)

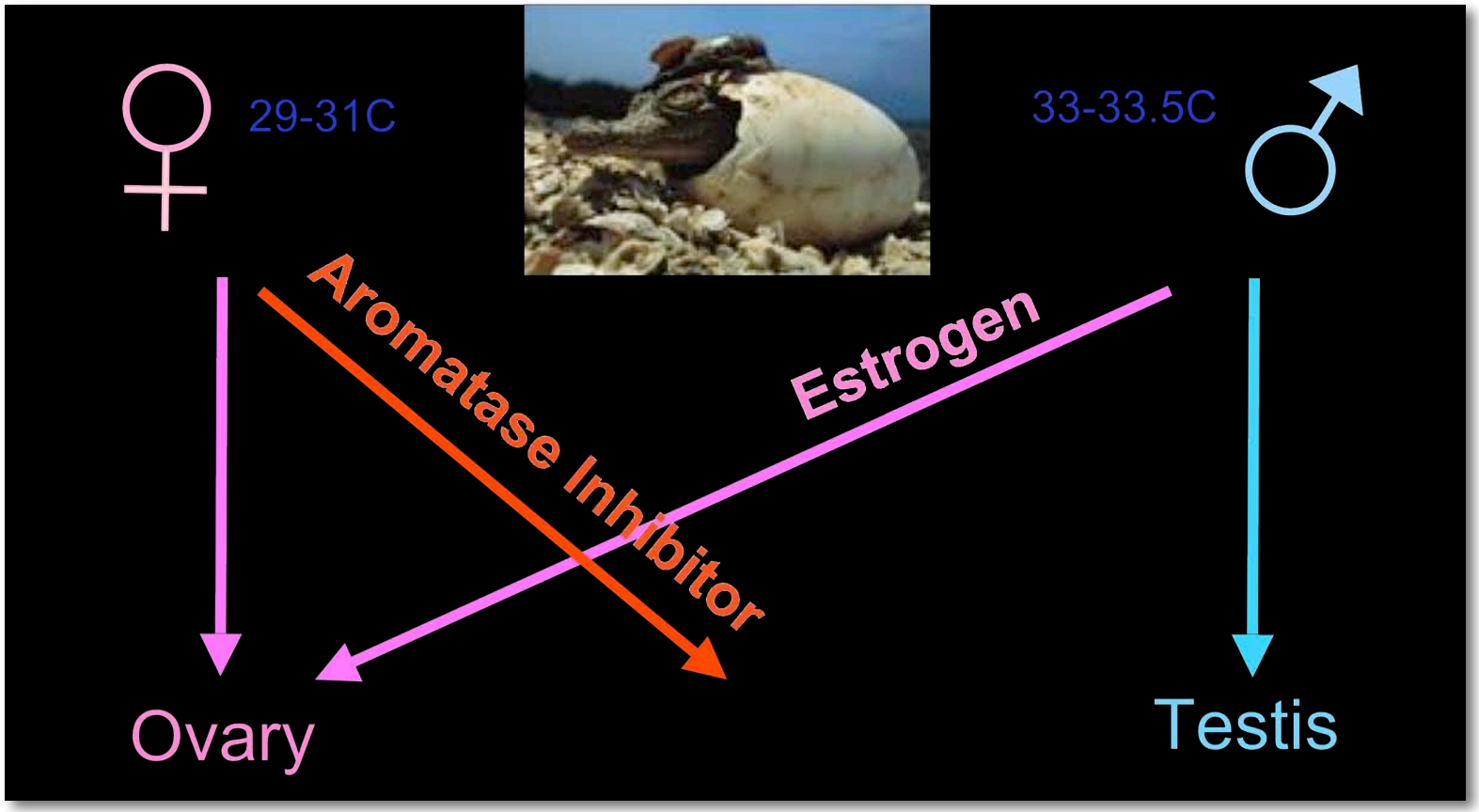
Social cues



Sex Differentiation in Frogs



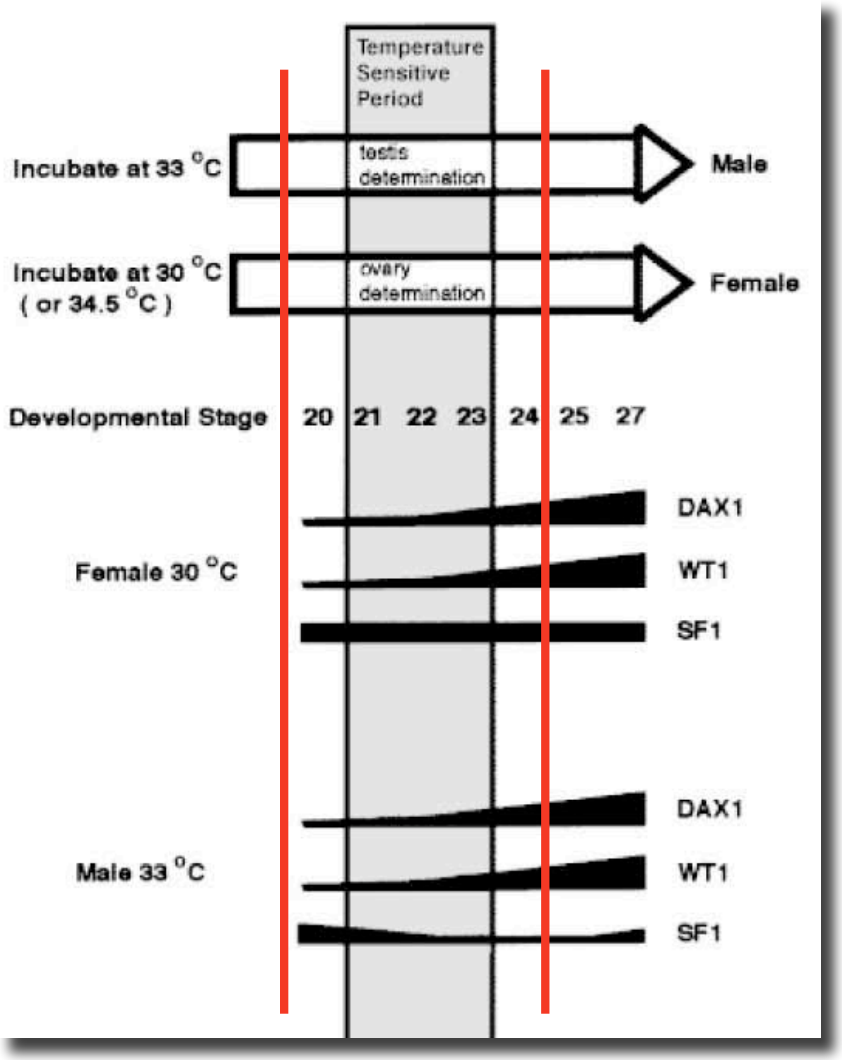
Sex Differentiation in Alligators



TSD and Genes

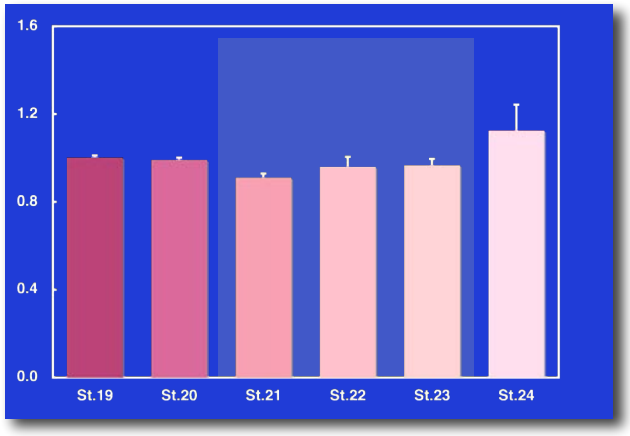
- Alligators have no SRY gene
- Gonadal differentiation
  - DAX-1
  - SF-1
  - WT-1
  - SOX9
  - AMH
  - DMRT-1
  - P450arom
  - ERα β
  - Heat Shock

Female Gonads (♀)

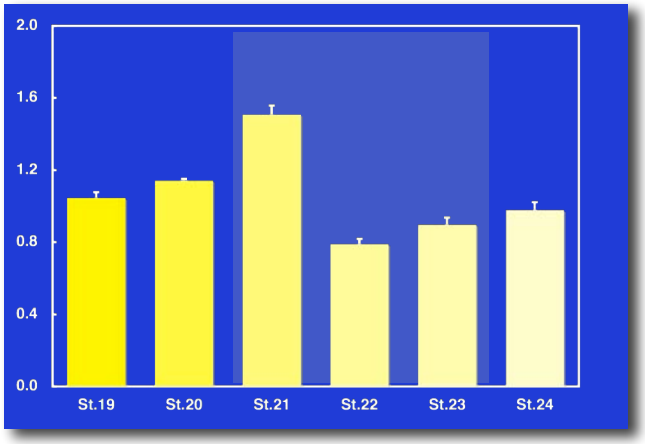


Western & Sinclair JEZ 290 (2001)

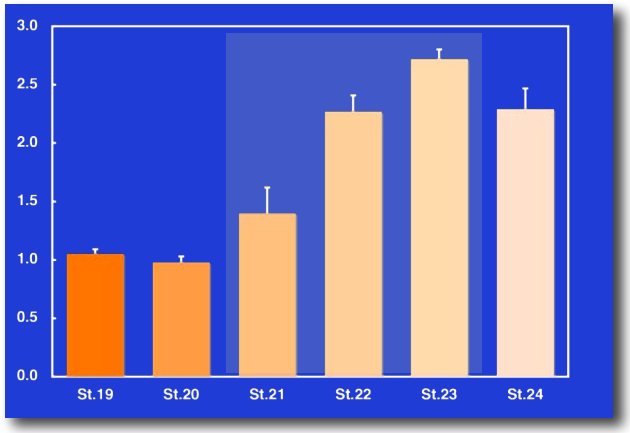
Dax1



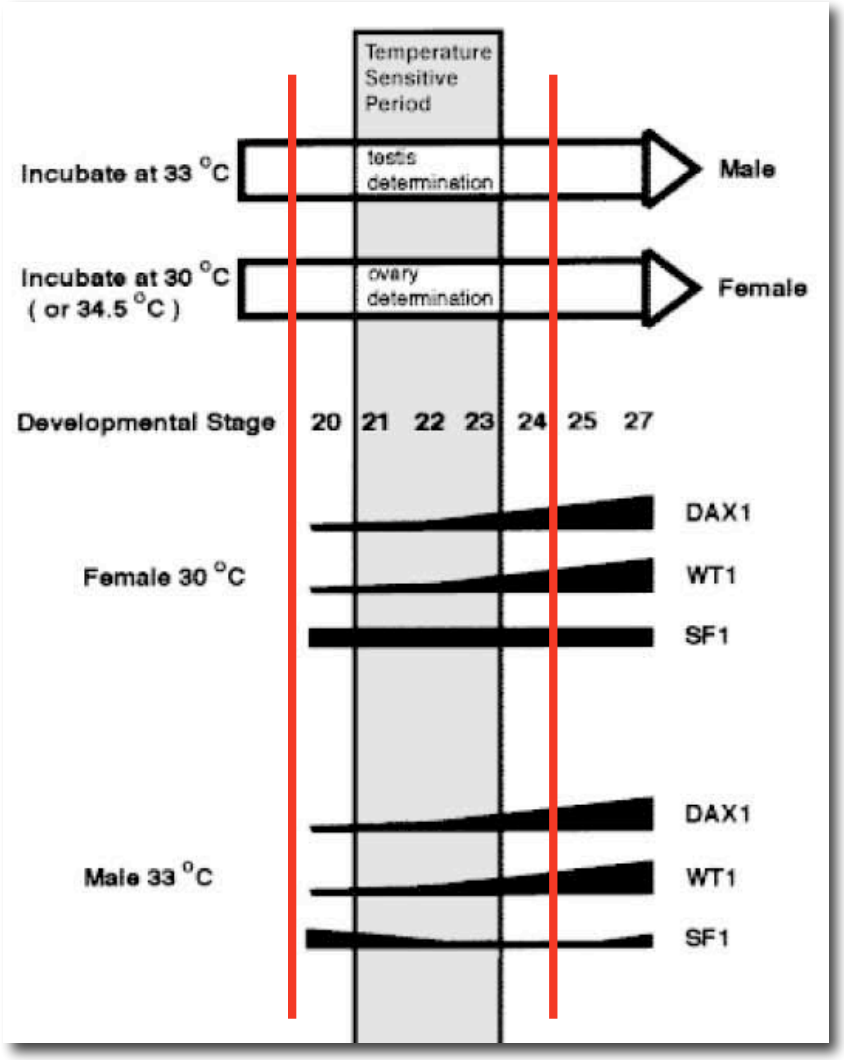
WT1



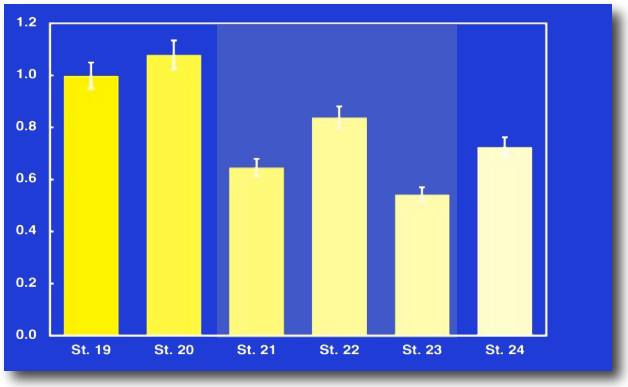
SF1



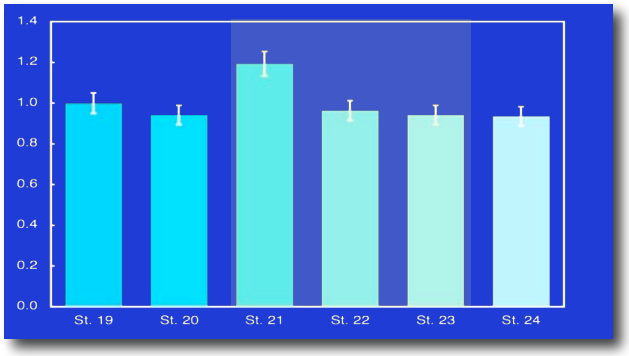
Male Gonads (♂)



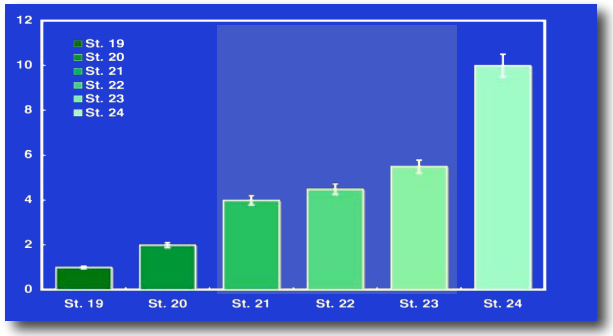
WT1



Sox9

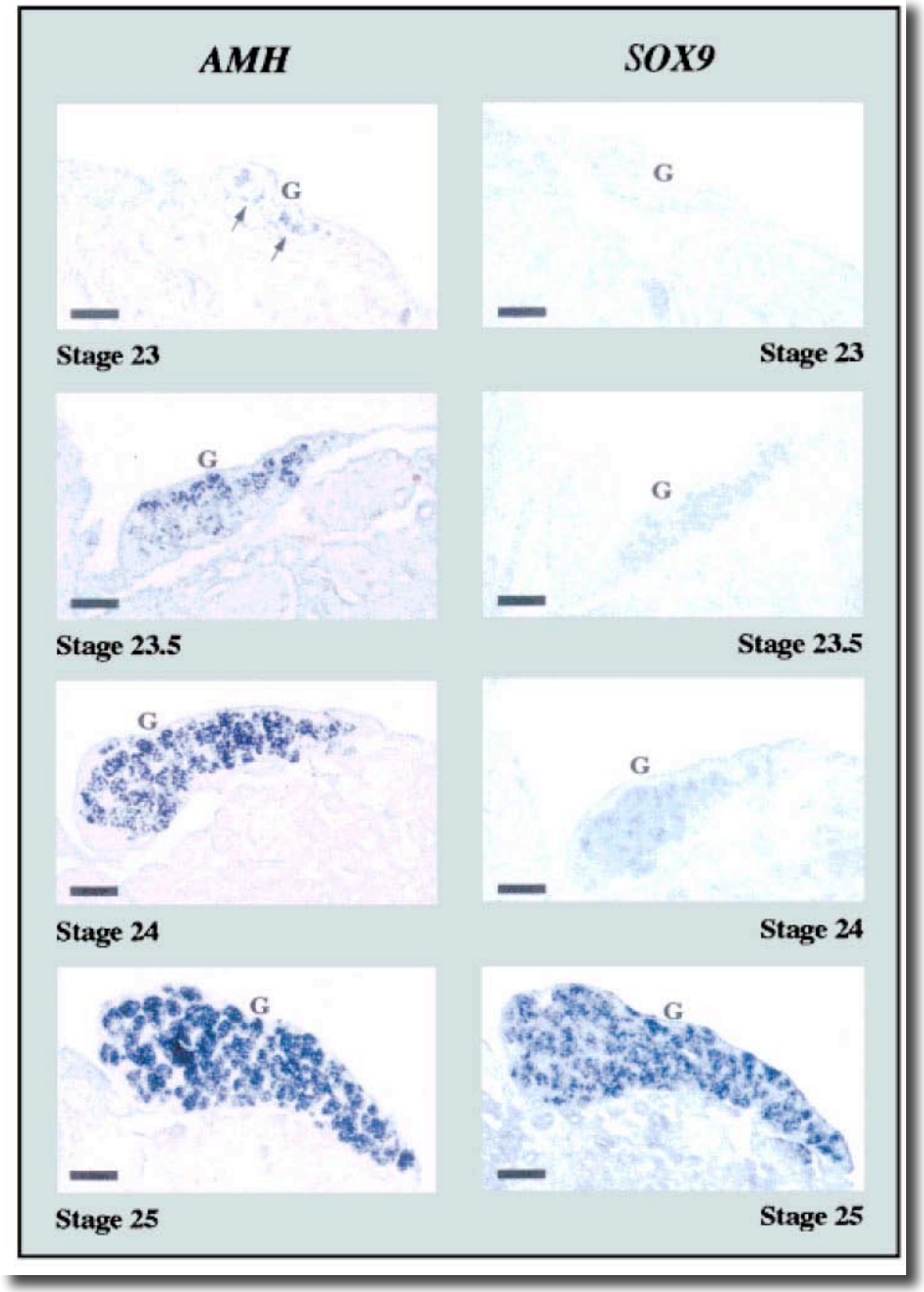


AMH



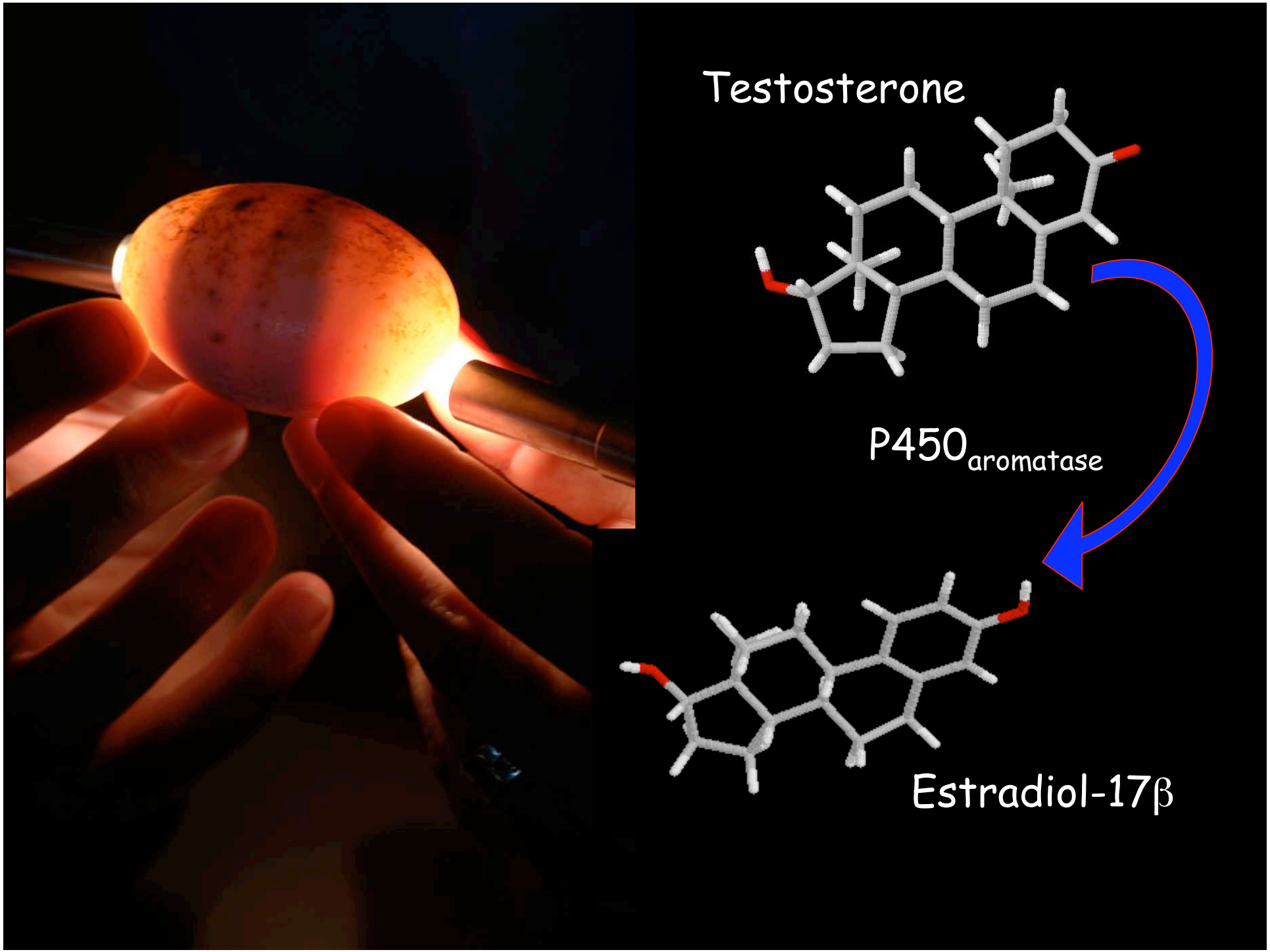
Western & Sinclair JEZ 290 (2001)

American Alligator



Embryos @ 33°C

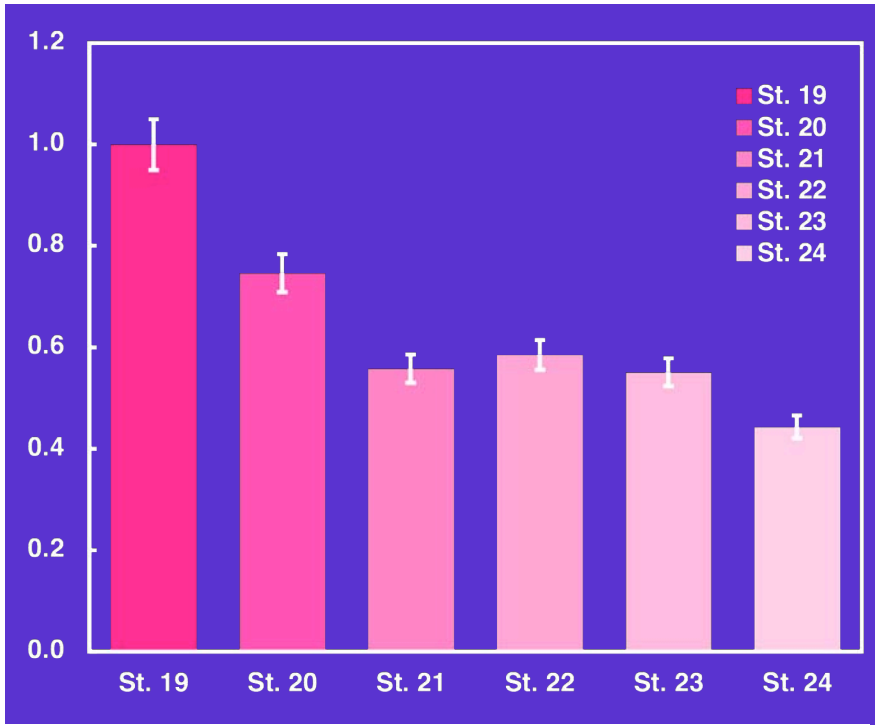
Western & Sinclair JEZ 290 (2001)


Testosterone
P450aromatase
Estradiol-17β

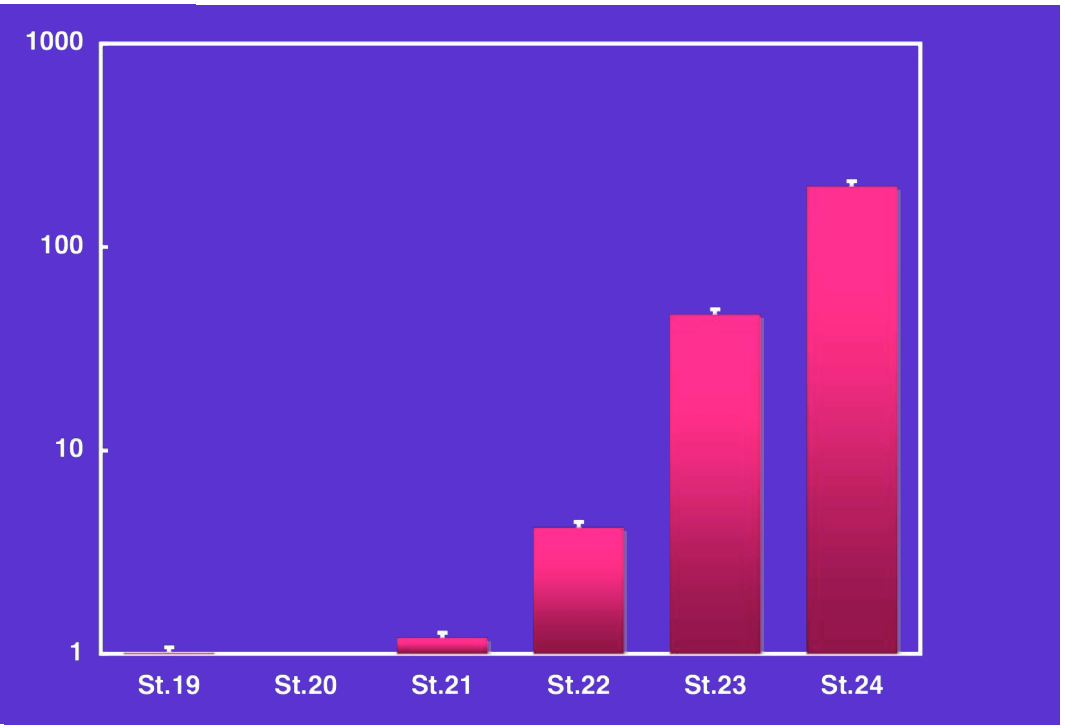
Quantitative Gene Expression in GAMs

$P450_{aromatase}$

Male Gonads (♂)

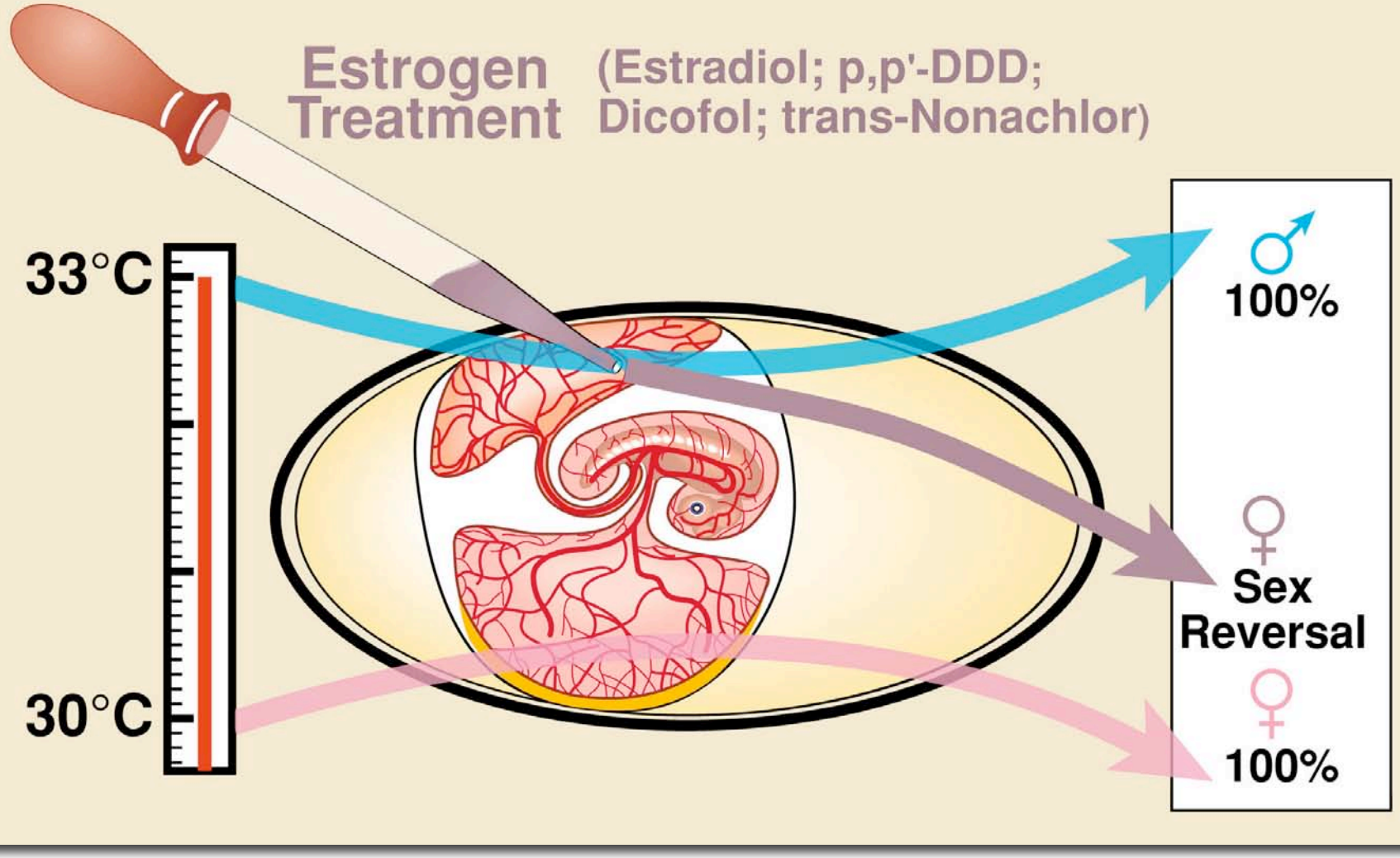


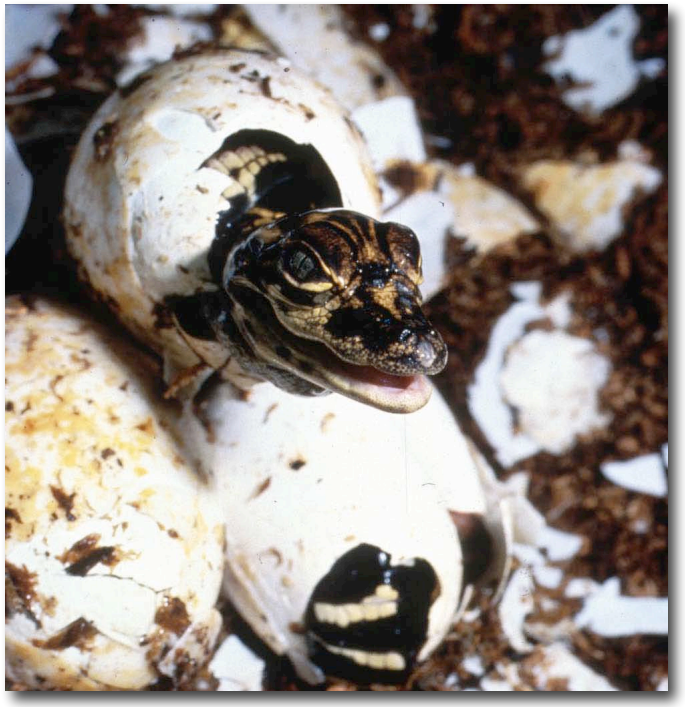
Female Gonads (♀)

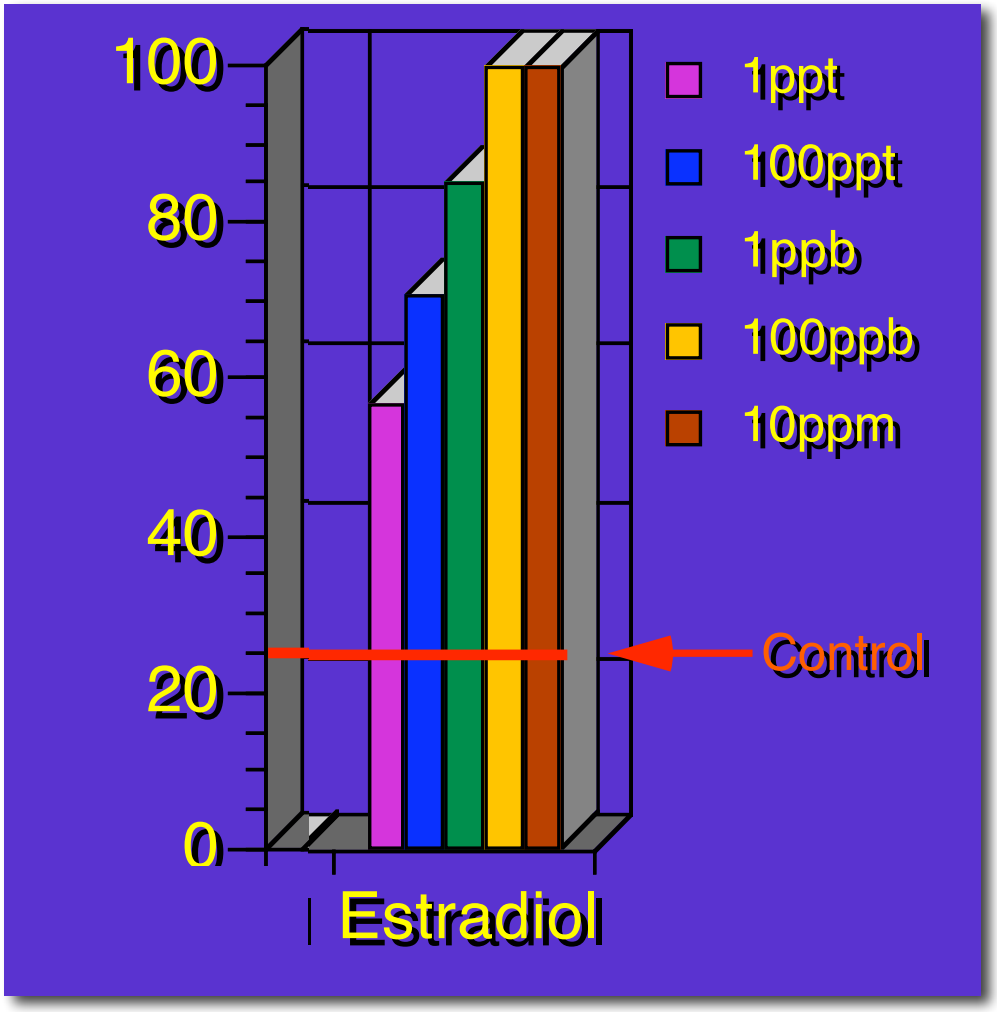


Katsu et al., unpubl. data

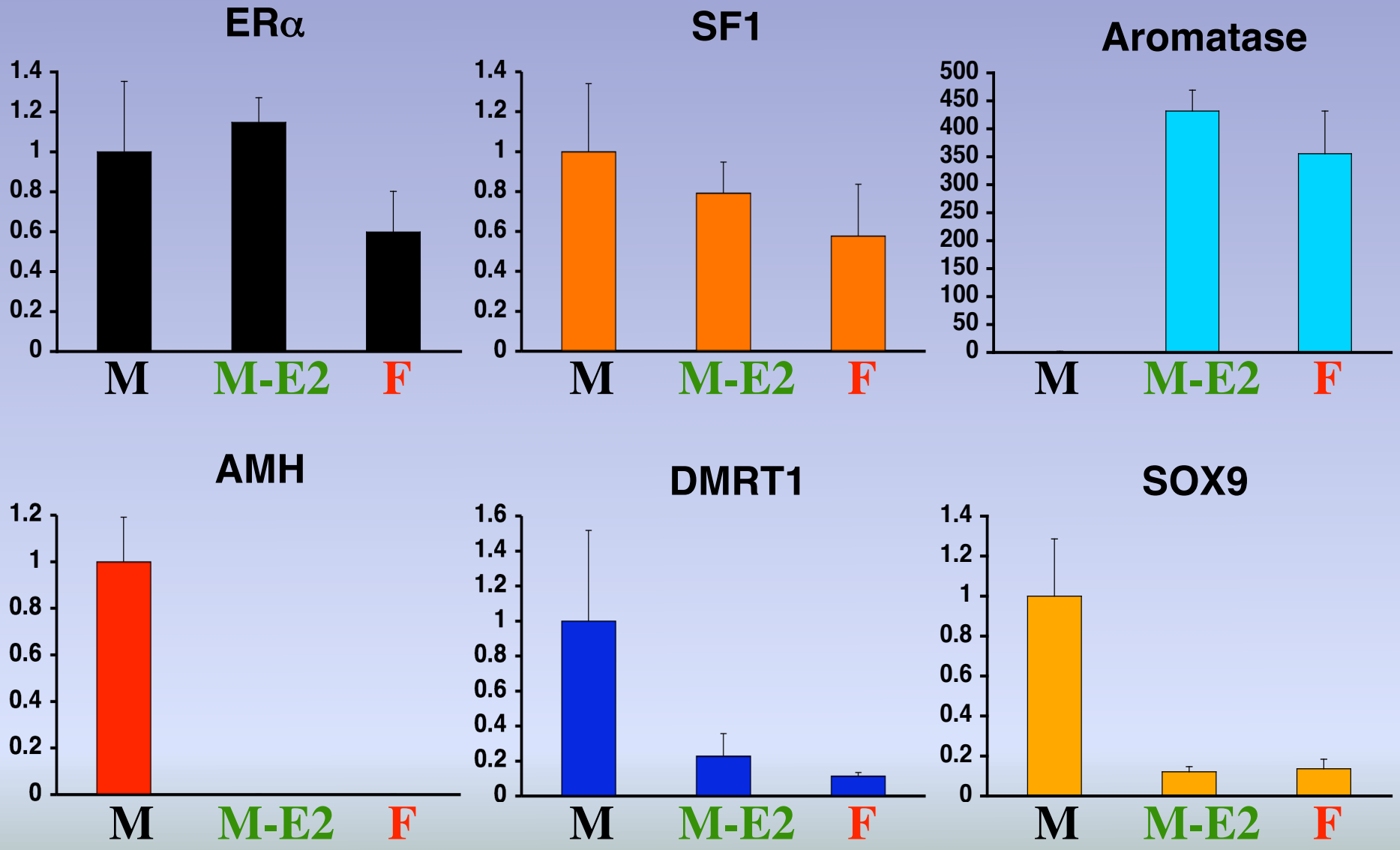
Sex Determination in Alligators






100
80
60
40
20
0
1ppt
100ppt
1ppb
100ppb
10ppm
Control
Estradiol

Gene Expression in Neonatal Gonads Incubated at Male or Female Temperatures, or at Male Temperature Exposed to Estrogen



Katsu et al. unpubl. data