Numerical Simulation and Modelling for EDA: Past, Present and Future

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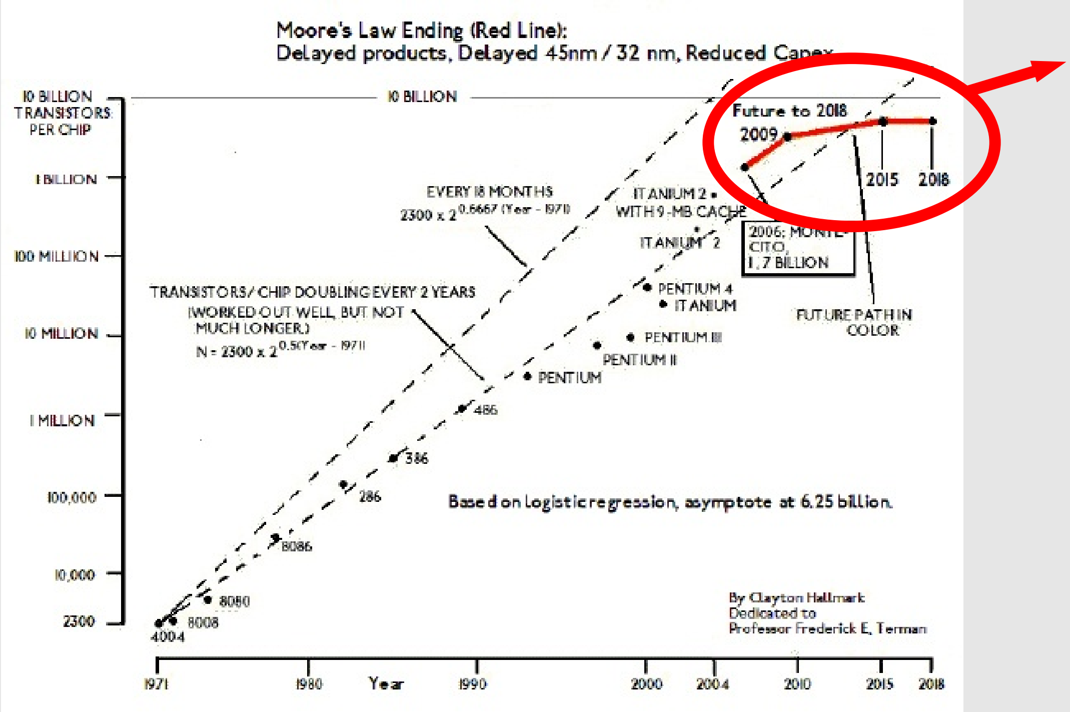
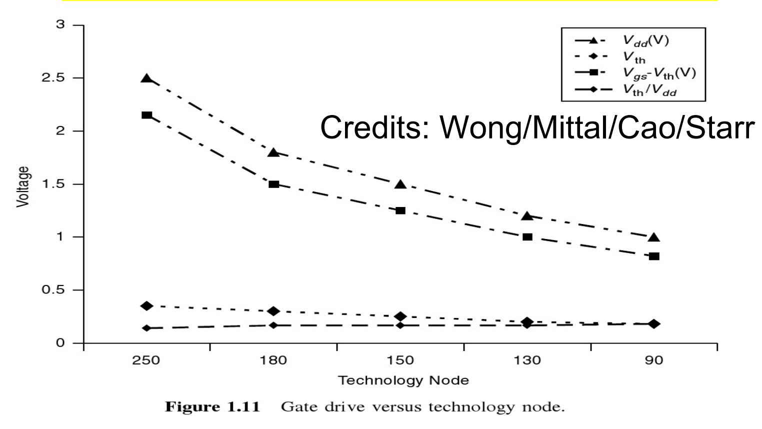
Resurgence of Simulation



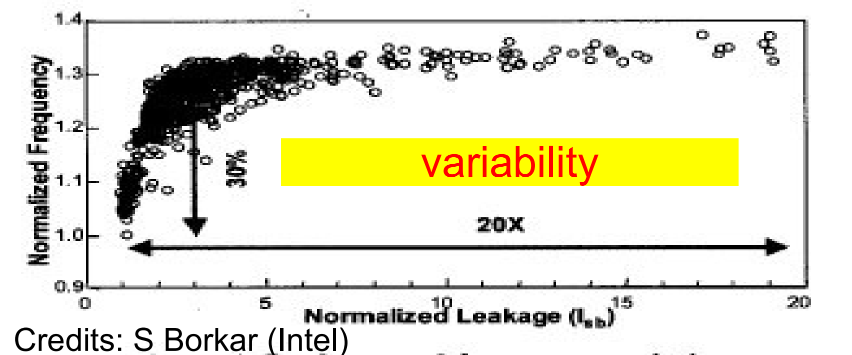
"Analog Issues" = breakdown of "clean" digital abstractions

shrinking supplies, noise margins



Credits: Wong/Mittal/Cao/Starr

Figure 1.11 Gate drive versus technology node.

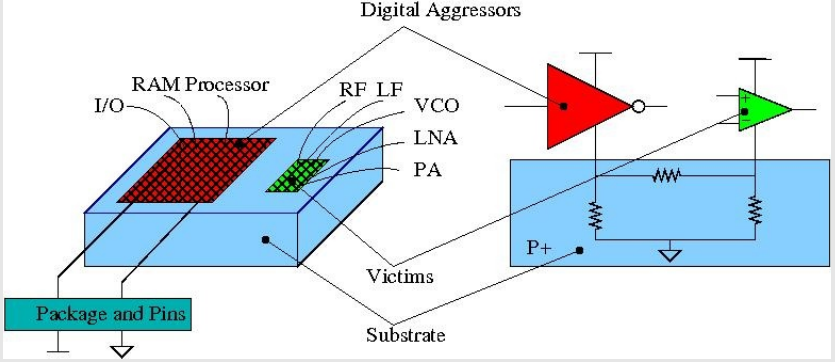


variability

Credits: S Borkar (Intel)

Figure 1: Leakage and frequency variations

substrate and supply interference



Fact: O(months) of simulation time spent characterizing digital cell libraries

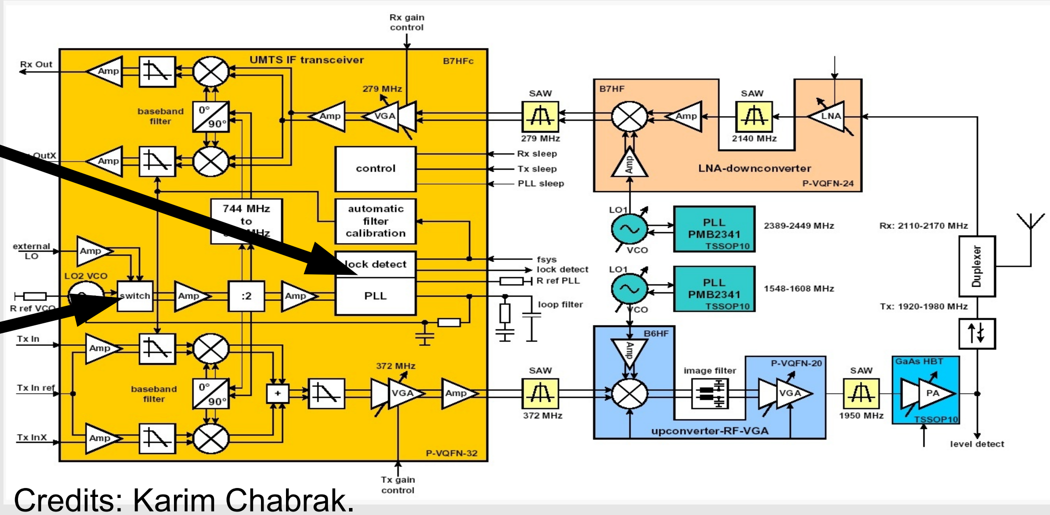
Numerical Simulation in EDA

- SPICE (analog): 70s
  - DC, AC, transient, DC noise
- RF: 70s-90s
  - periodic steady state, time-varying AC, time-varying noise
- interconnect, interference (digital): 80s-00s
  - LTI model reduction
- today's challenges:
  - variability
  - scale ("fast SPICE")
  - proliferation of experimental devices (nano)
  - system-level: macromodelling
  - applications outside EDA

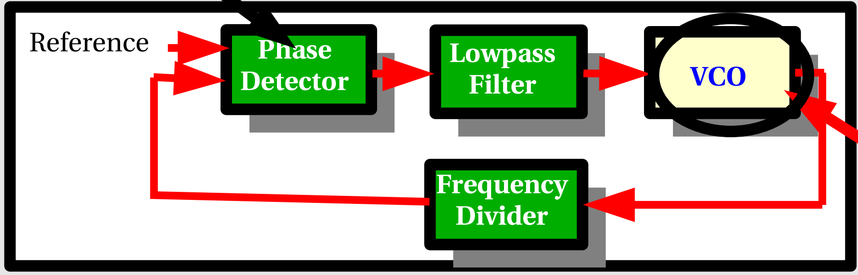
System Level Abstraction

High-level models

Low-level models



Credits: Karim Chabrak.



Reference

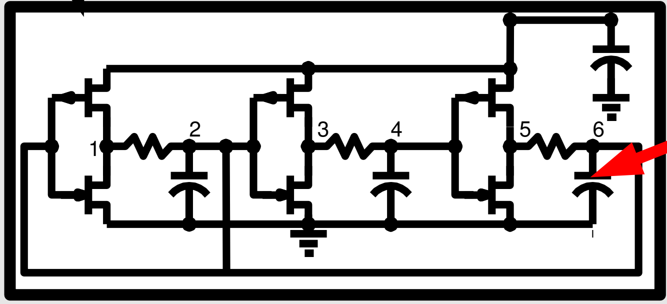
Phase Detector

Lowpass Filter

VCO

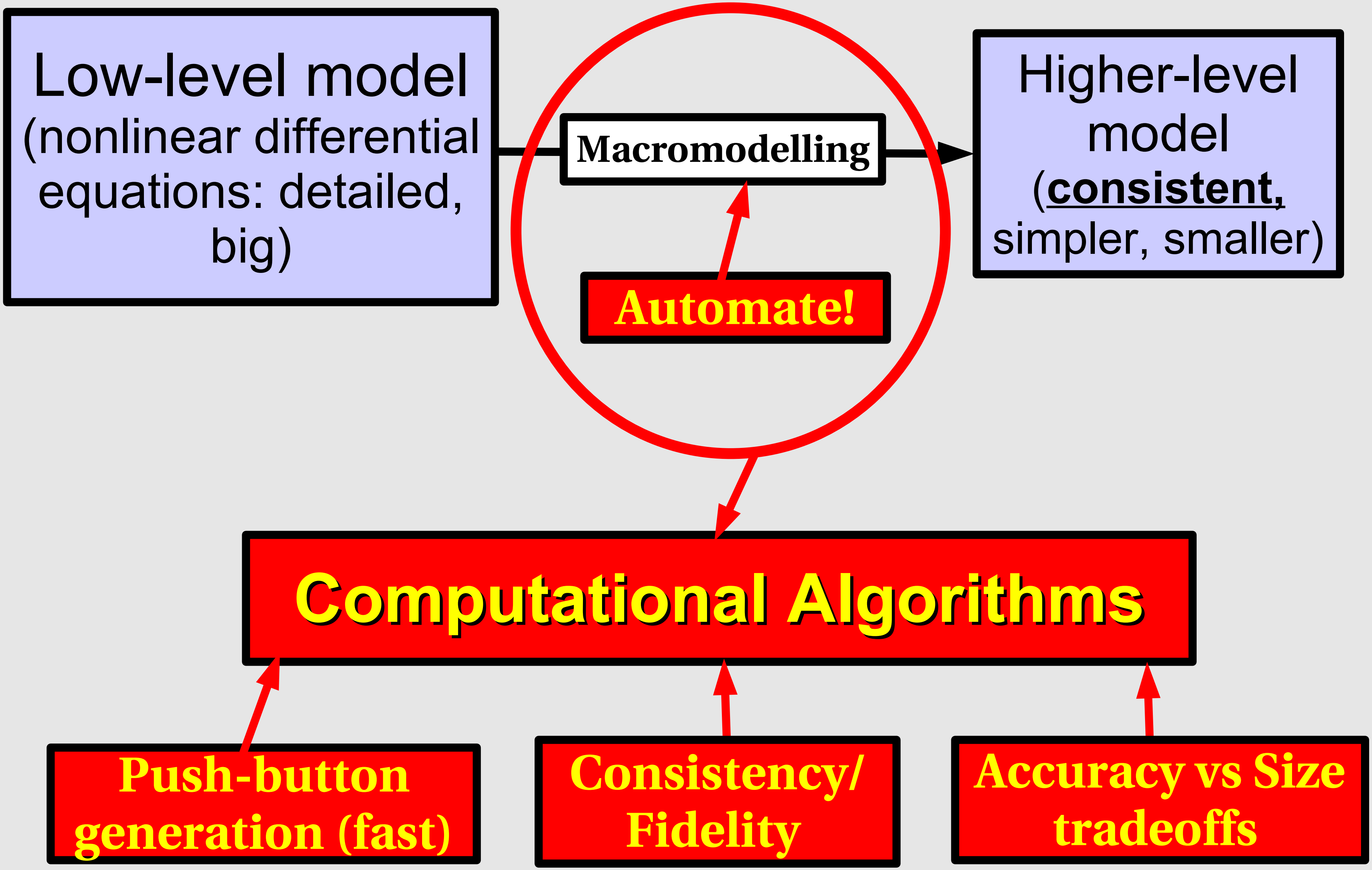
Frequency Divider

Model?



Accurate? Consistent?

Computational Macromodelling



Low-level model (nonlinear differential equations: detailed, big)

Macromodelling

Higher-level model (**consistent,** simpler, smaller)

Automate!

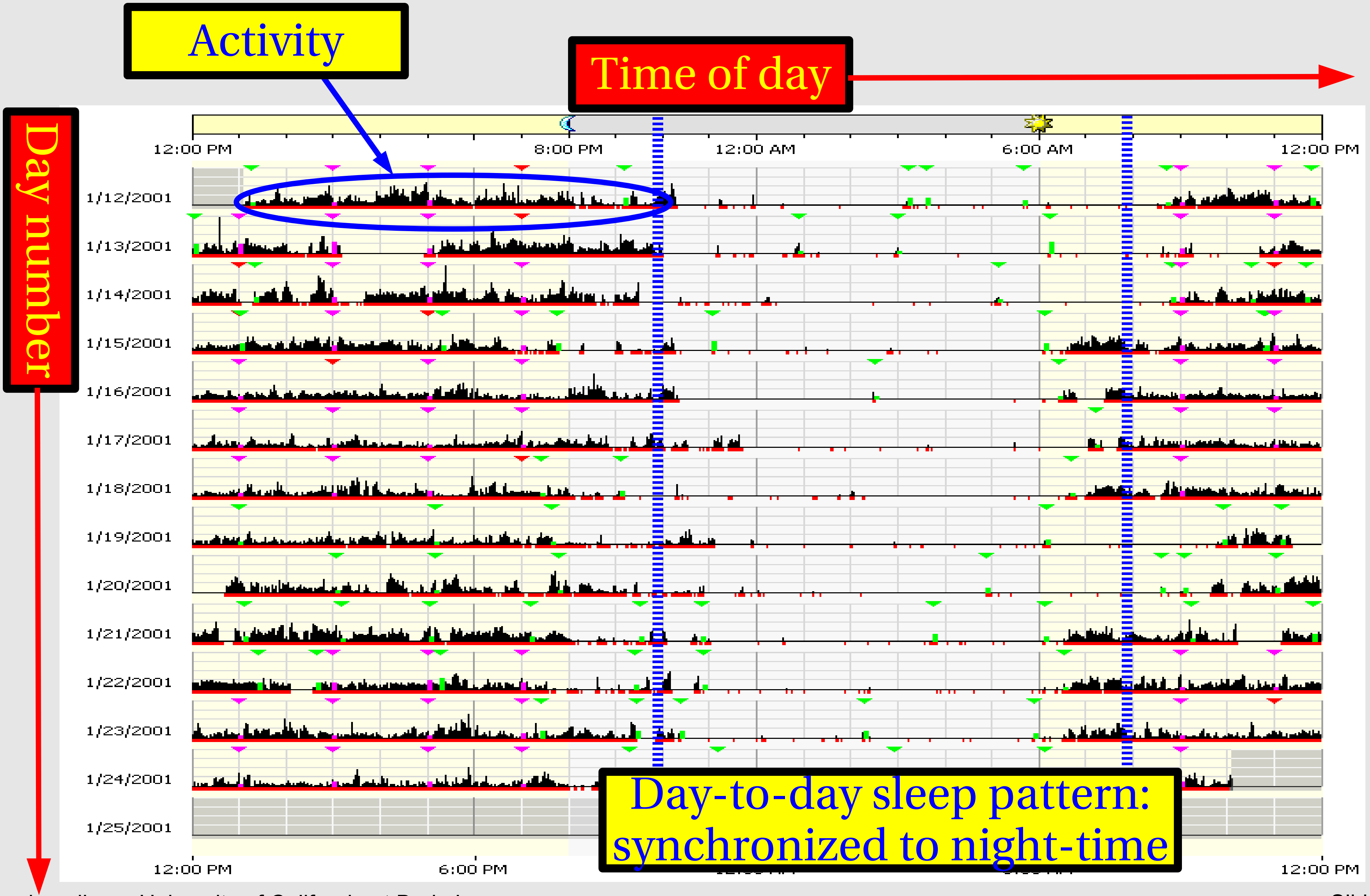
Computational Algorithms

Push-button generation (fast)

Consistency/ Fidelity

Accuracy vs Size tradeoffs

Circadian Biological Oscillators (Human Sleep/Wake Patterns)



Activity

Time of day

Day number

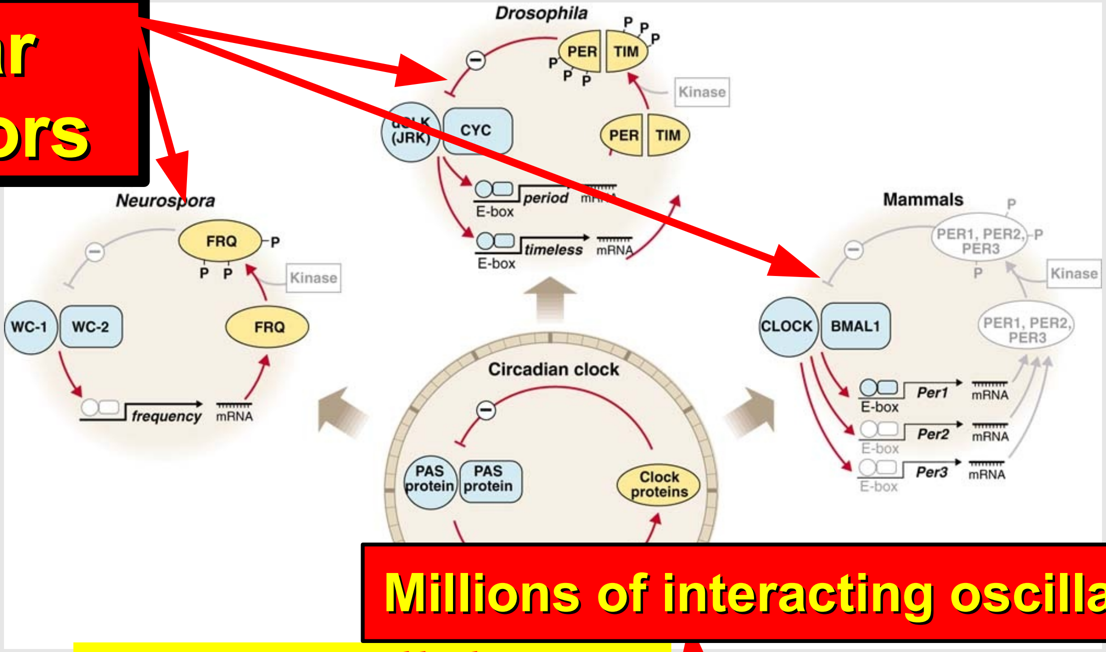
Day-to-day sleep pattern: synchronized to night-time

Circadian Rhythm Oscillators

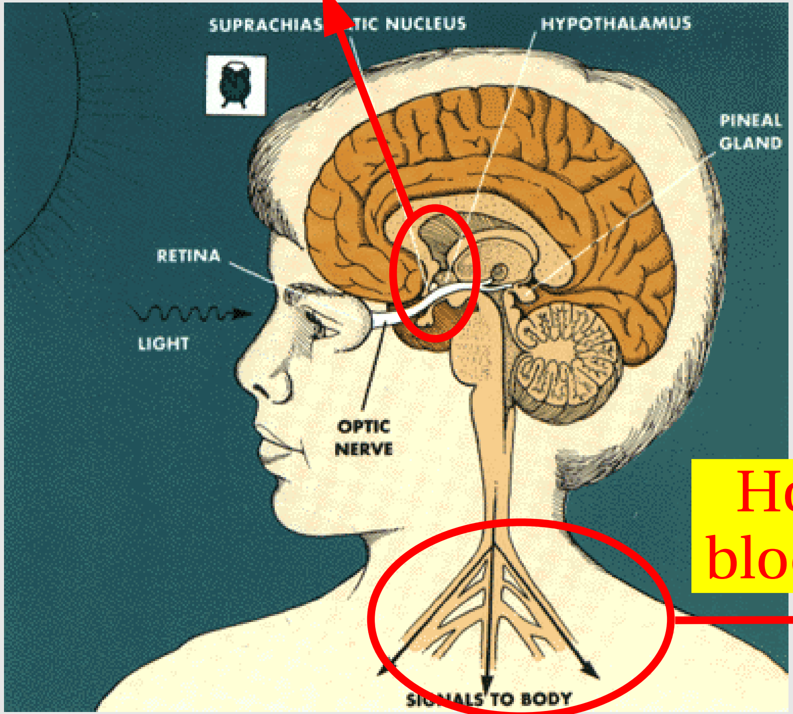
Cellular Oscillators

Credits: U Mass Amherst

Suprachiasmatic Nuclei (SCN) lock to 24 hour period influence pineal gland and hypothalamus



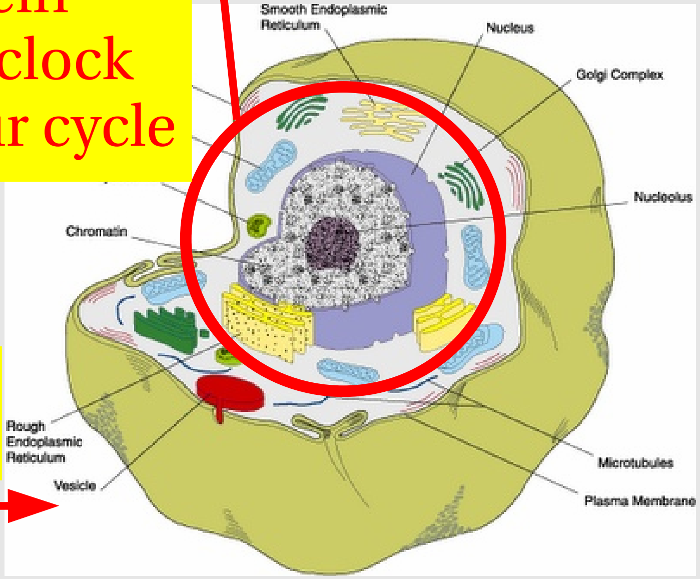
Millions of interacting oscillators



Credits: glimmerveen.nl

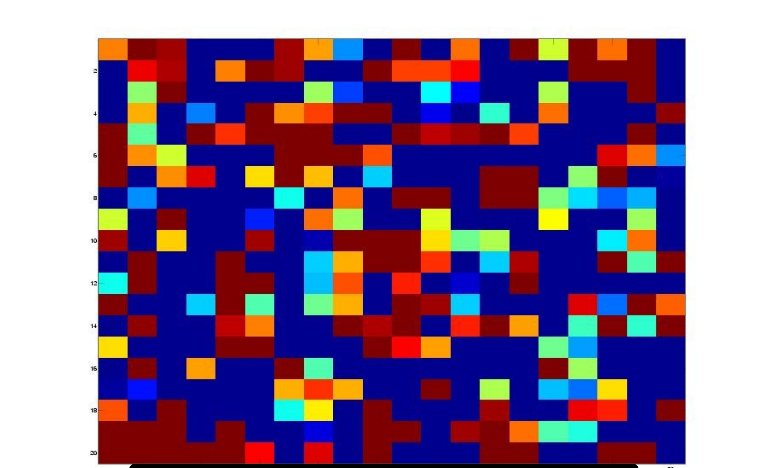
Intracellular DNA/protein biochemical clock locks to 24 hour cycle

Hormones through blood (eg, melatonin)

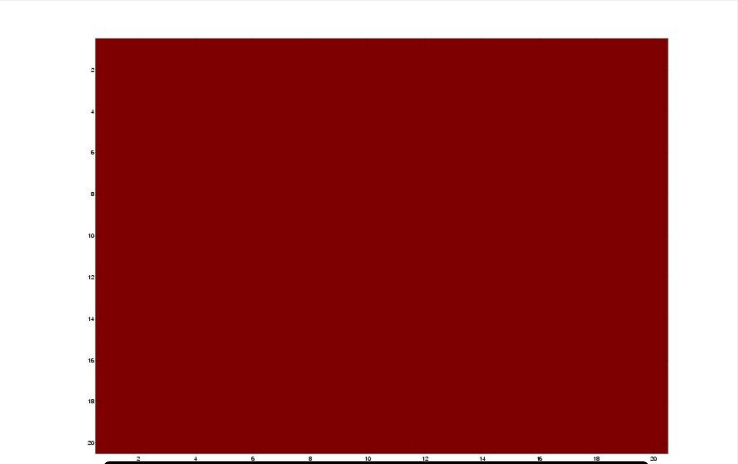


Credits: scienceblogs.com

Interacting Cellular Clocks

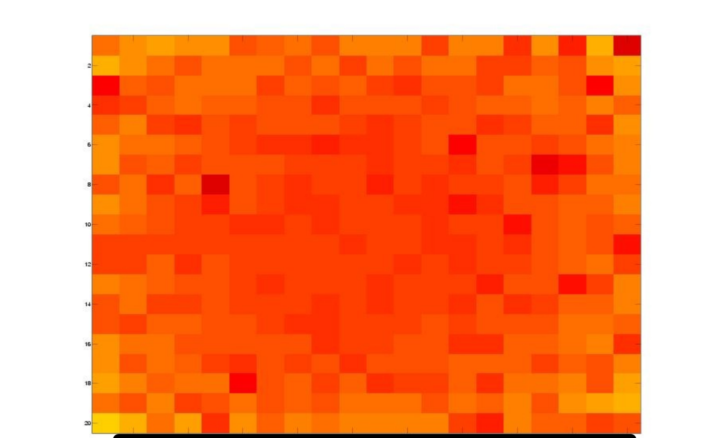


t=0



t=18h

- **16x16 grid of coupled cellular clocks**

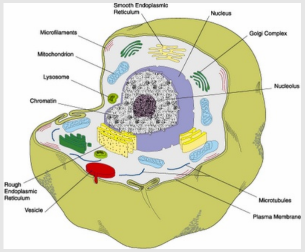


t=12h

Speedup: 240x

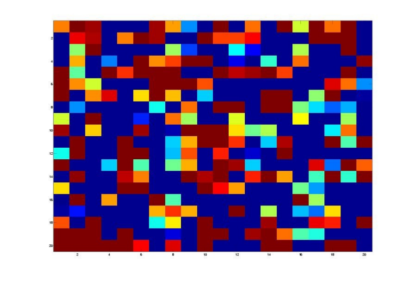
Circadian Systems

Cell

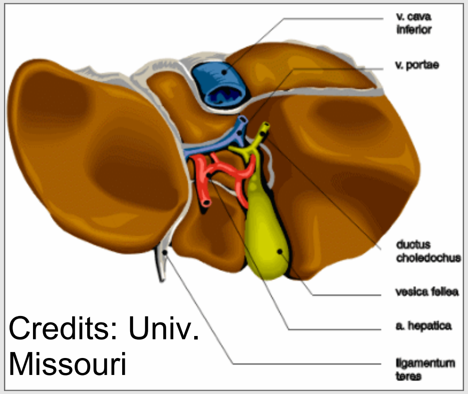


Credits: scienceblogs.com

Tissue



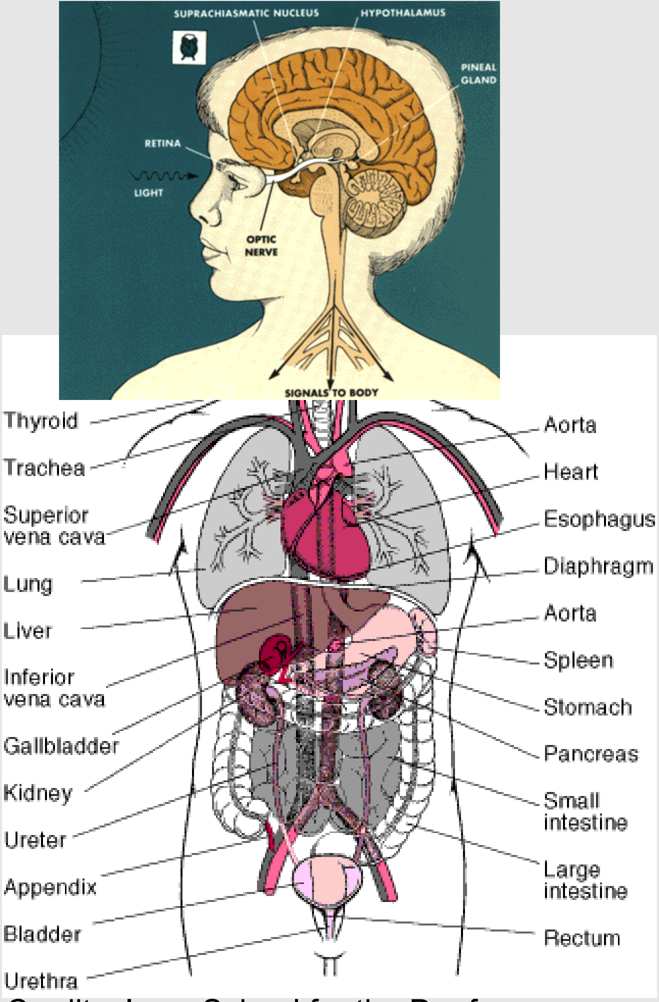
Organ



Credits: Univ. Missouri

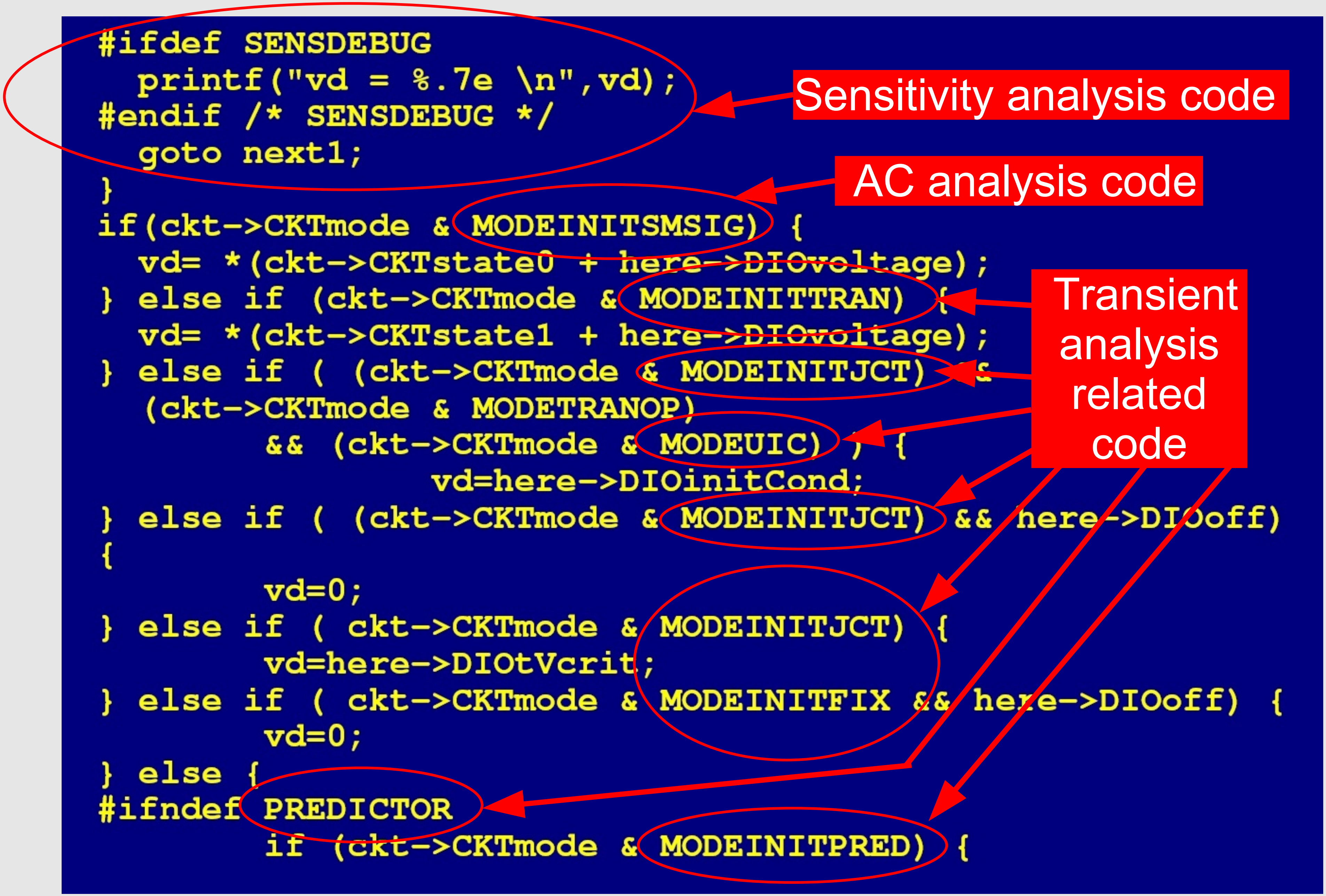
Organism

Credits: glimmerveen.nl



Credits: Iowa School for the Deaf

Excerpt from SPICE3's *dioload.c*



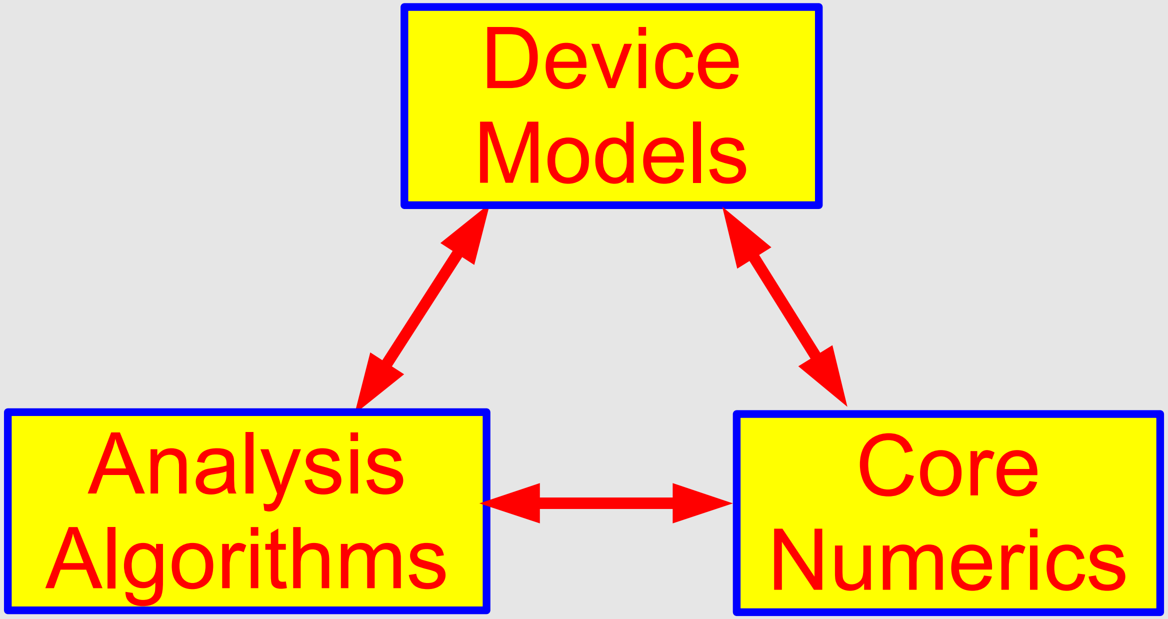
```
#ifdef SENSDEBUG
  printf("vd = %.7e \n",vd);
#endif /* SENSDEBUG */
  goto next1;
}
if(ckt->CKTmode & MODEINITSMSIG) {
  vd= *(ckt->CKTstate0 + here->DIOvoltage);
} else if (ckt->CKTmode & MODEINITTRAN) {
  vd= *(ckt->CKTstate1 + here->DIOvoltage);
} else if ( (ckt->CKTmode & MODEINITJCT) &&
   (ckt->CKTmode & MODETRANOP)
        && (ckt->CKTmode & MODEUIC) ) {
                vd=here->DIOinitCond;
} else if ( (ckt->CKTmode & MODEINITJCT) && here->DIOoff)
{
        vd=0;
} else if ( ckt->CKTmode & MODEINITJCT) {
        vd=here->DIOtVcrit;
} else if ( ckt->CKTmode & MODEINITFIX && here->DIOoff) {
        vd=0;
} else {
#ifndef PREDICTOR
        if (ckt->CKTmode & MODEINITPRED) {
```

Sensitivity analysis code

AC analysis code

Transient analysis related code

Modular Software Infrastructure for Research in Simulation



- foster collaborative research, effective teaching
  - modular (reflecting mathematical structure)
  - open source, freely distributed, effectively documented
    - ➔ reproducible research
  - short, high-level code (MATLAB/Octave/Python)