Computational Complexity

Lecture 1
in which we talk about
Time Complexity, P, NP and coNP

Evolution of Computation

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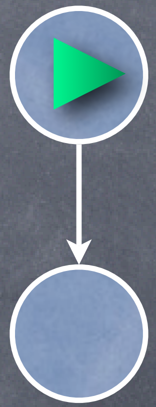

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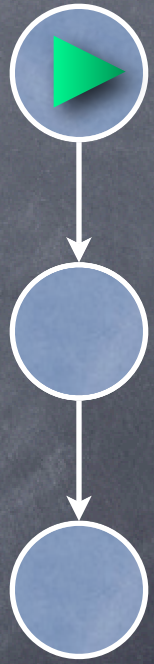

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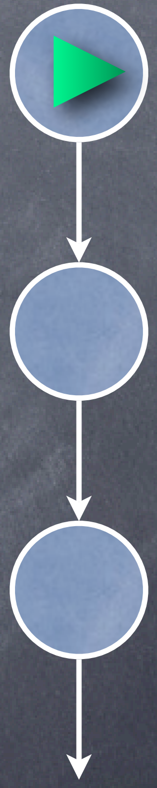

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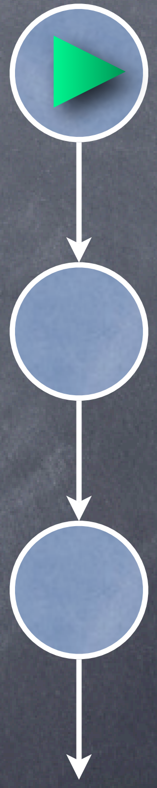

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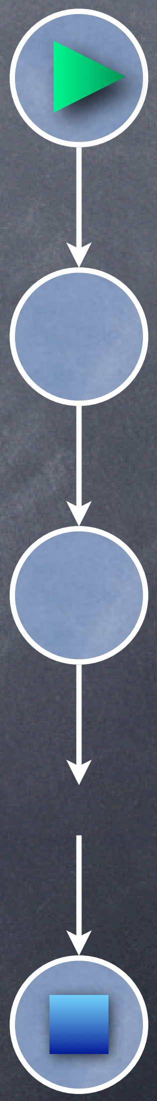

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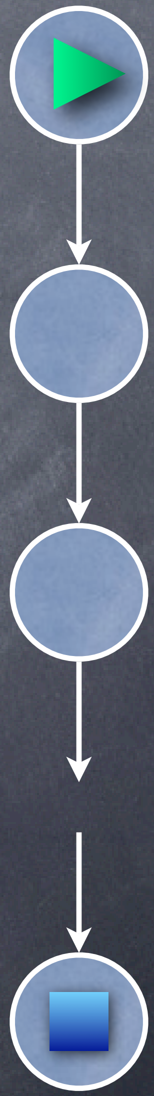
  - output explicitly encoded in the final configuration (say, in the control-state)



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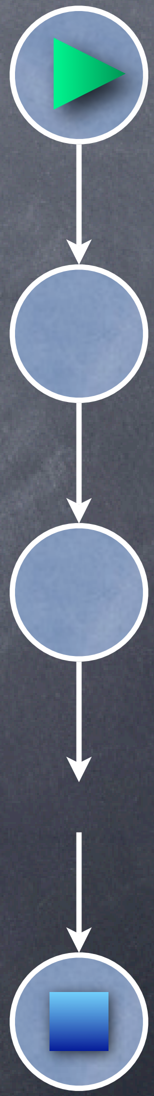

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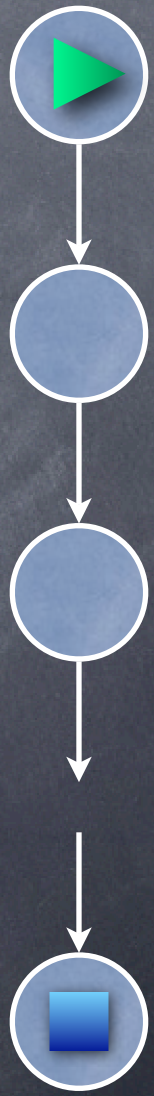
- Deterministic TM computation model



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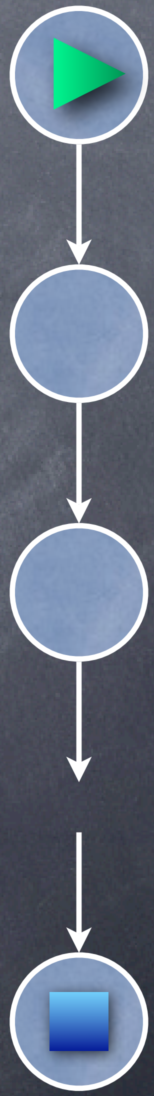

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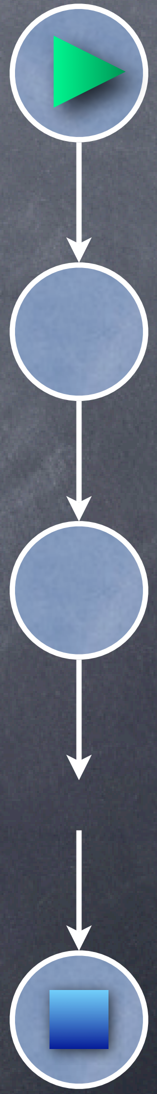

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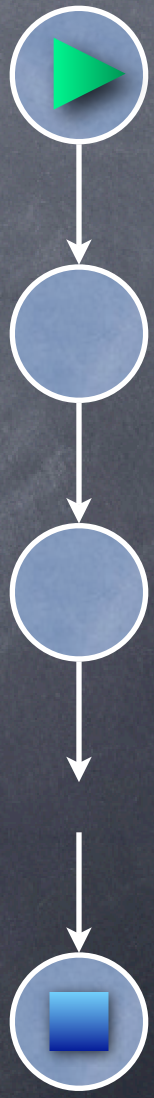
  - (Note: complexity T is a function of n)



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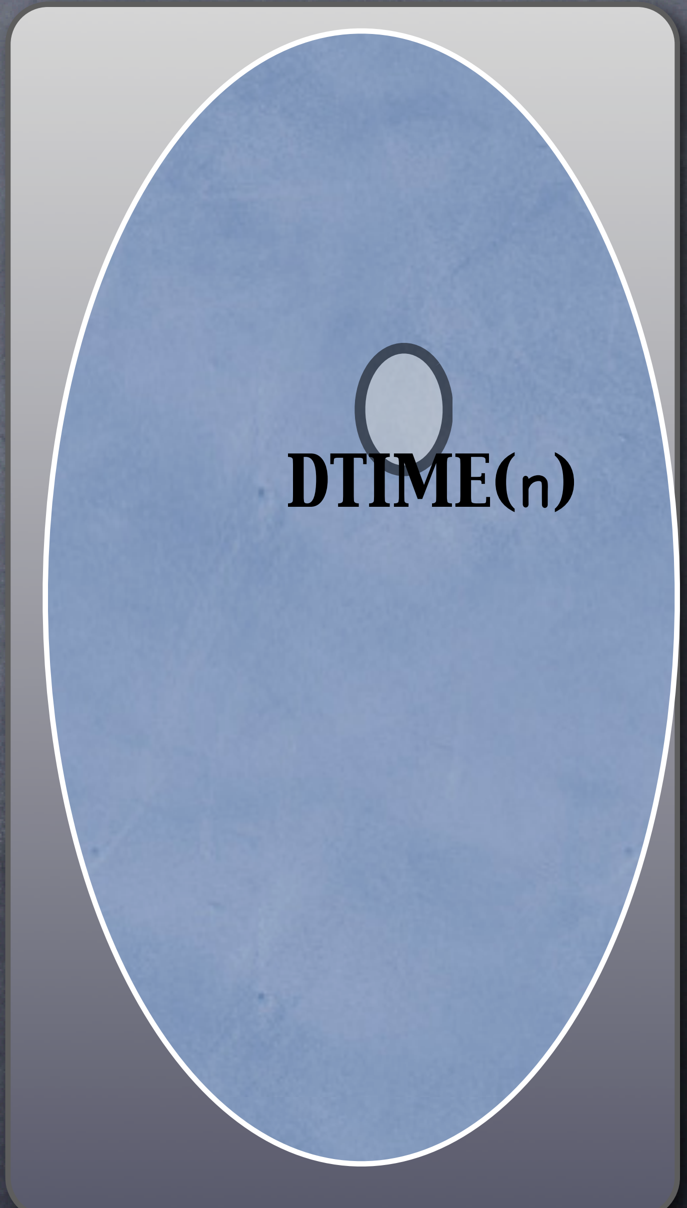

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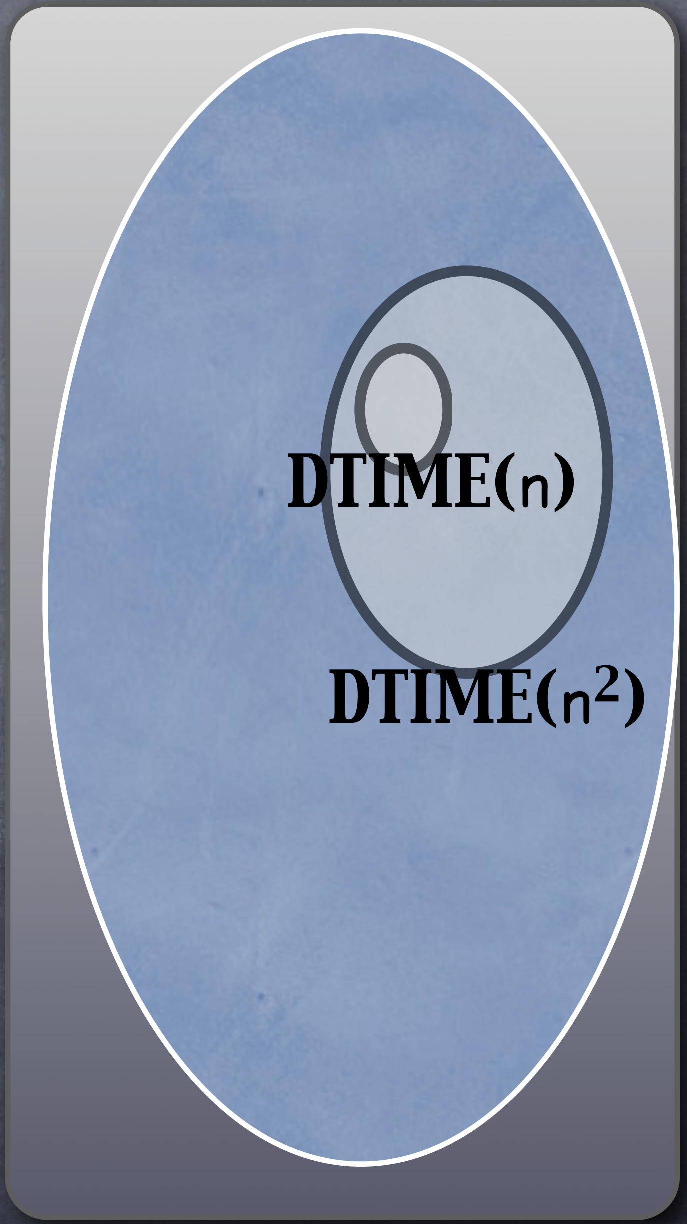

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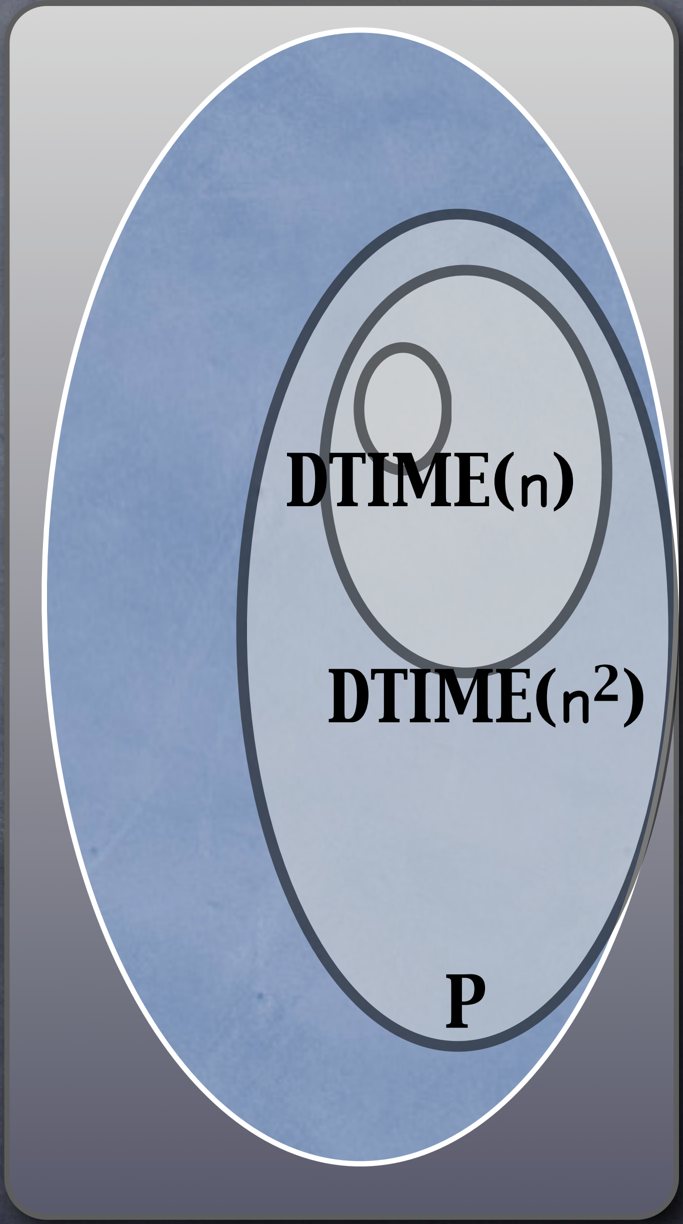

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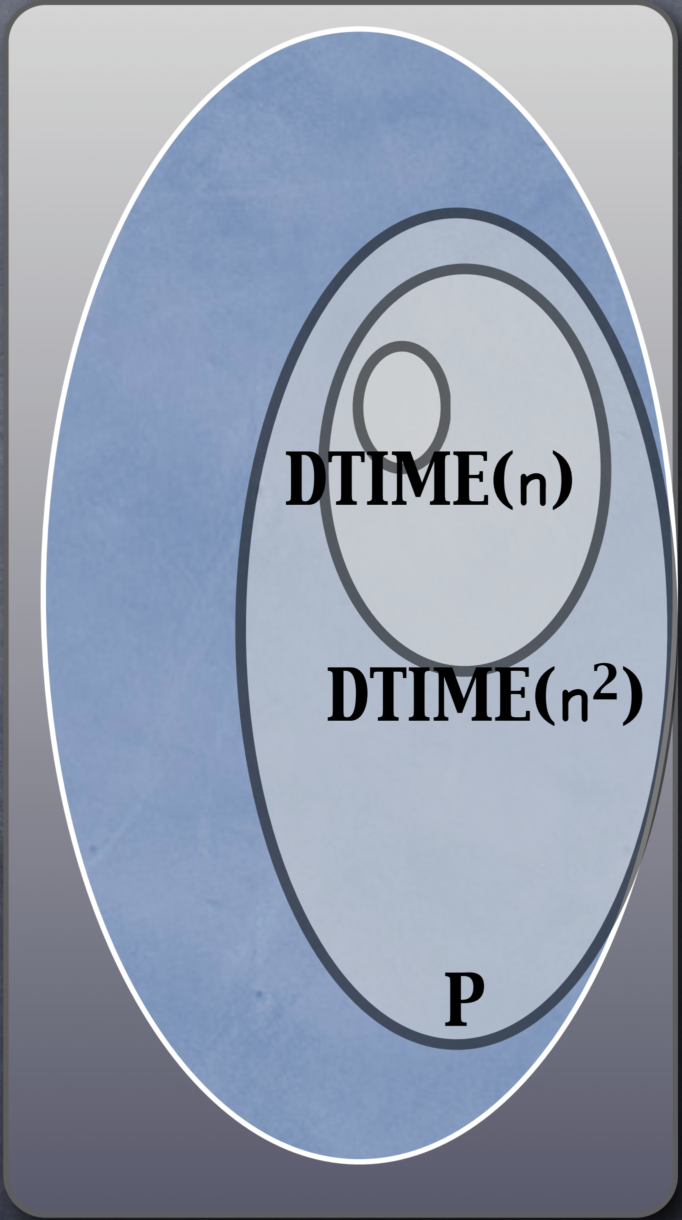

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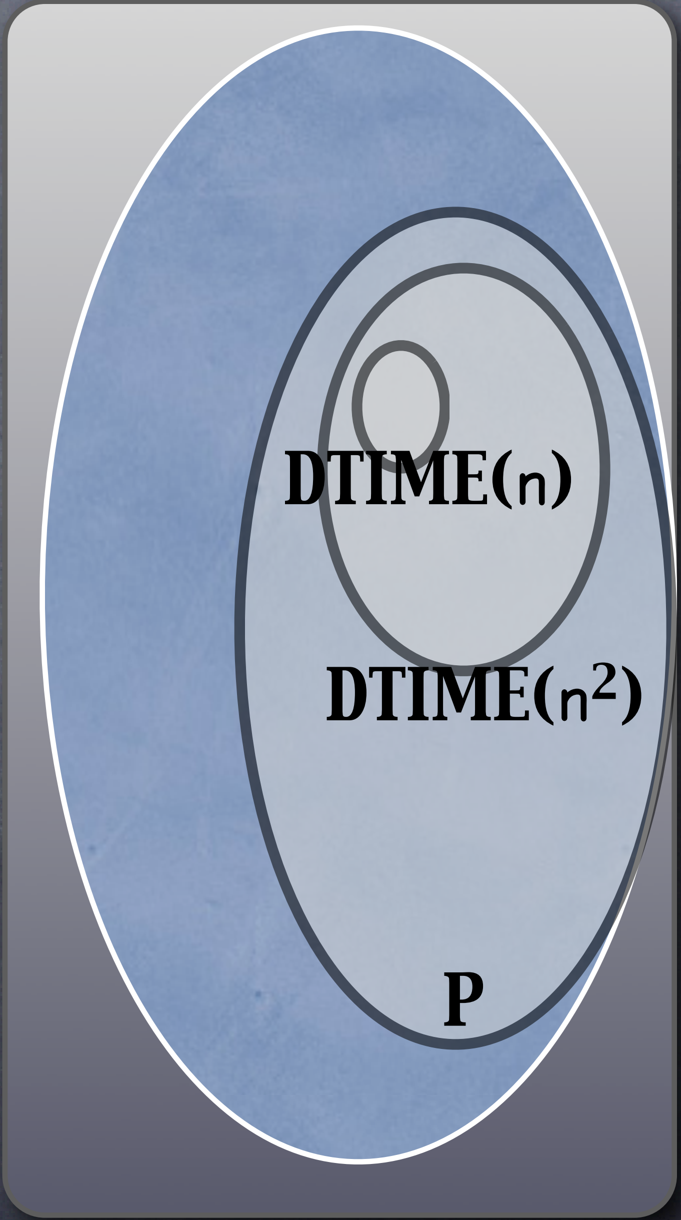
- But P is robust: Models can simulate each other with only "polynomial slow down"



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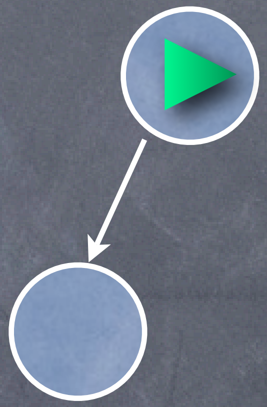

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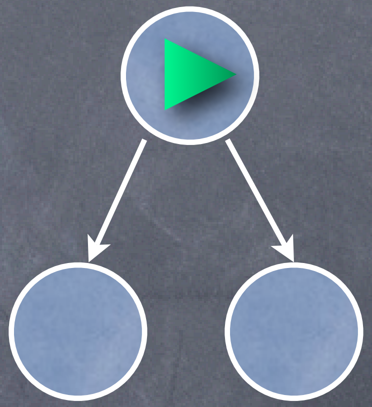

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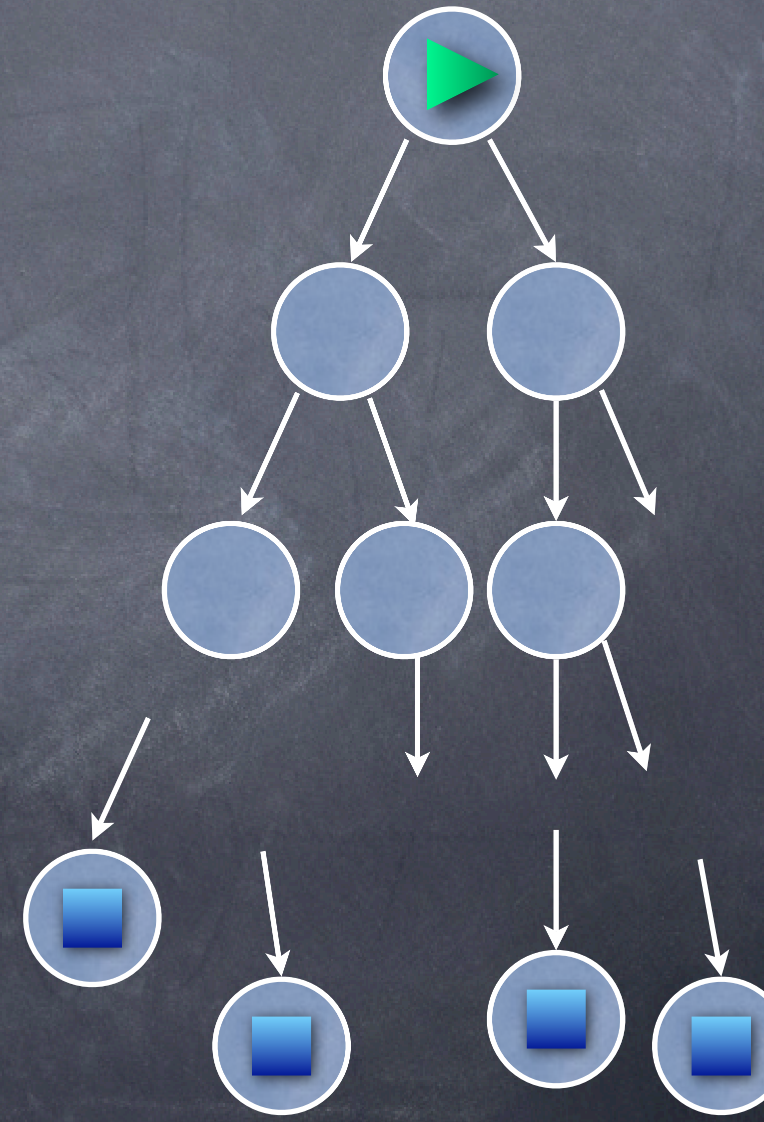

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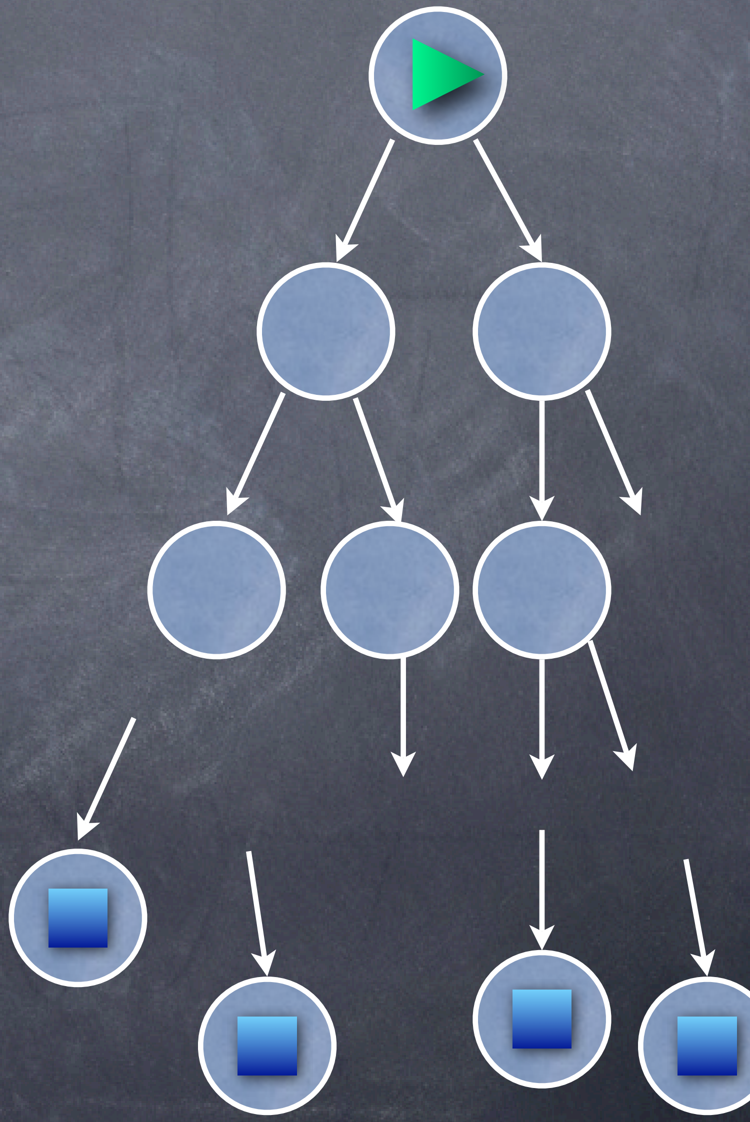

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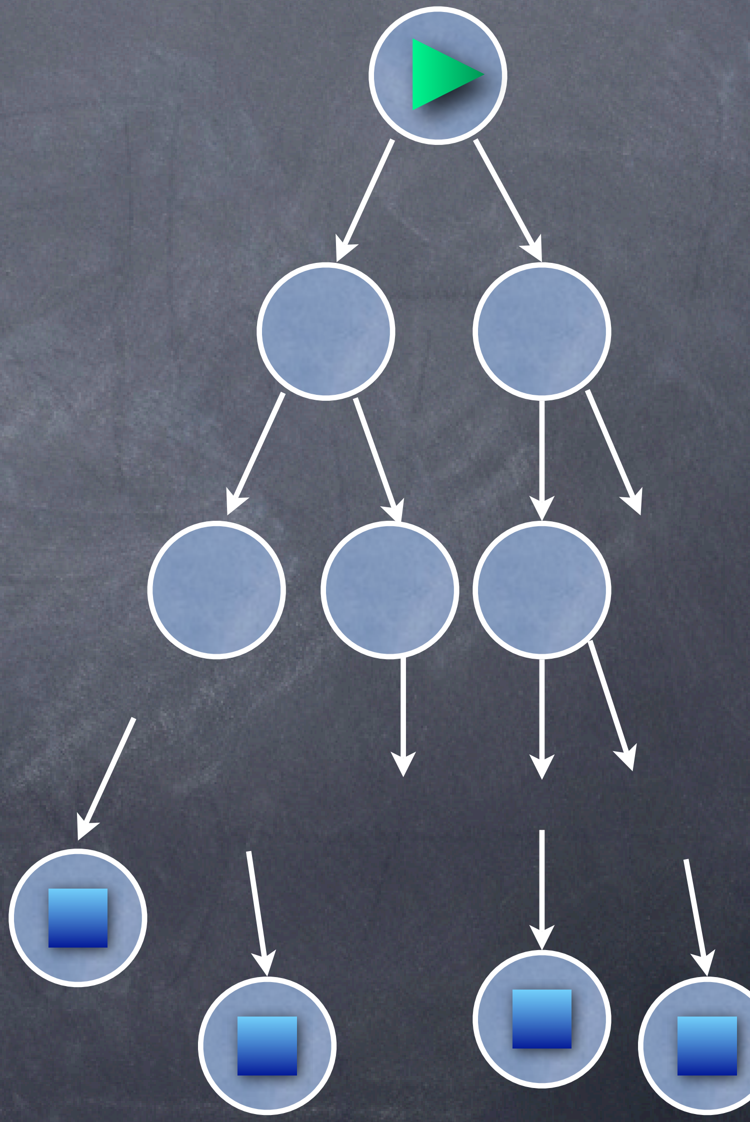

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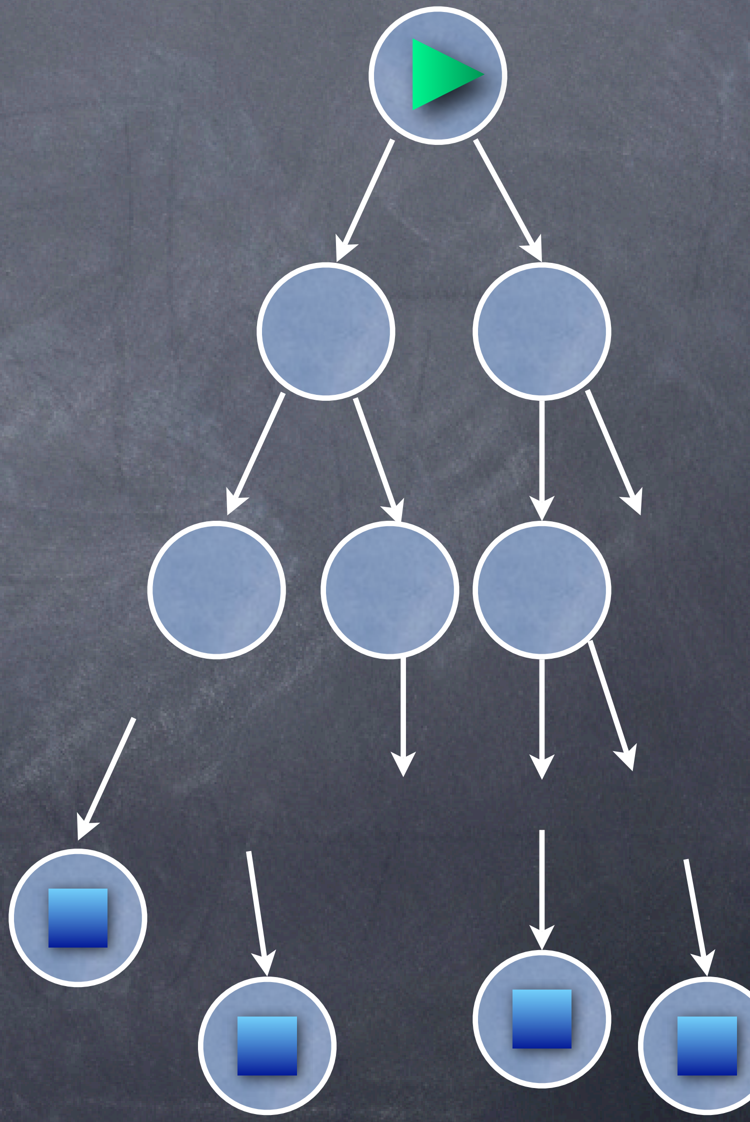
- L ∈ NTIME(T): an NTM decides L in time at most T



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- Non-deterministic computation: essentially guess w and verify

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- Note: Completeness and soundness

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- All problems in P (empty certificate)

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  - For next bit query oracle with $(x,00)$ and $(x,01)$

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- Solve all sorts of optimization problems efficiently!

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      - No! L′ in DTIME($2^{poly(|x|)}$)

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    - L = $\{x \mid \exists w \text{ s.t. } (x,w) \in L'\}$, $|w| = O(2^{poly(|x|)})$, and L' in EXP?
      - No! L' in DTIME($2^{poly(|x|)}$)
        - i.e., L' in P

co-Class

co-Class

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co-Class

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co-Class

- co-X = { L | L^c is in X } (where $L^c = \{ x \mid x \notin L \}$)
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no counter-example

  - $L^c = \{ x \mid \nexists w \text{ s.t. } (x,w) \in L' \} = \{ x \mid \forall w\ (x,w) \in L'^c \}$

P, NP and co-NP

P, NP and co-NP

- Different possibilities

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- Different possibilities

P, NP and co-NP

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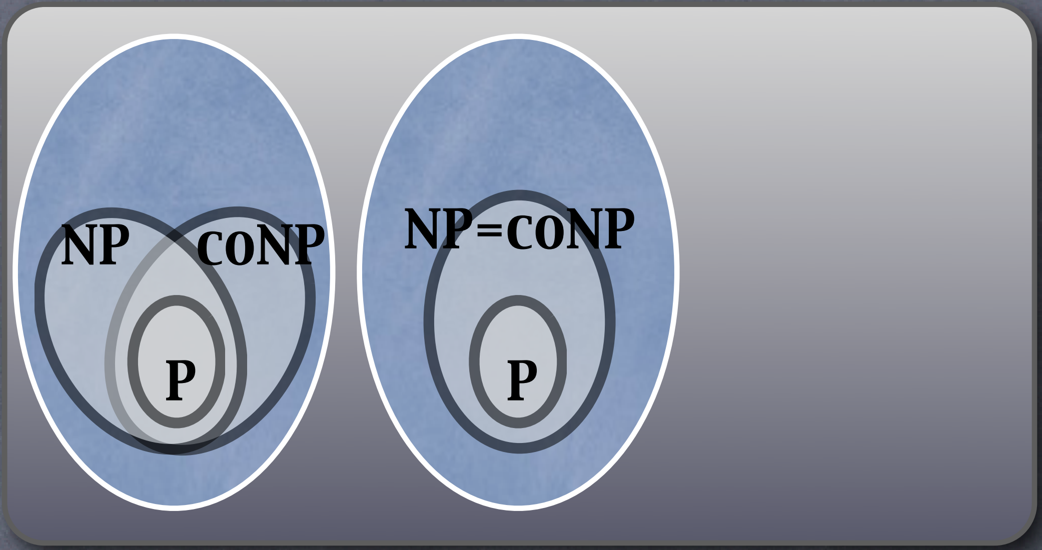

P, NP and co-NP

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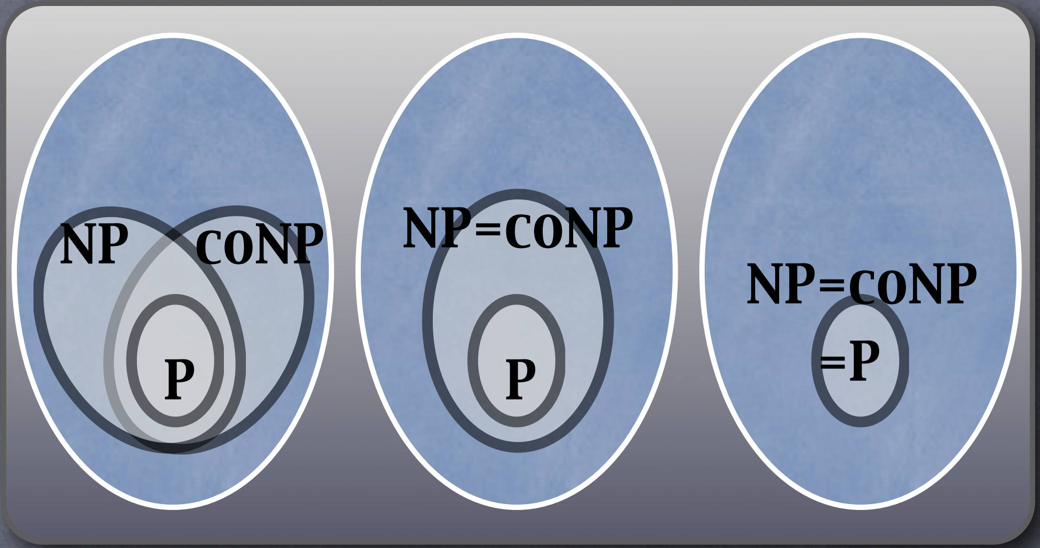
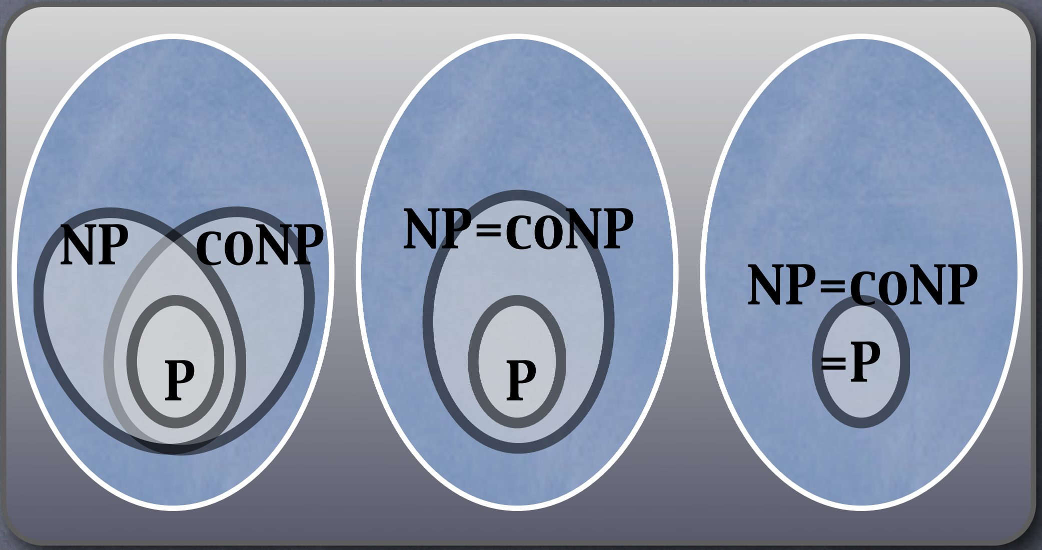


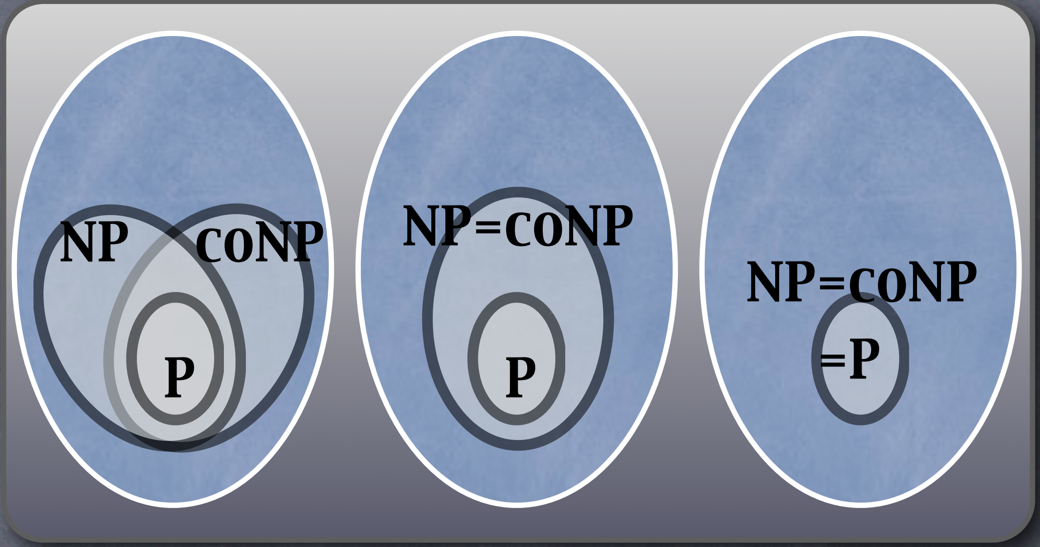
P, NP and co-NP

- Different possibilities
- If P=NP, then

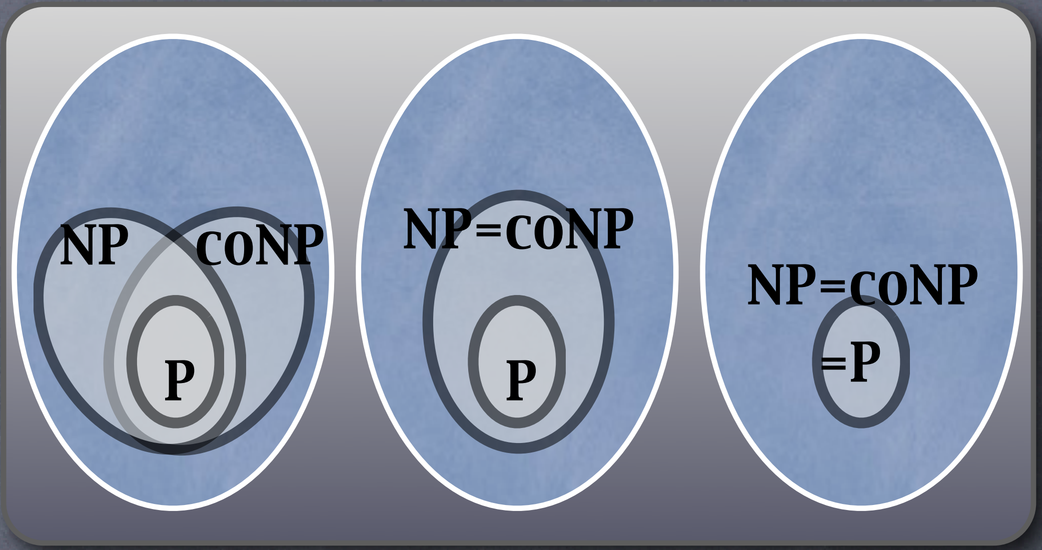


P, NP and co-NP

- Different possibilities
- If P=NP, then
    - coNP = coP = P = NP



P, NP and co-NP



- Different possibilities
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  - coNP = coP = P = NP
  - Also, EXP = NEXP [Exercise]

P, NP and co-NP

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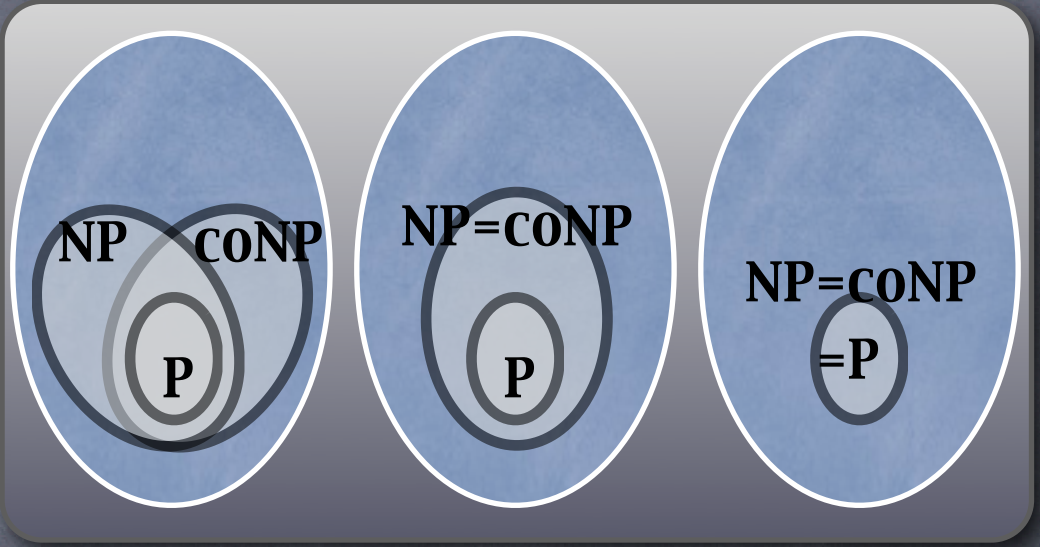
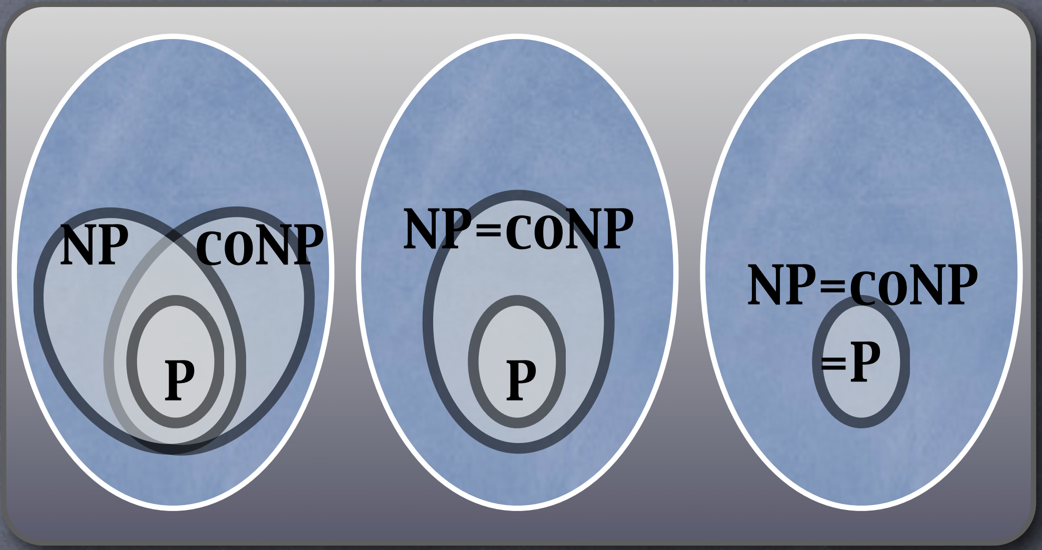
    - padding to scale up both classes



P, NP and co-NP



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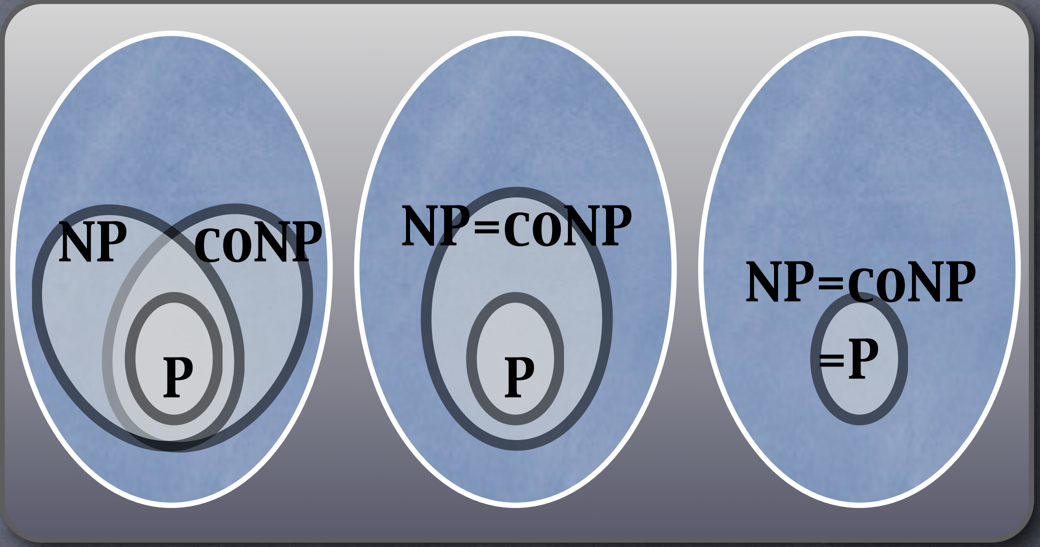
P, NP and co-NP



- Different possibilities
- If P=NP, then
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  - Also, EXP = NEXP [Exercise]
    - padding to scale up both classes
    - x → (x,pad), so that Exp(|x|) = Poly(|x,pad|)
  - If P=NP, then the complexity landscape would get greatly simplified than believed (more later)

Today

Today

- DTIME

Today

- DTIME
  - P, EXP

Today

- DTIME
  - P, EXP
- NTIME

Today

- DTIME
  - P, EXP
- NTIME
  - Two views: non-determinism and certificate

Today

- DTIME
  - P, EXP
- NTIME
  - Two views: non-determinism and certificate
  - NP, NEXP

Today

- DTIME
  - P, EXP
- NTIME
  - Two views: non-determinism and certificate
  - NP, NEXP
- co-NTIME

Today

- DTIME
  - P, EXP
- NTIME
  - Two views: non-determinism and certificate
  - NP, NEXP
- co-NTIME
  - Two views: co-NTM and "no counter-example"

Next ~~Class~~ Lecture

Next ~~Class~~ Lecture

- NP completeness

Next ~~Class~~ Lecture

- NP completeness
    - As hard as it gets inside NP

Next ~~Class~~ Lecture

- NP completeness
  - As hard as it gets inside NP
    - a la reductions (of course)