

MORPHOSIS

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DEPARTMENT OF ENGINEERING MATHEMATICS



DEC 3, 2015
SHANGHAI LECTURES



MORPHOSIS

THE NEXT LEVEL IN MORPHOLOGICAL COMPUTATION

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TOY EXAMPLE



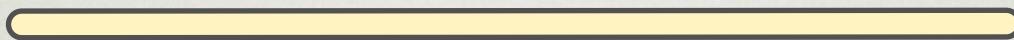
Slinky

TOY EXAMPLE



https://www.youtube.com/watch?v=711bZ_pLusQ

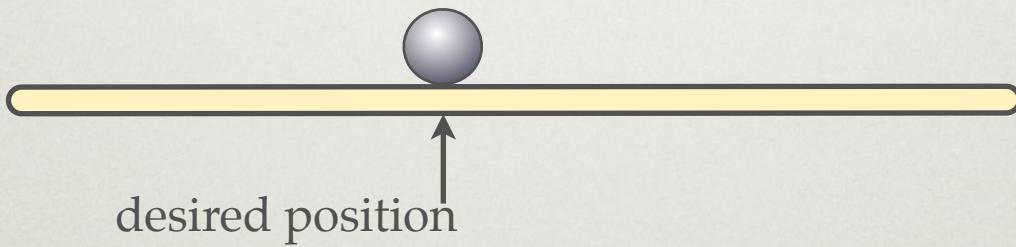
SIMPLE THOUGHT EXPERIMENT



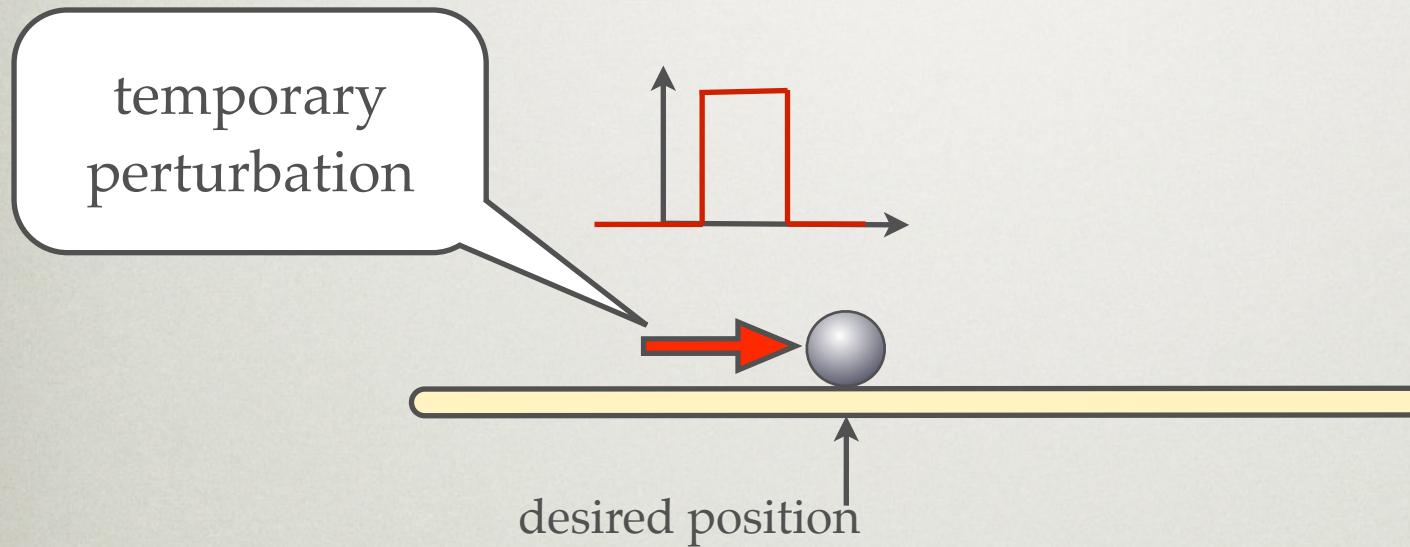
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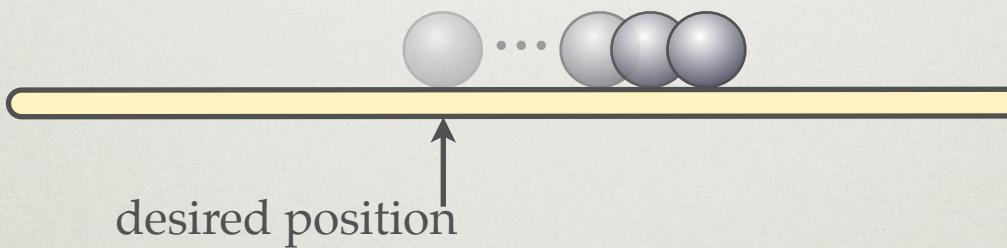
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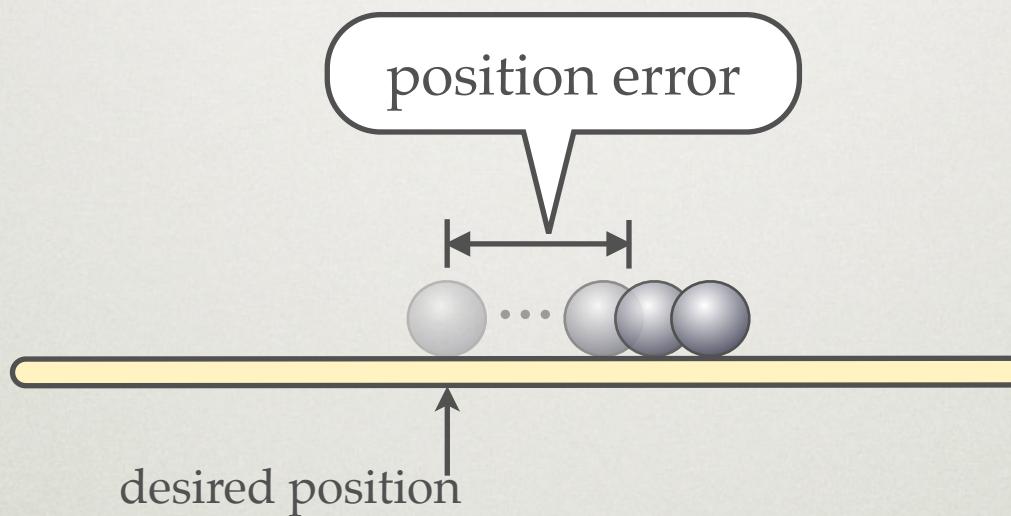
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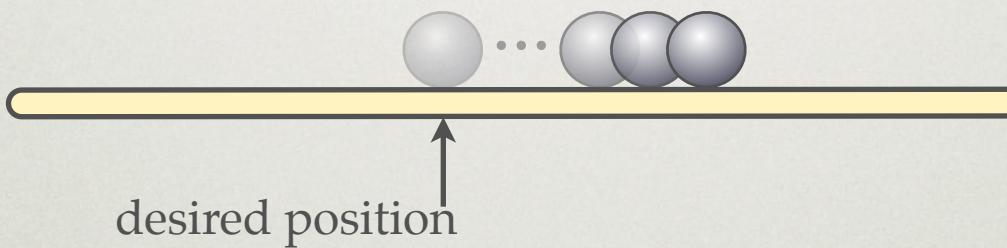
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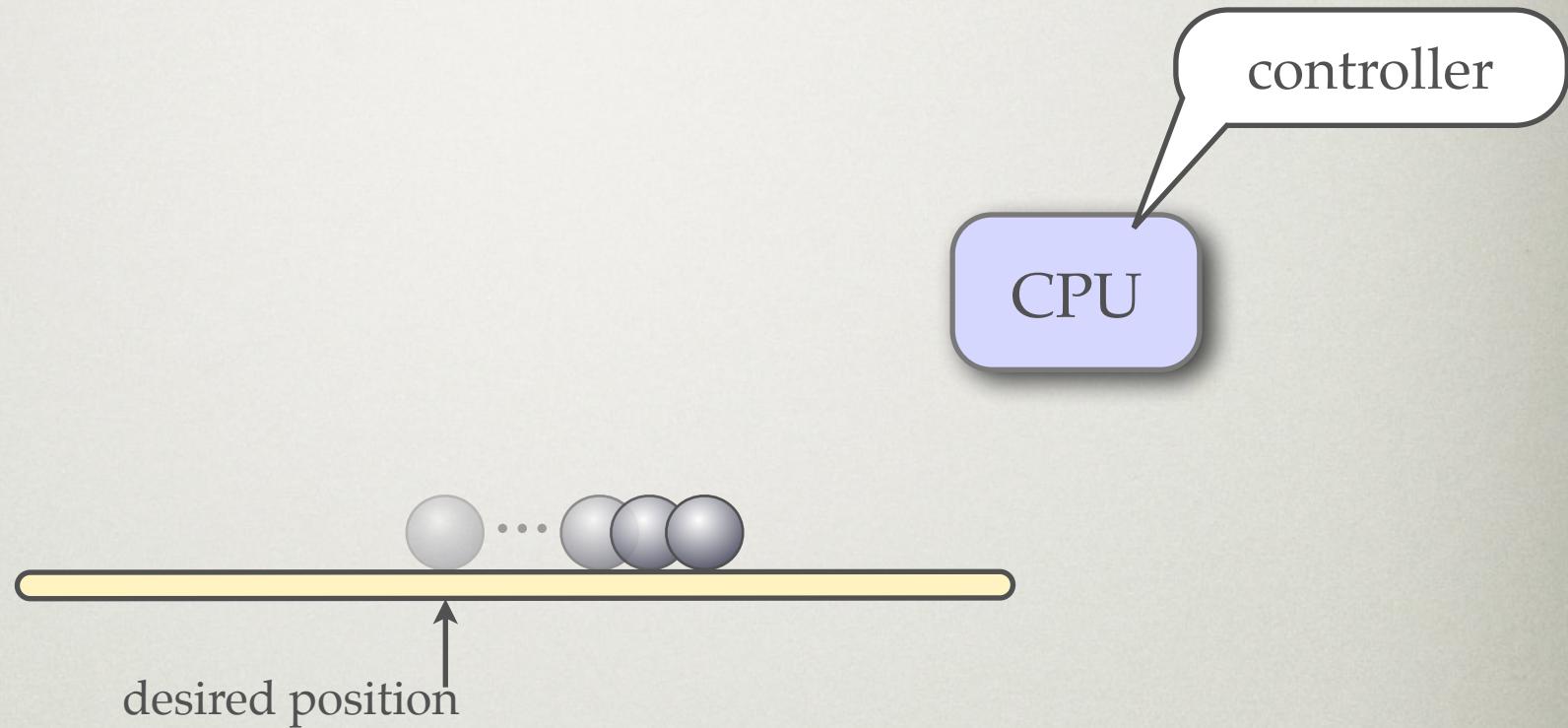
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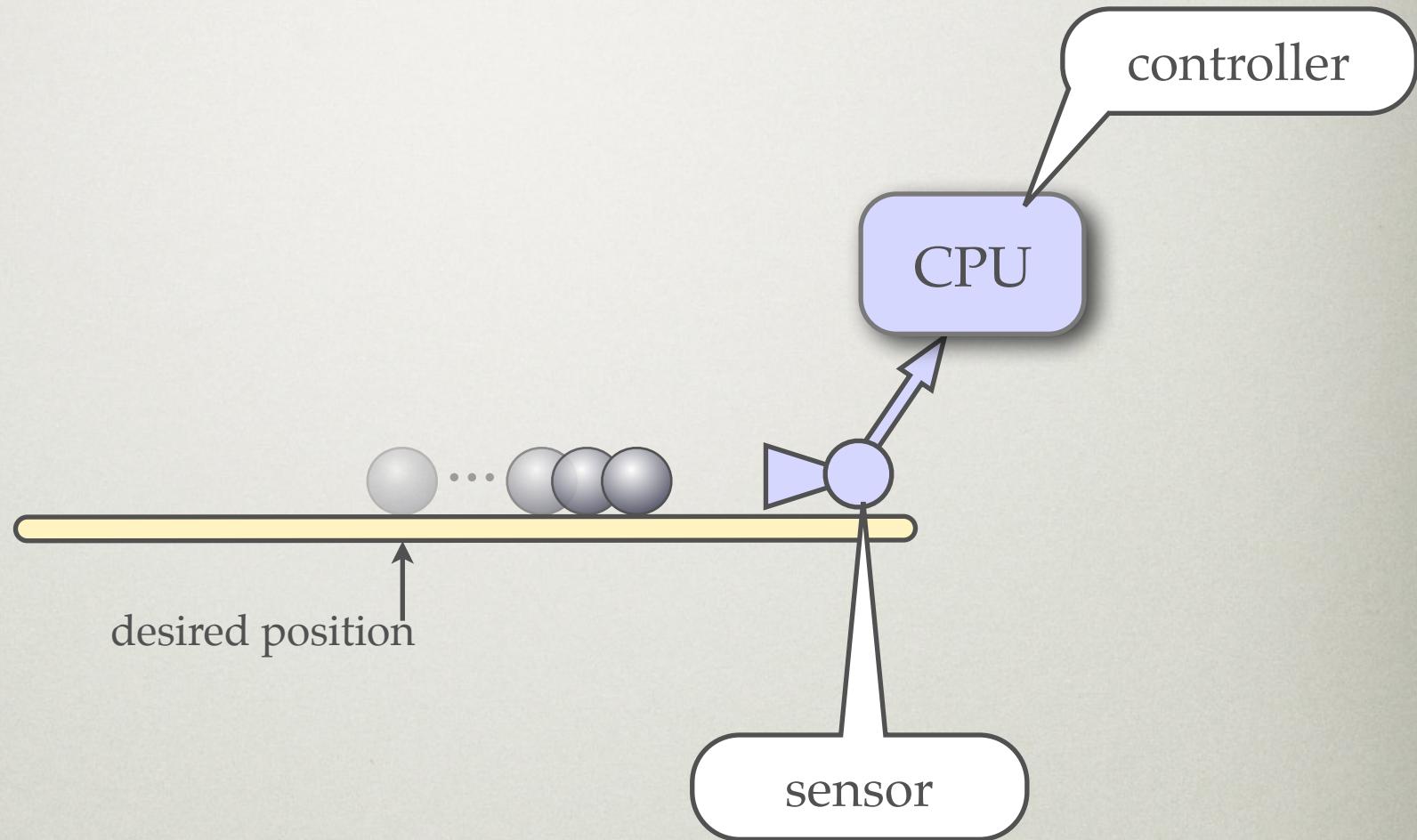
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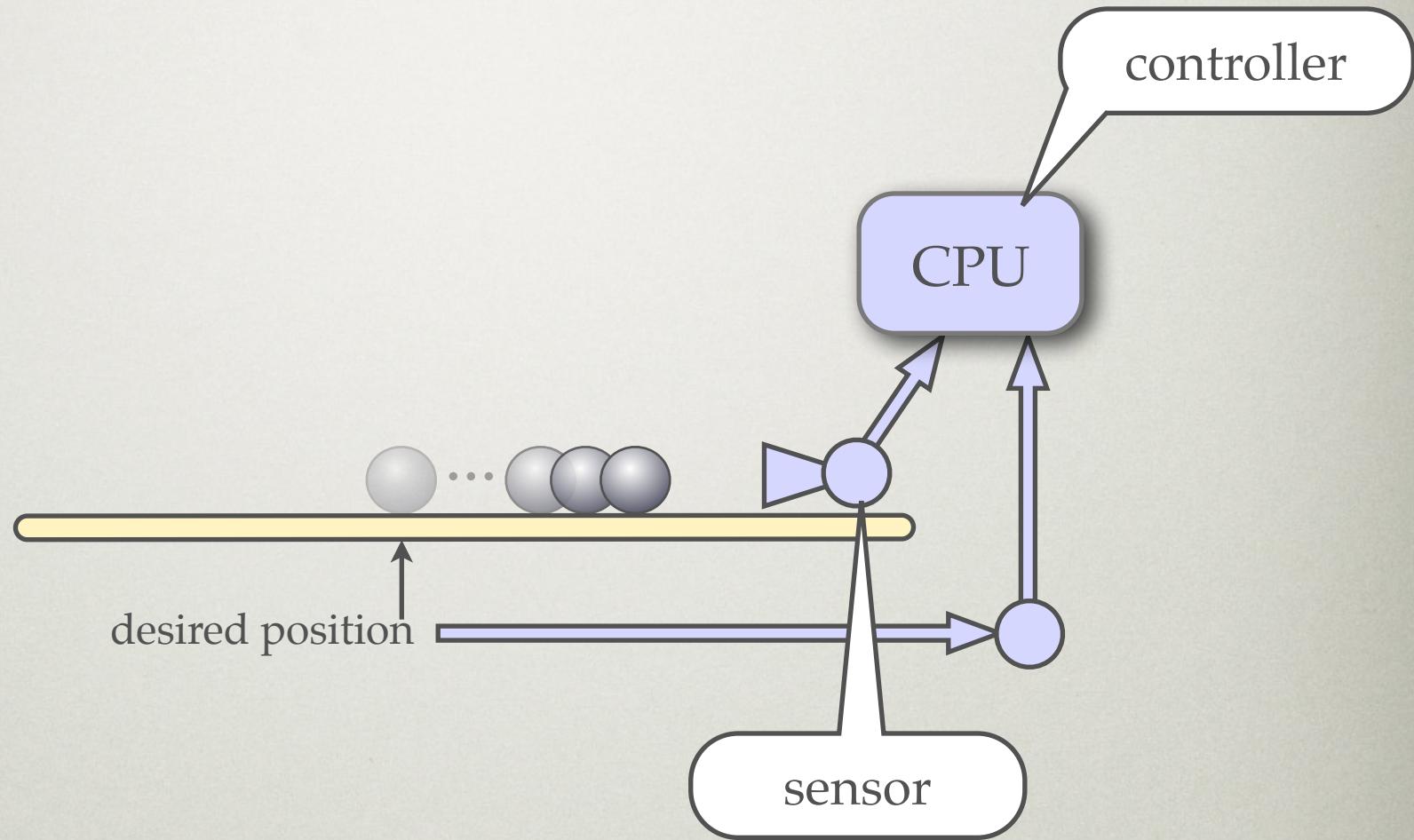
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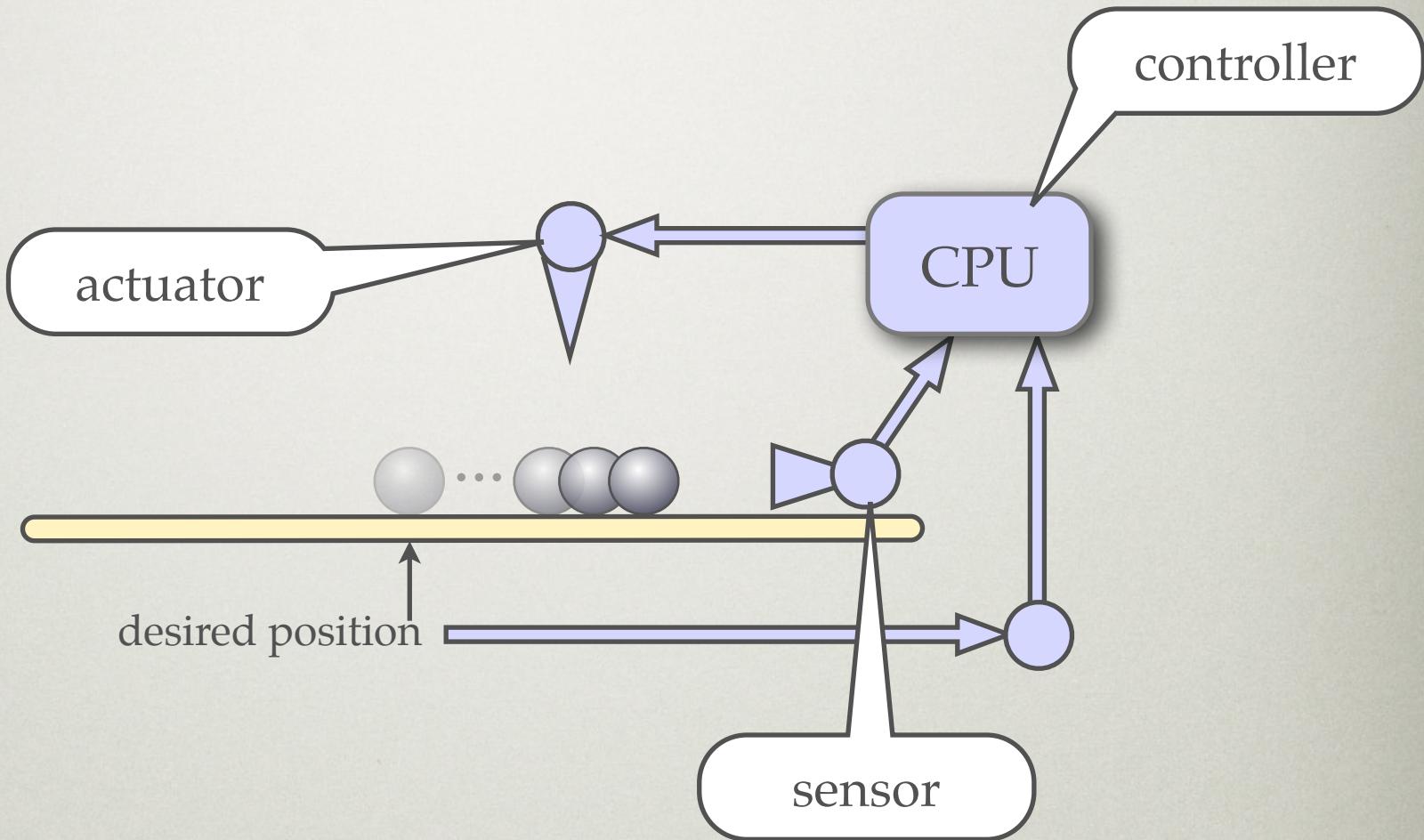
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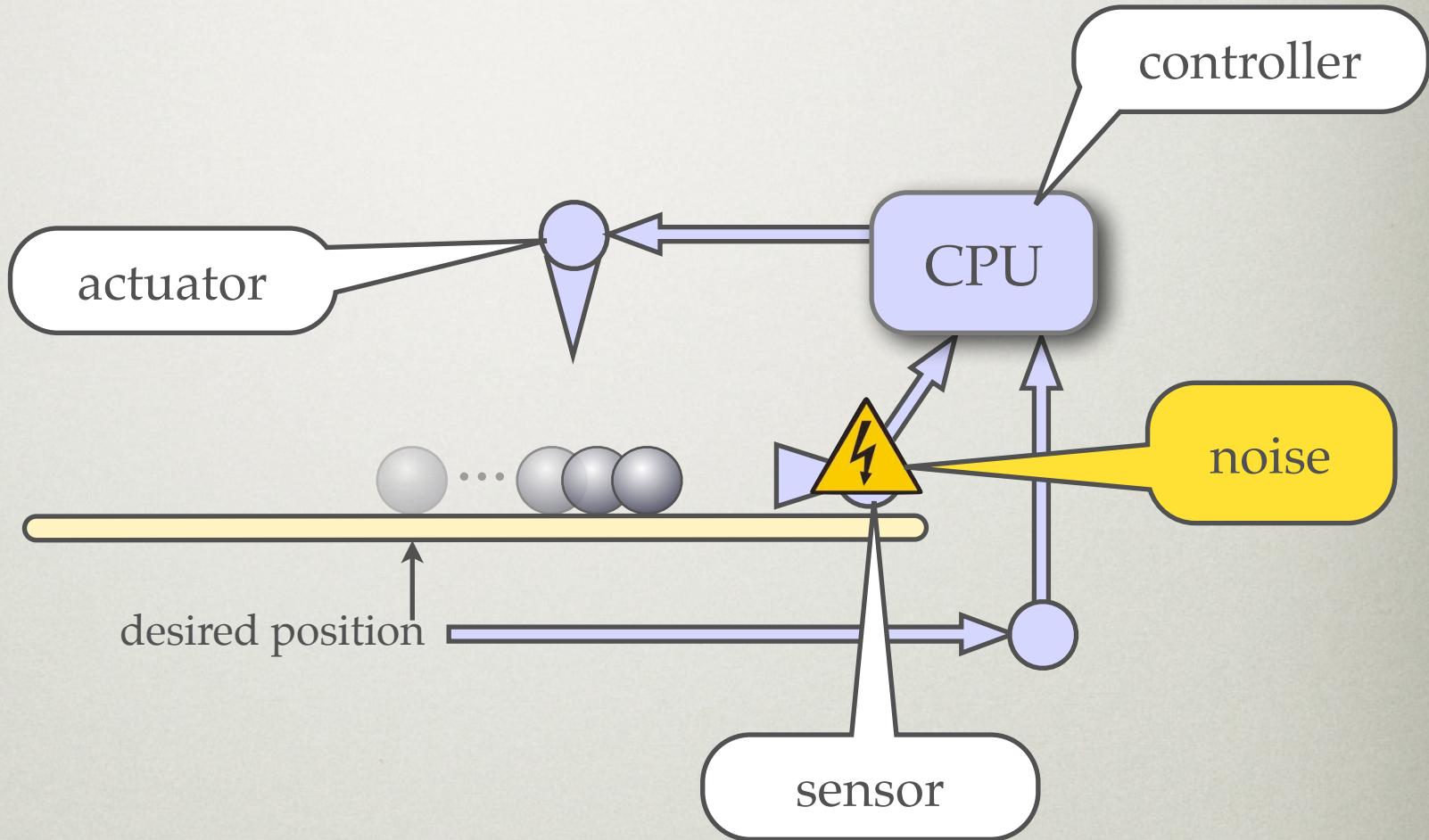
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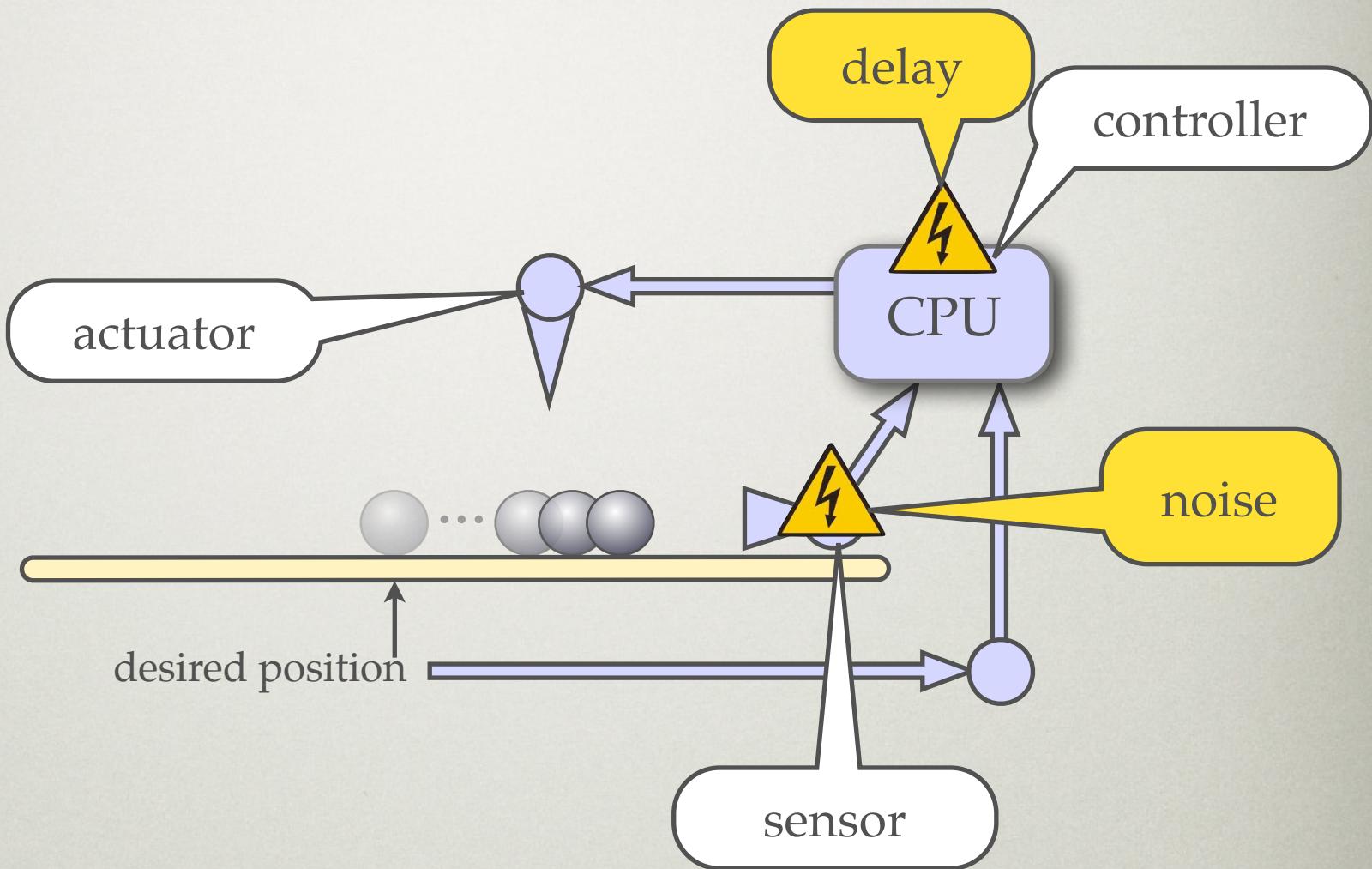
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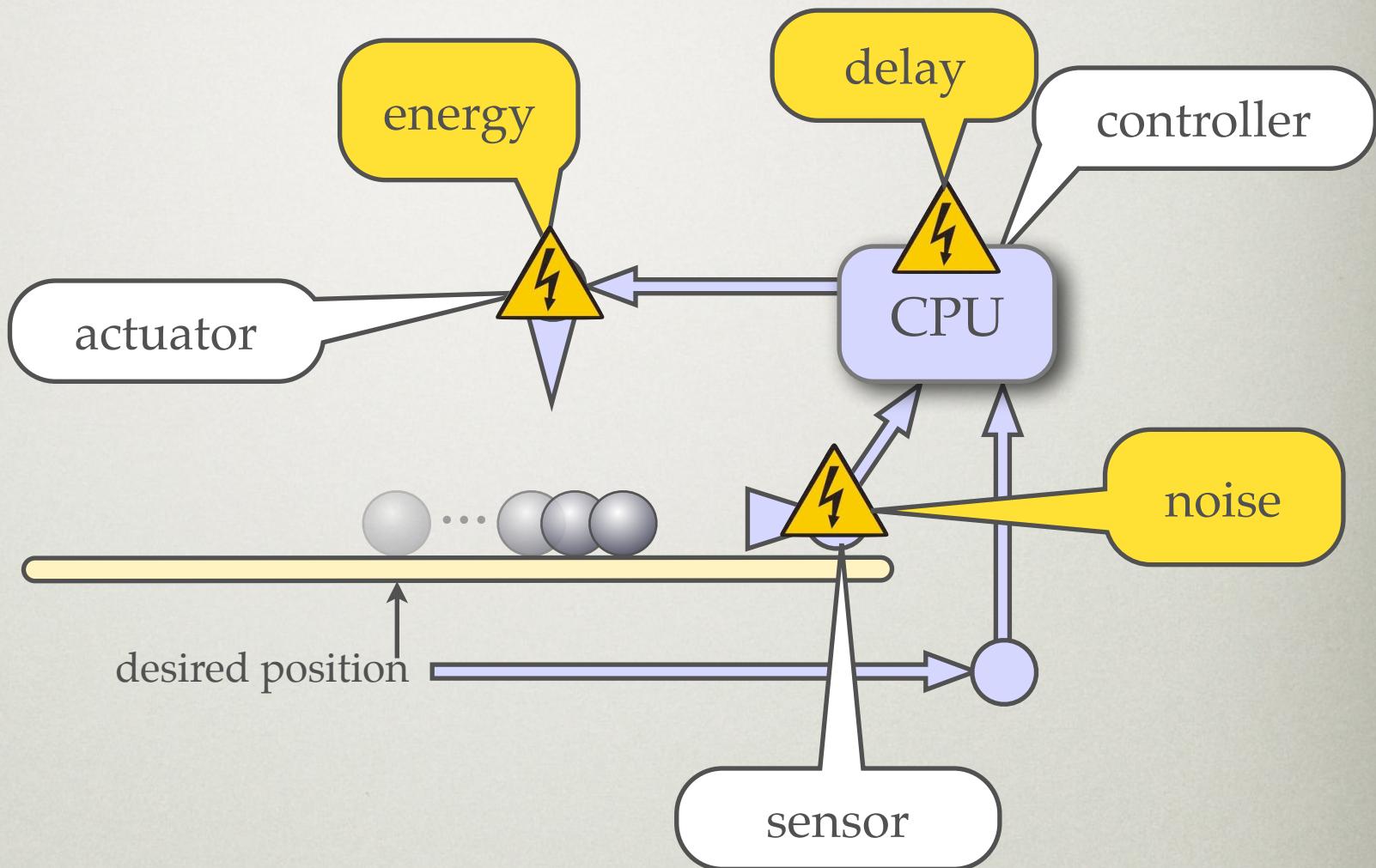
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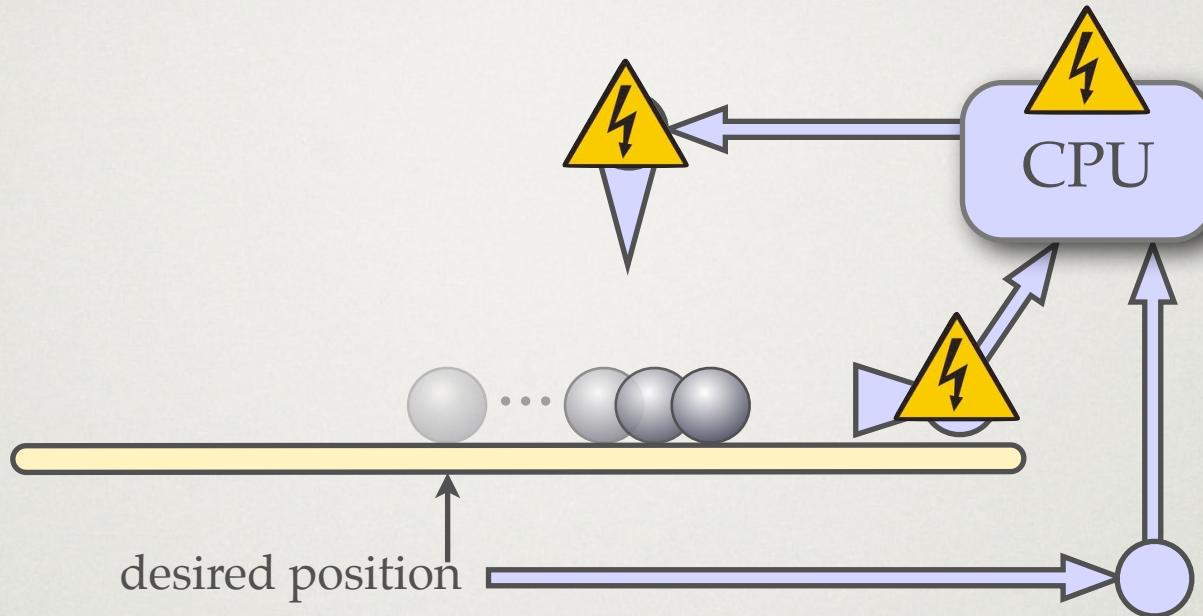
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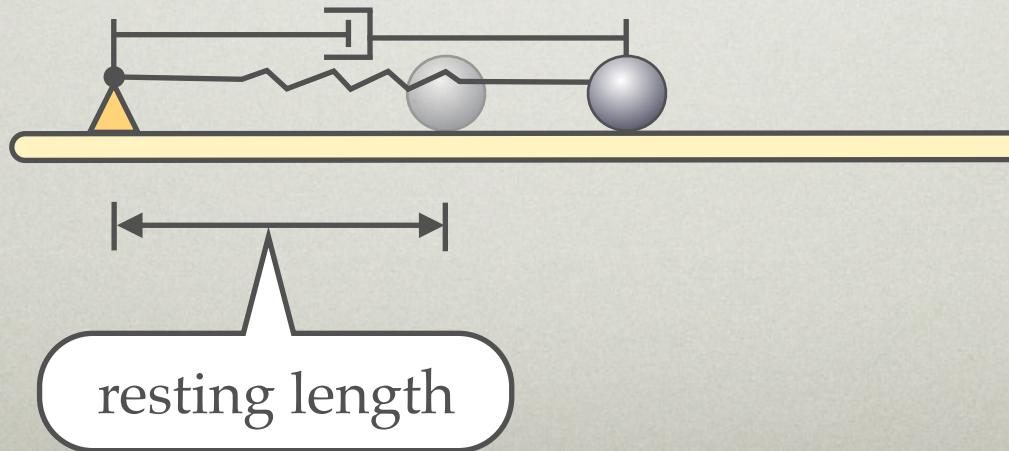
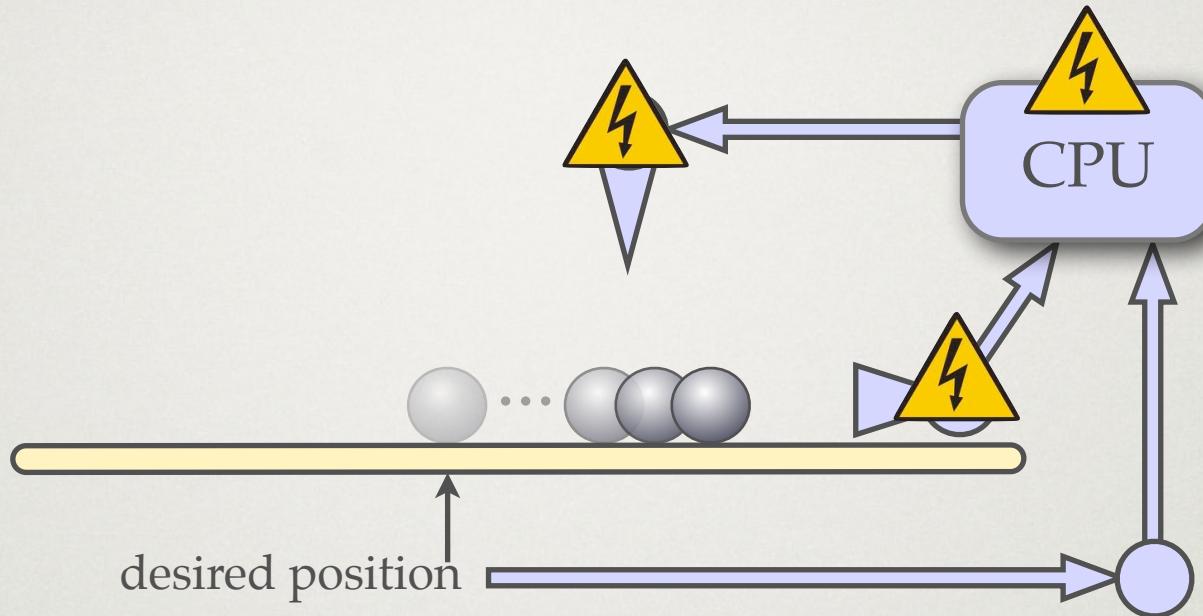
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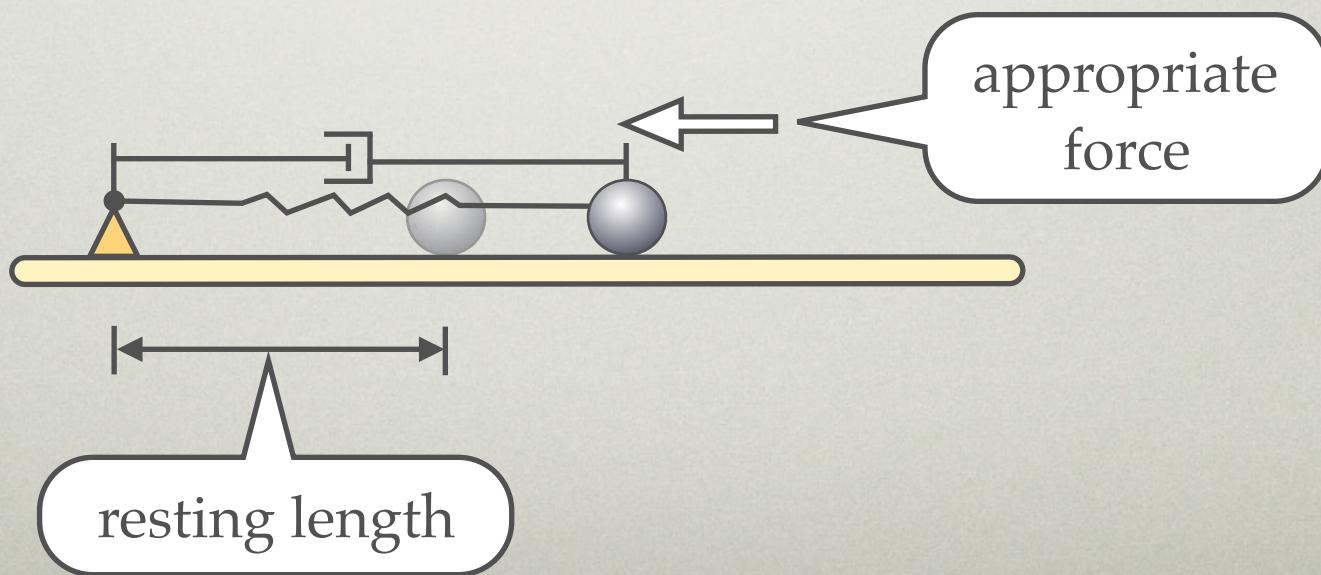
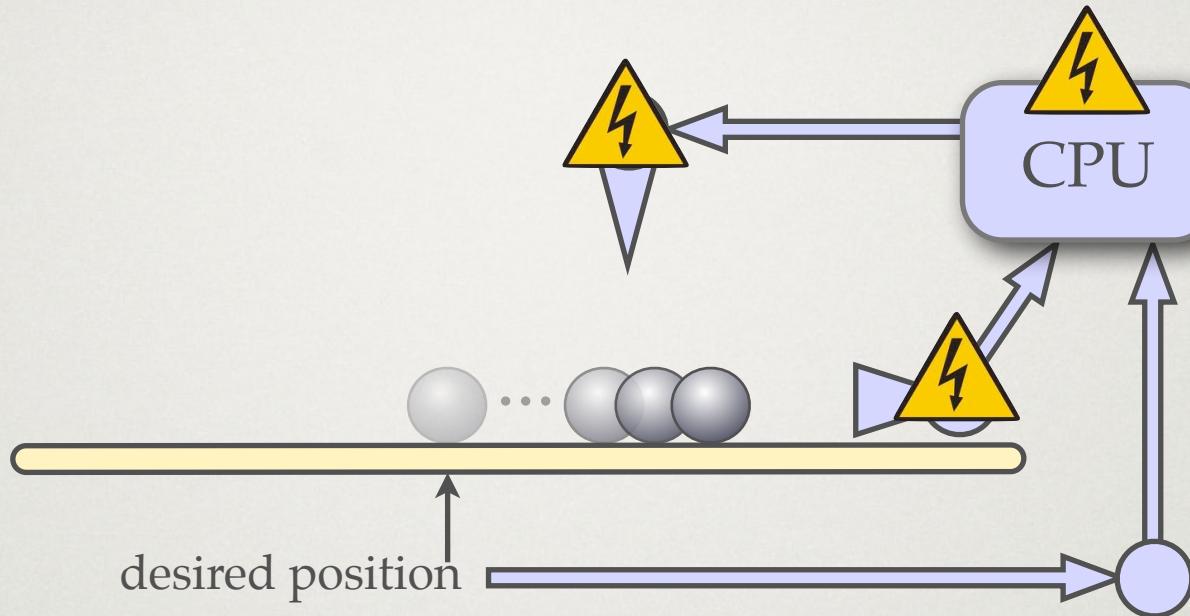
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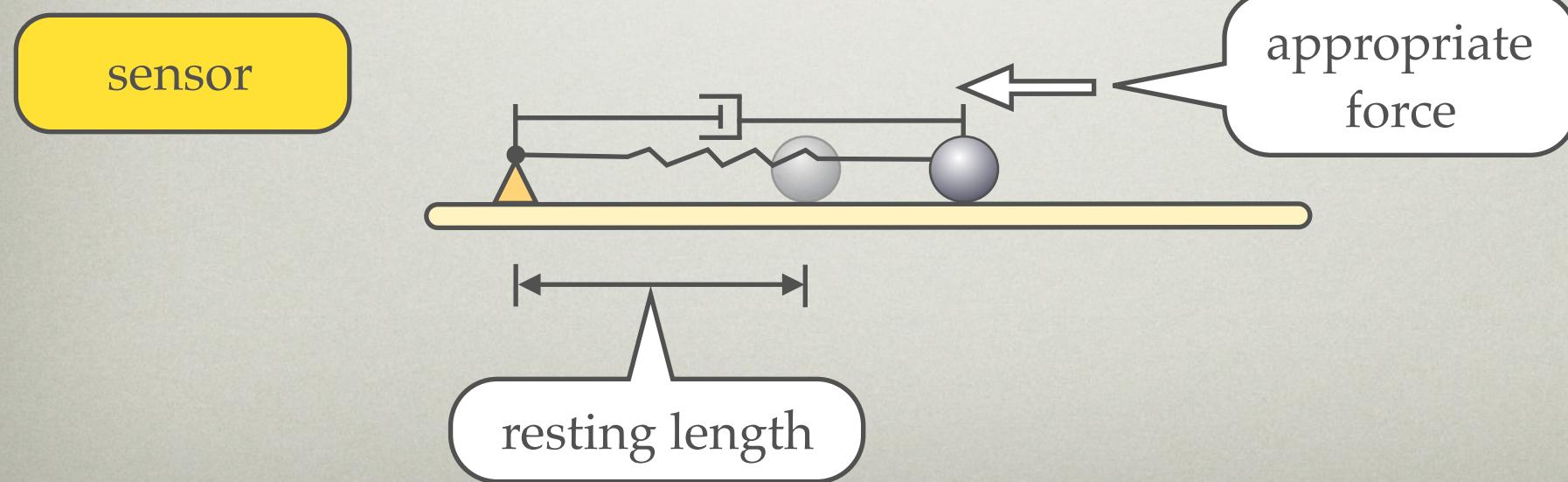
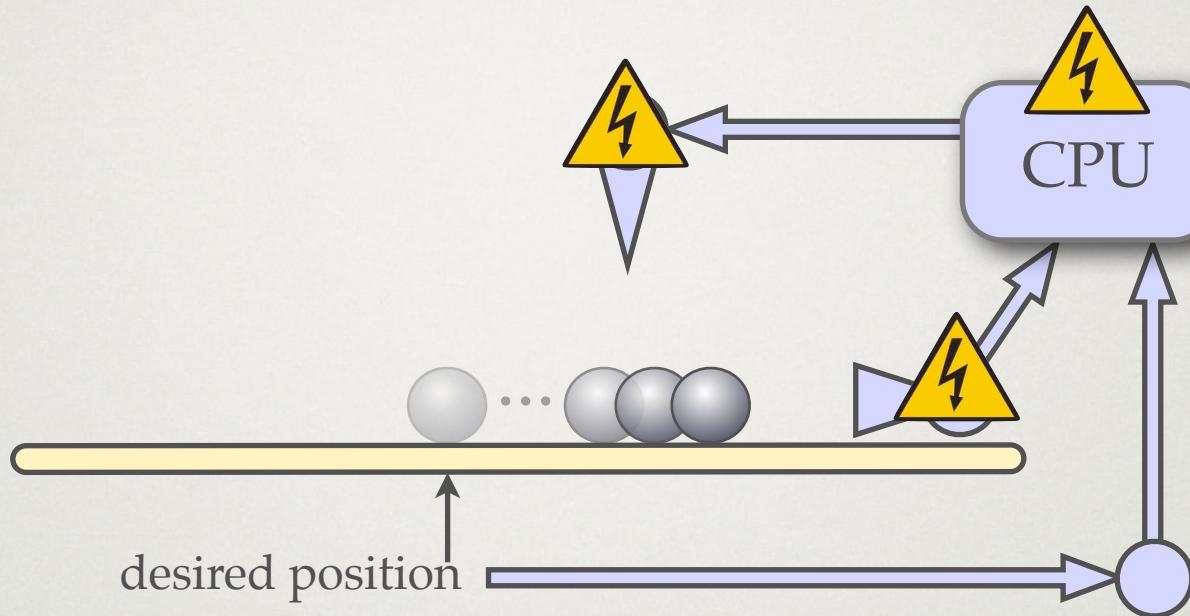
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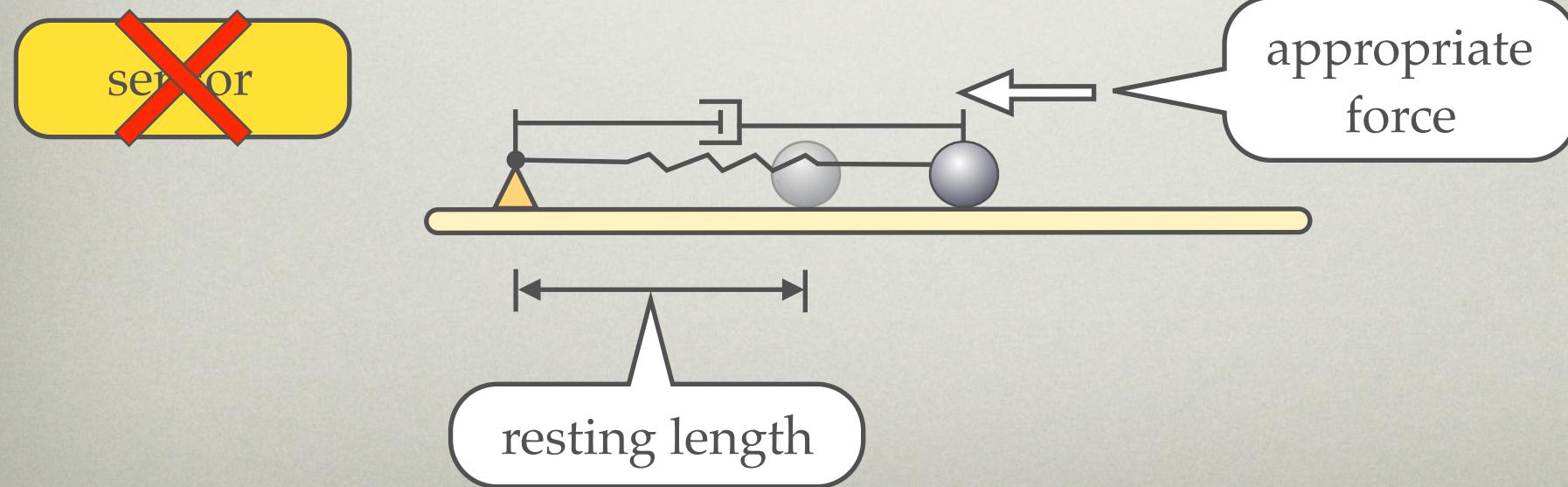
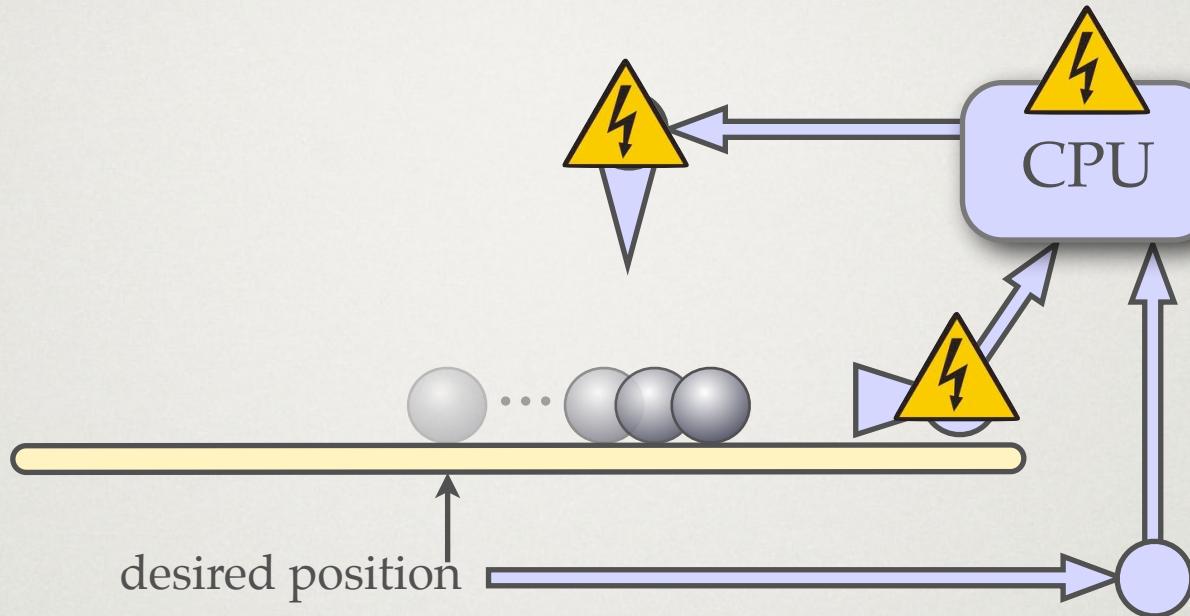
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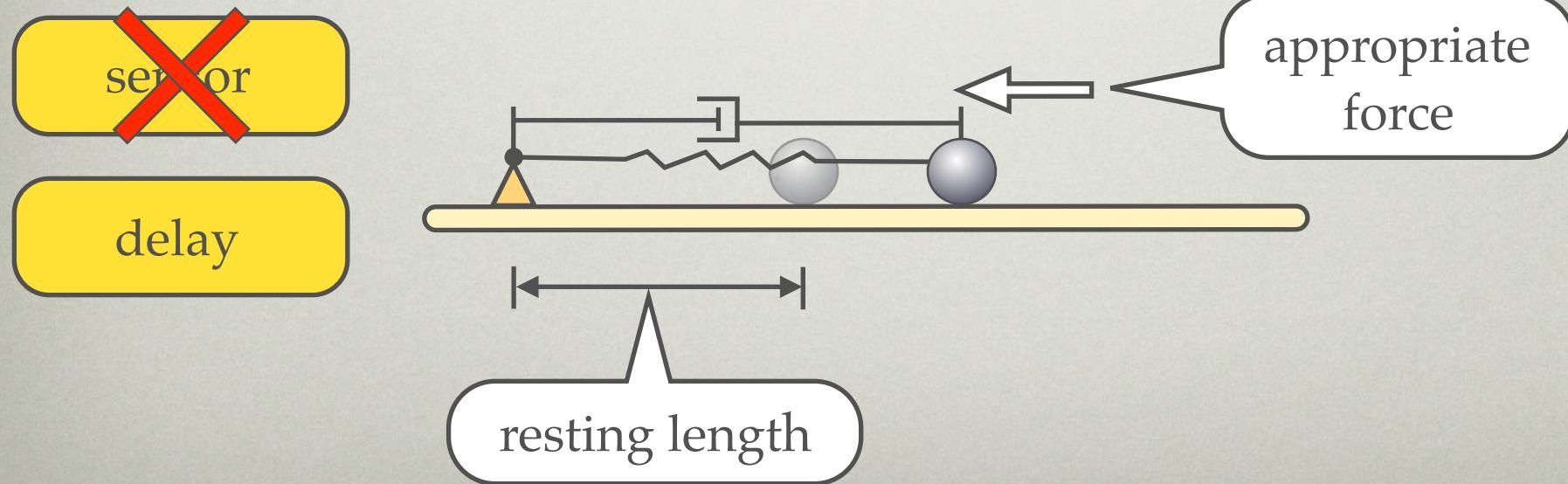
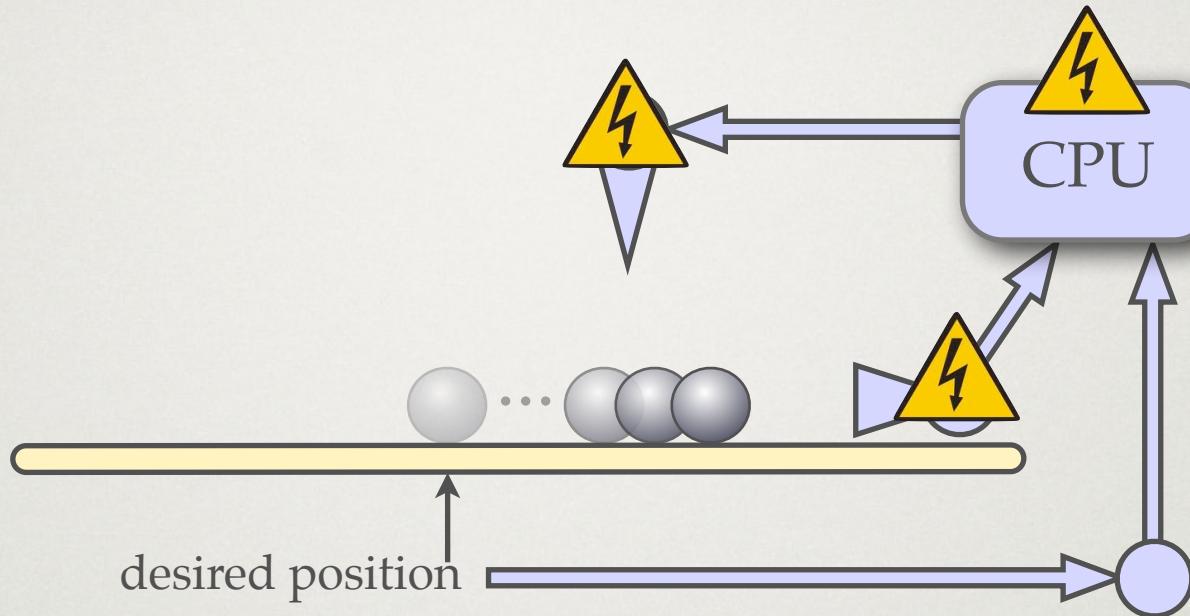
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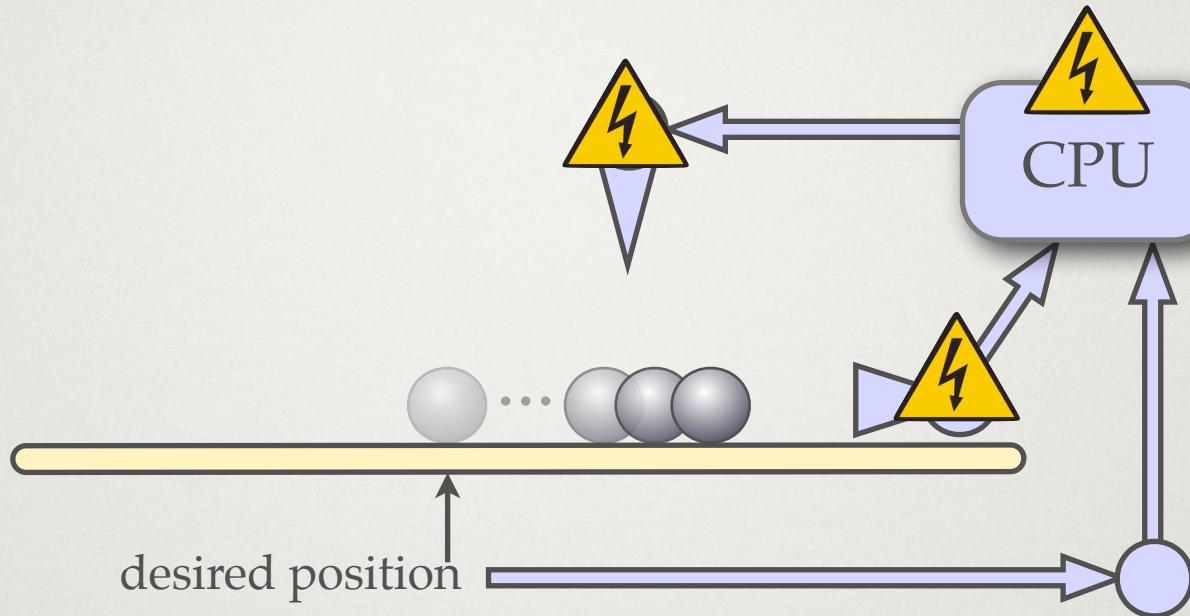
SIMPLE THOUGHT EXPERIMENT



SIMPLE THOUGHT EXPERIMENT

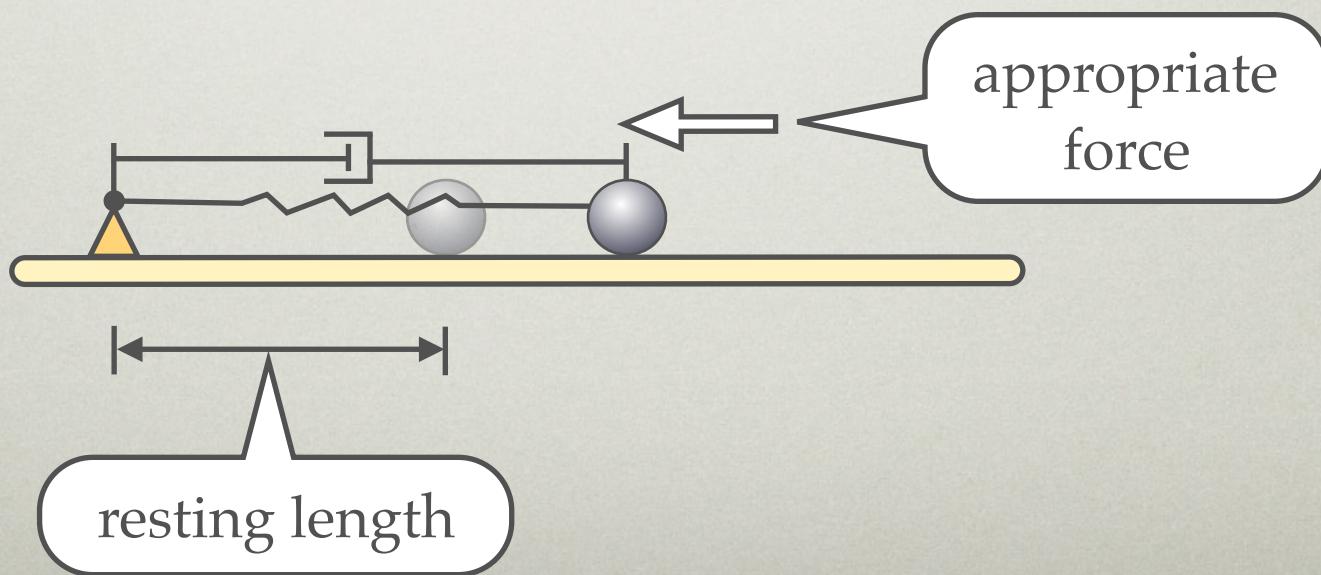


SIMPLE THOUGHT EXPERIMENT

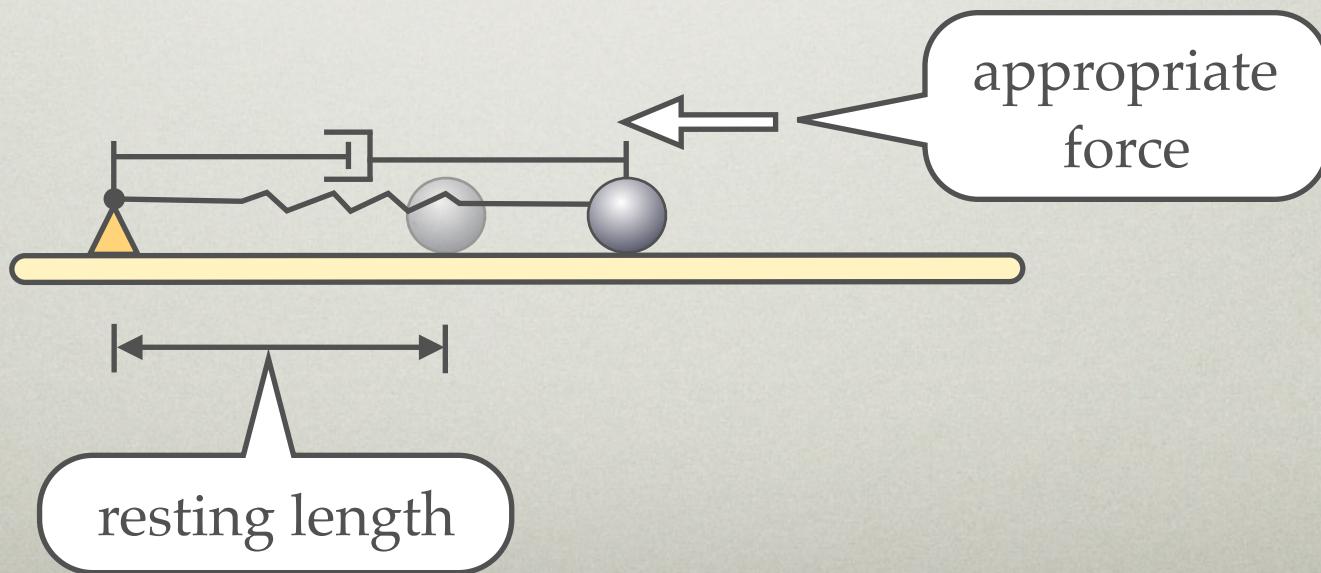
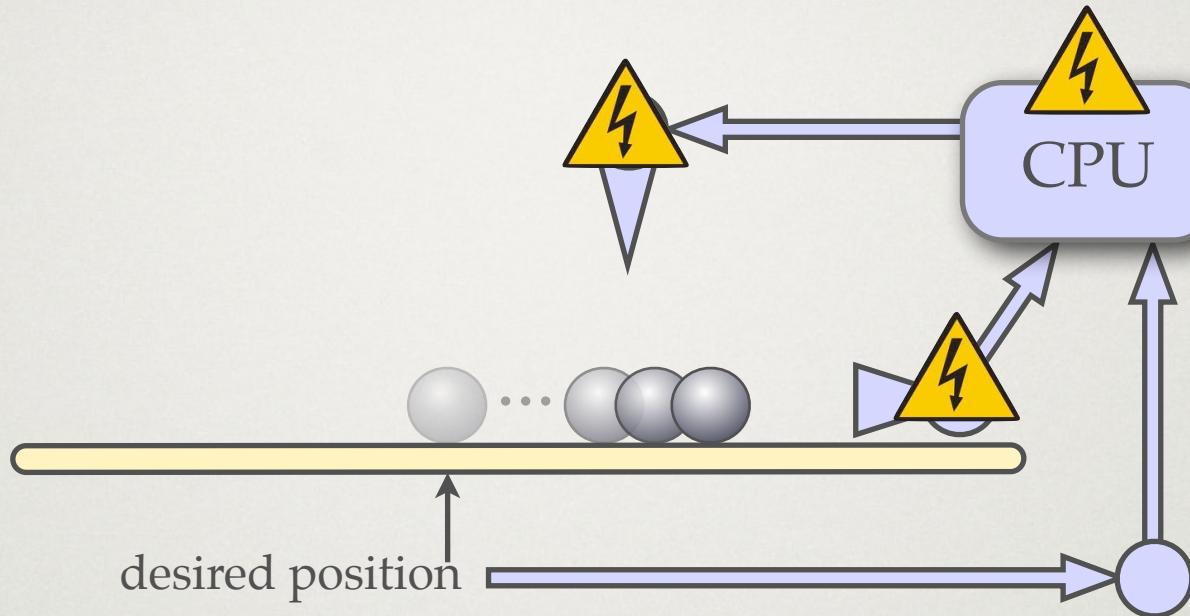


~~sensor~~

~~delay~~

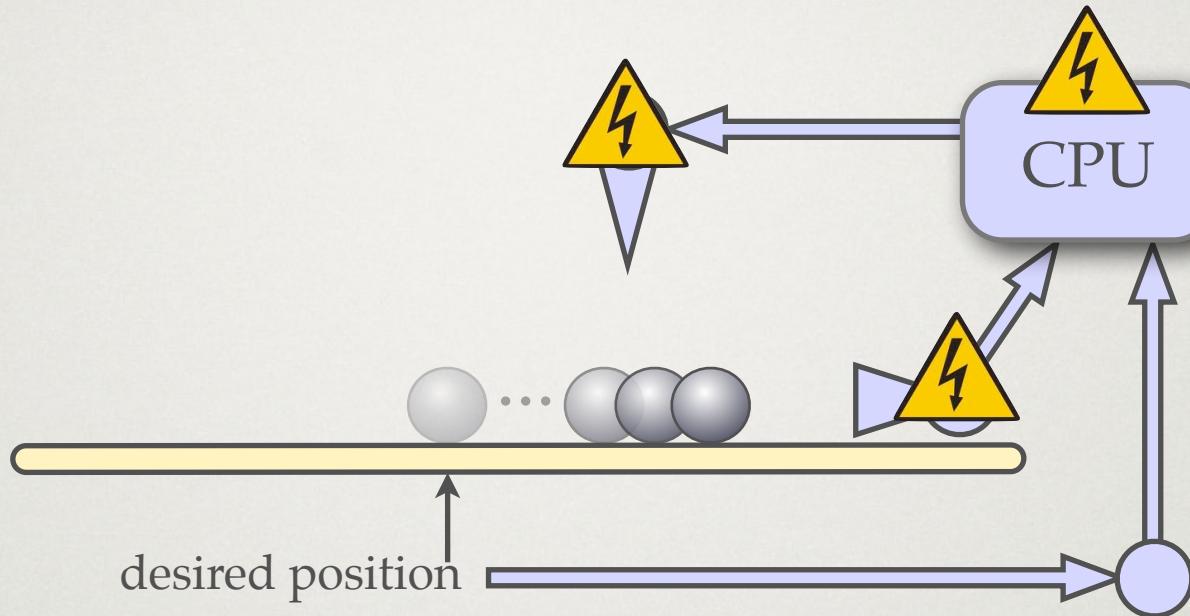


SIMPLE THOUGHT EXPERIMENT

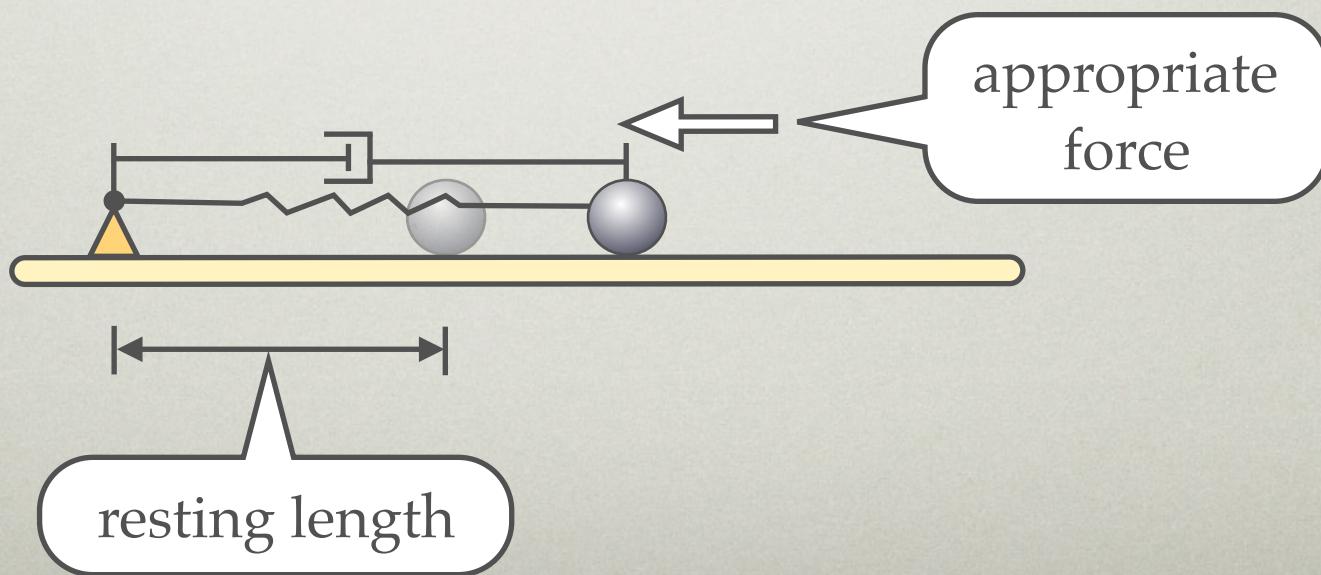


- X sensor
- X delay
- energy

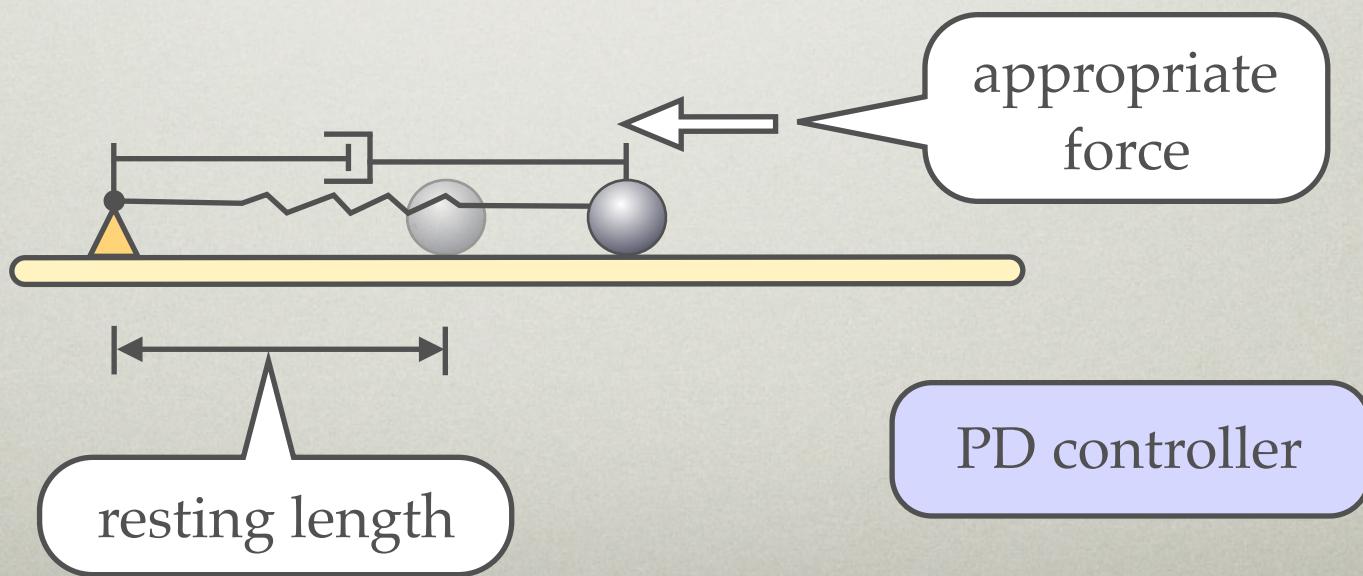
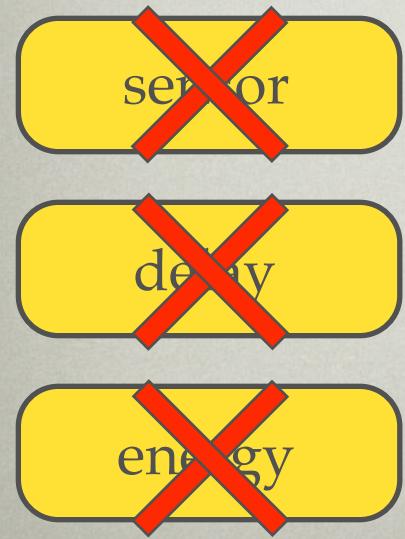
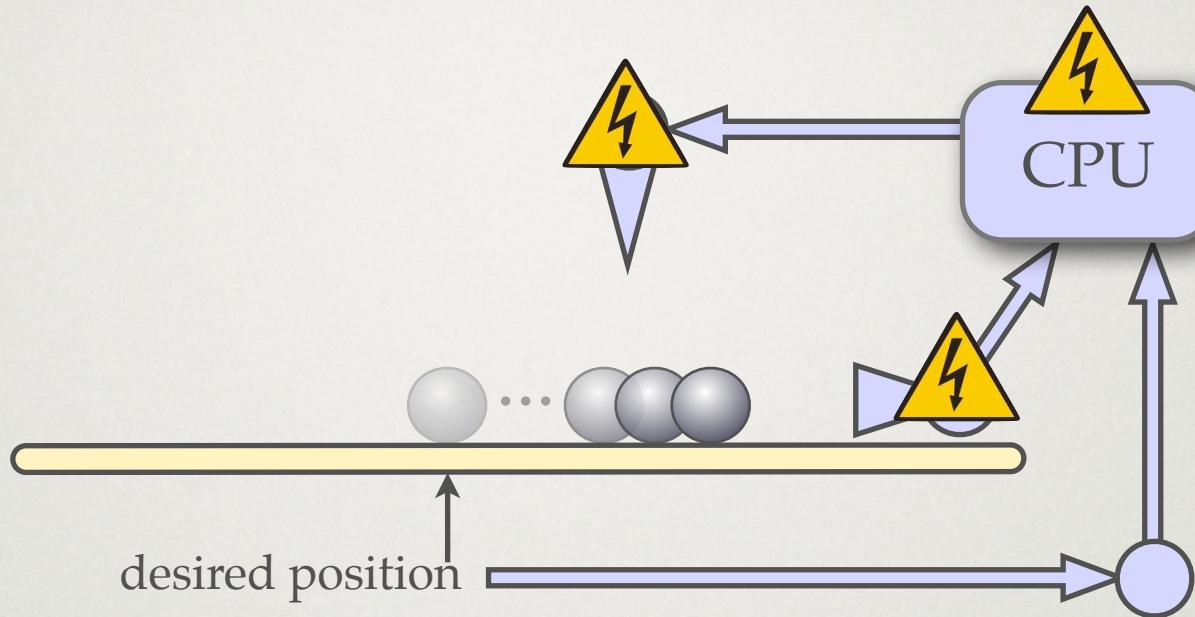
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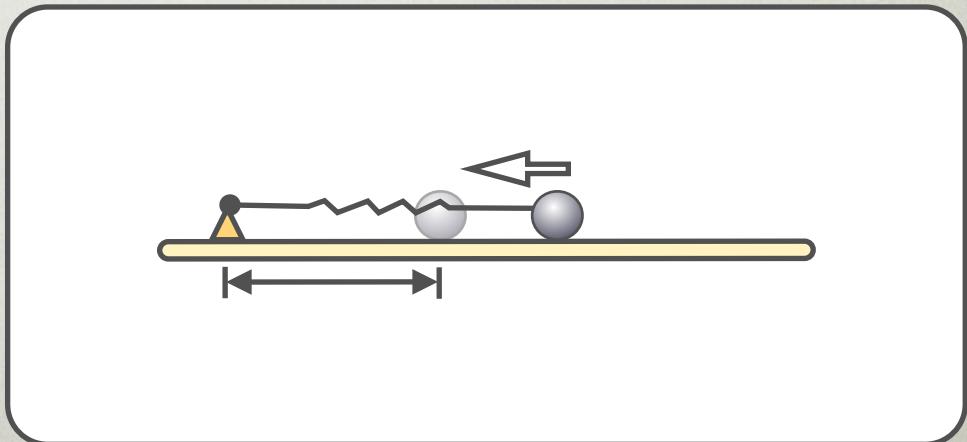
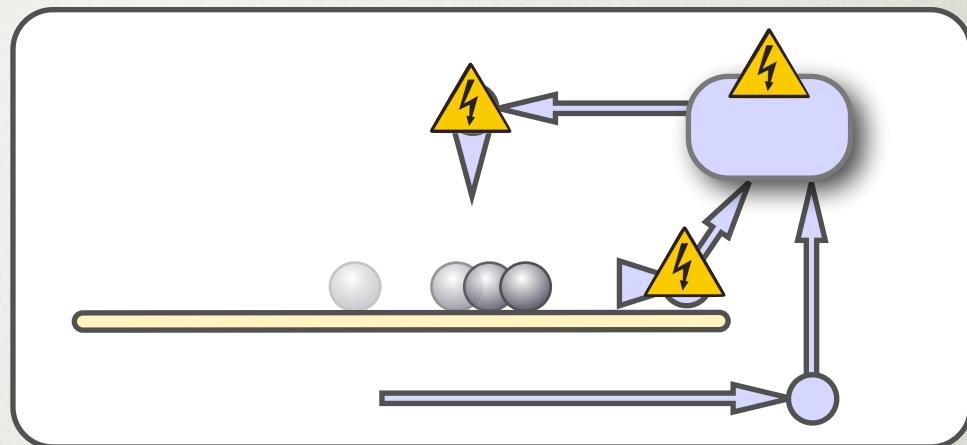
- X sensor
- X delay
- X energy



SIMPLE THOUGHT EXPERIMENT

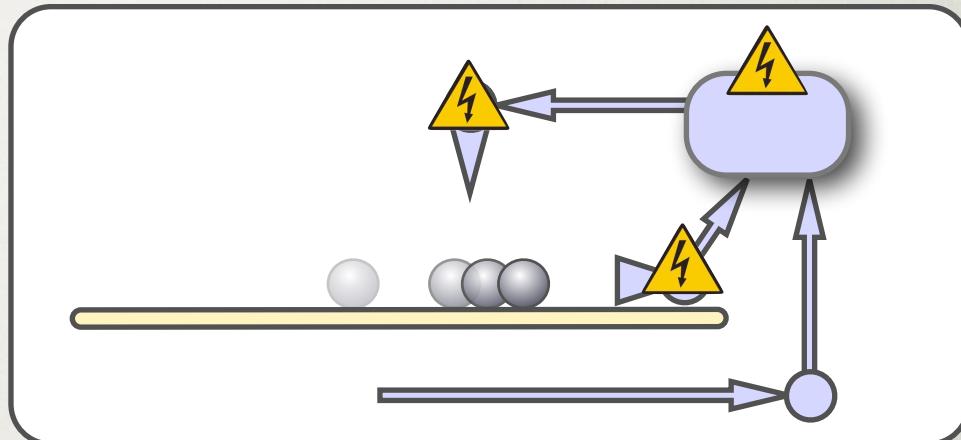


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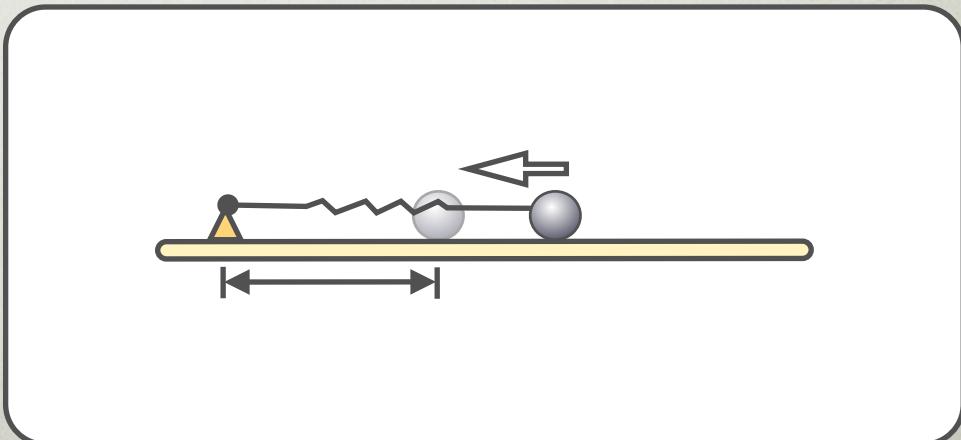


SIMPLE THOUGHT EXPERIMENT

Computation

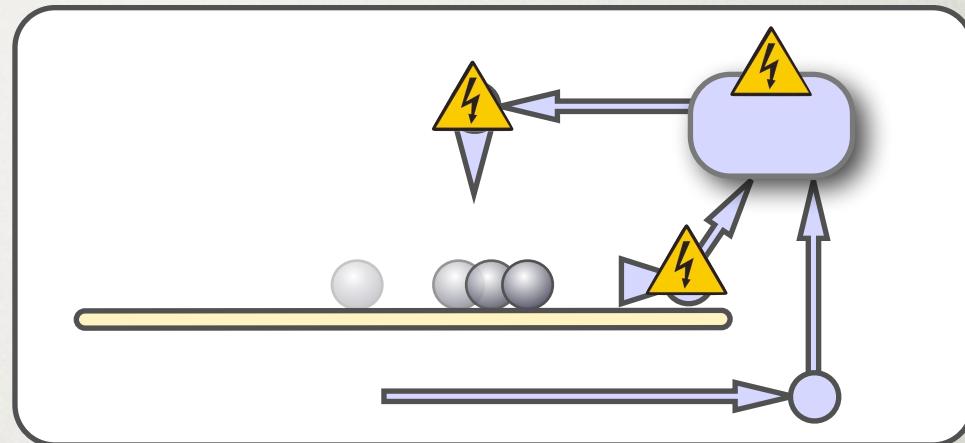


Computation

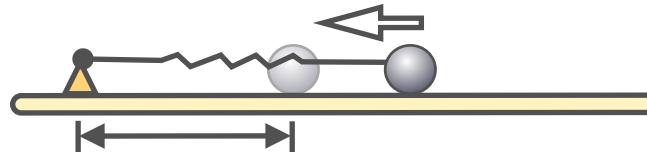


SIMPLE THOUGHT EXPERIMENT

Computation



Computation

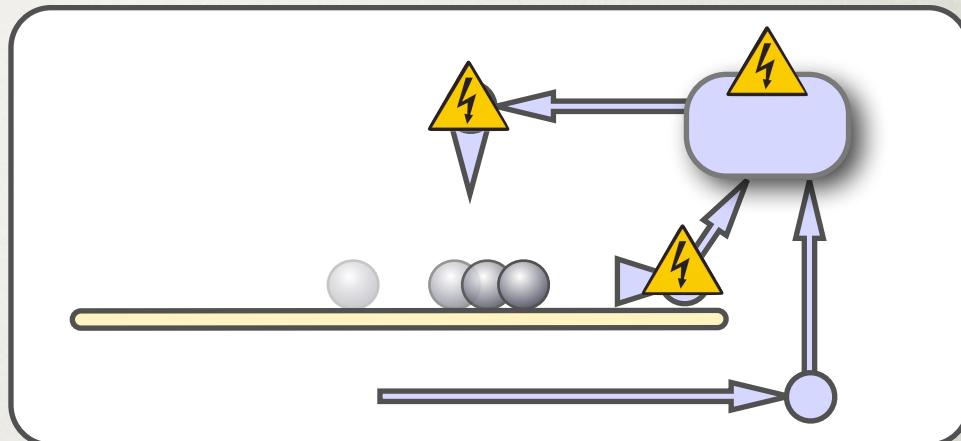


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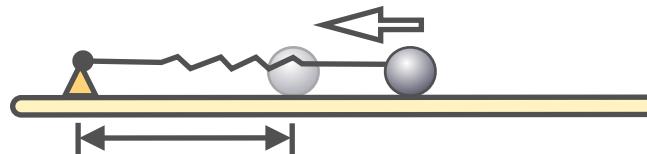
Computation



Controller



Computation

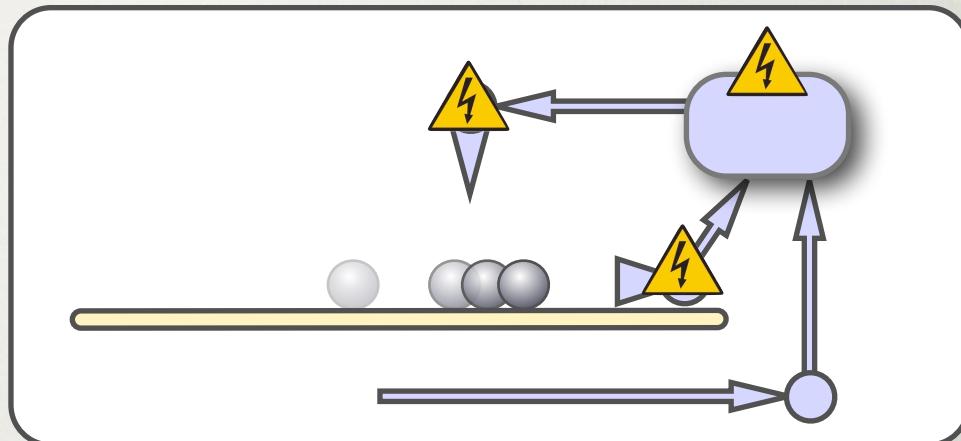


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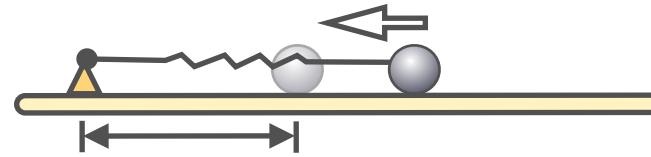
Computation



Controller



Computation

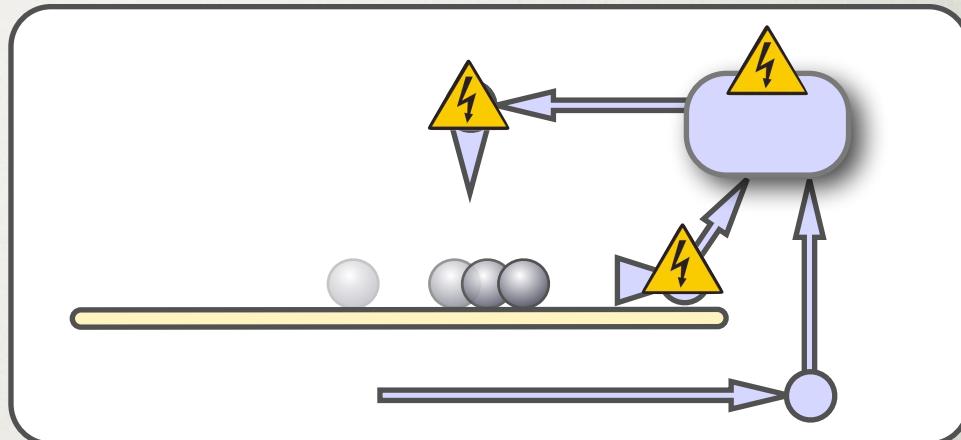


SIMPLE THOUGHT EXPERIMENT

Computation



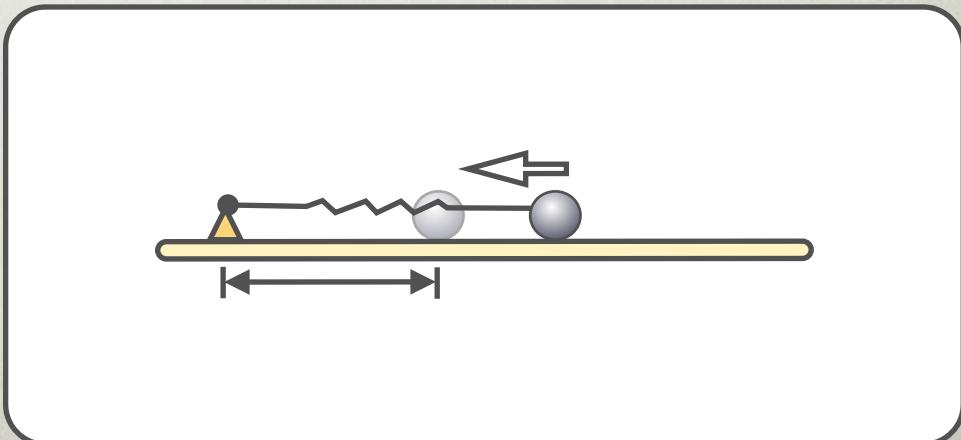
Controller



Computation

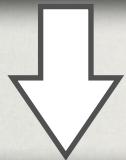


Morphology

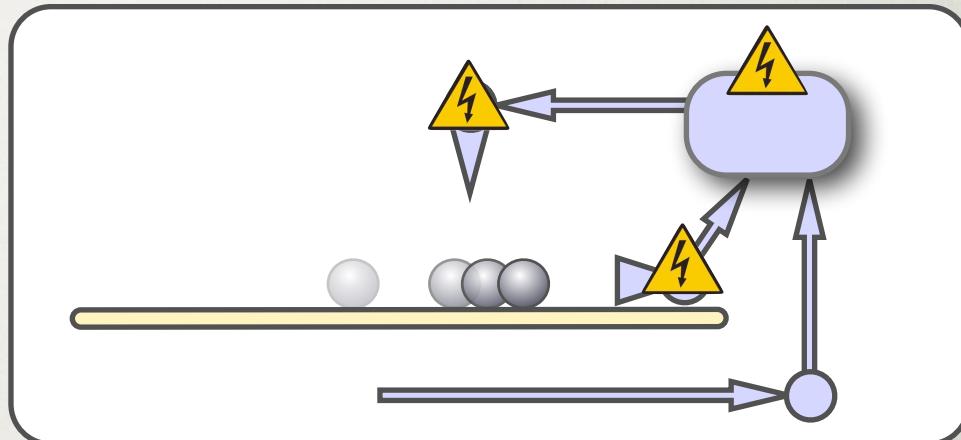


SIMPLE THOUGHT EXPERIMENT

Computation



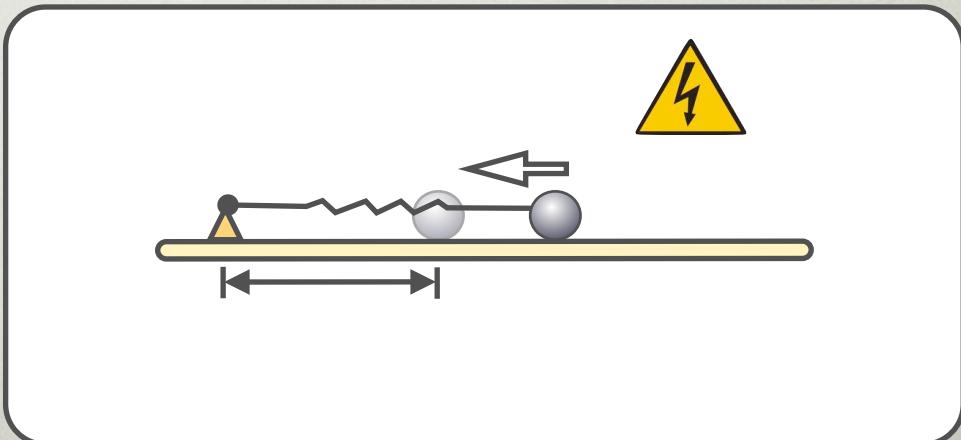
Controller



Computation



Morphology

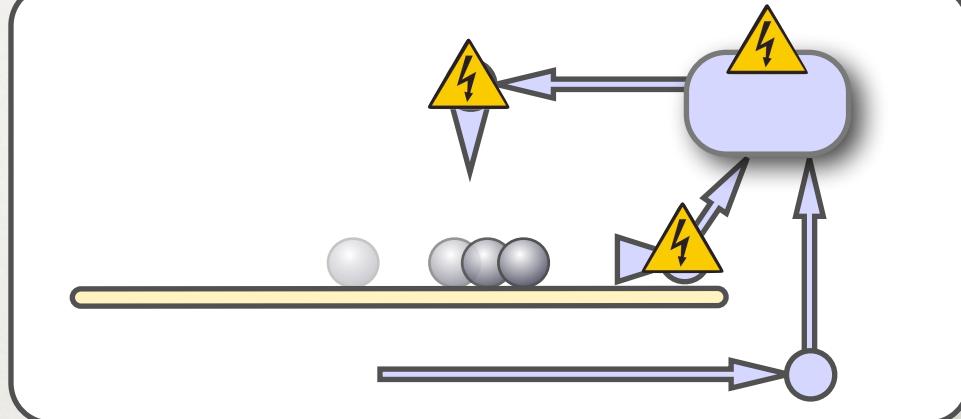


SIMPLE THOUGHT EXPERIMENT

Computation



Controller

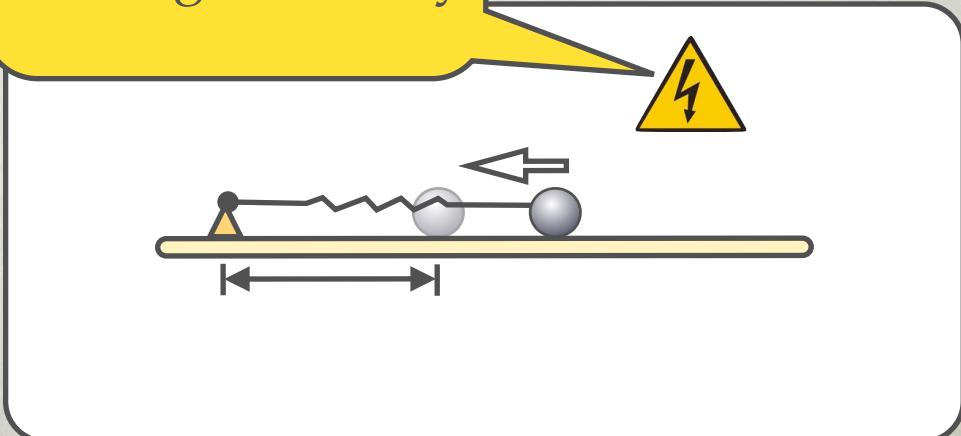


Computation



Morphology

missing flexibility

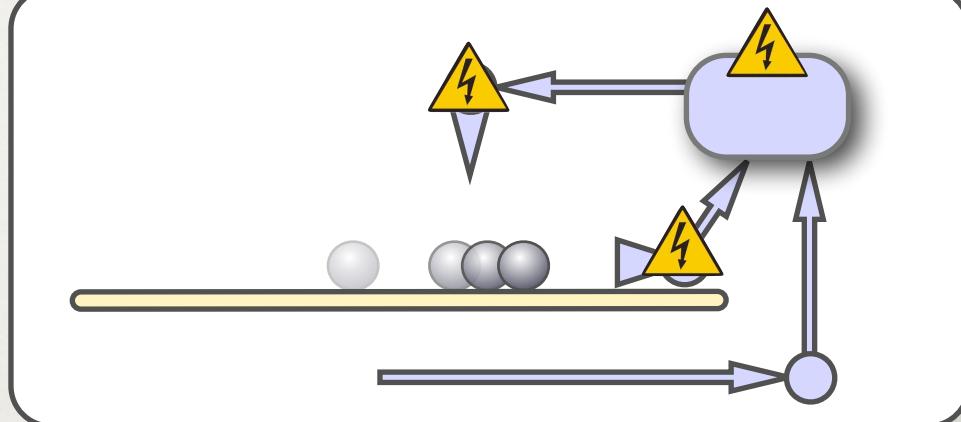


SIMPLE THOUGHT EXPERIMENT

Computation



Controller

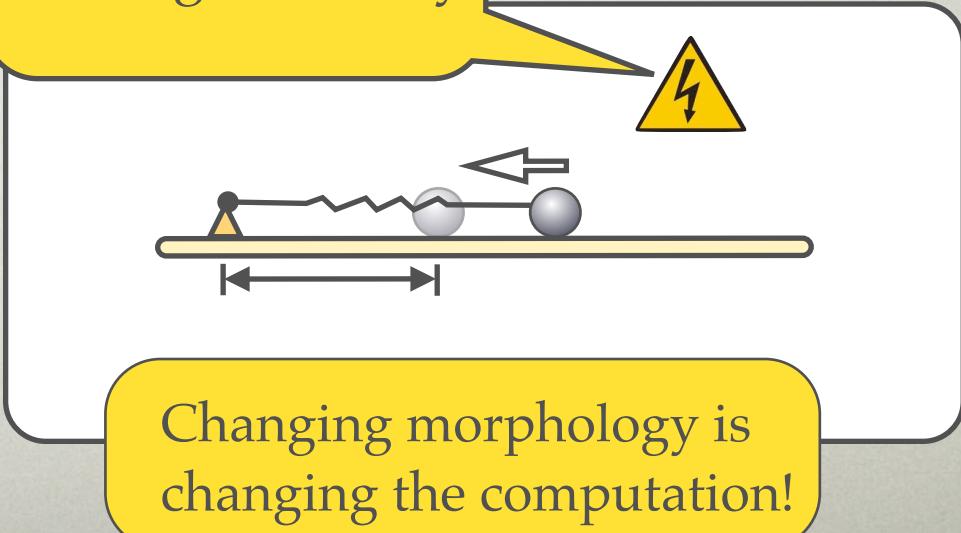


Computation



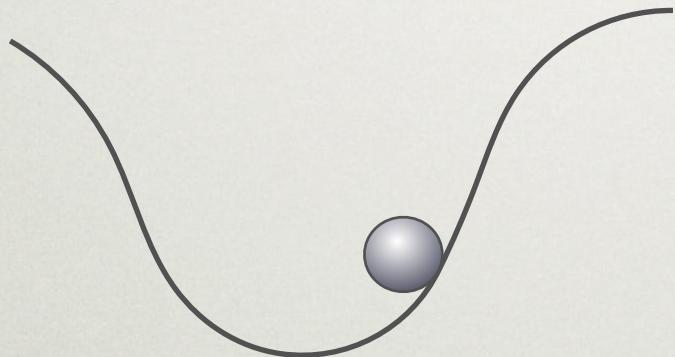
Morphology

missing flexibility

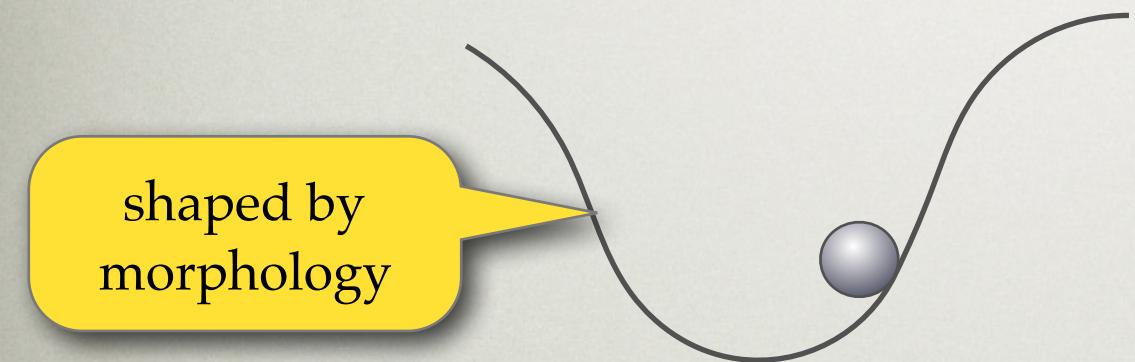


ATTRACTOR LANDSCAPE

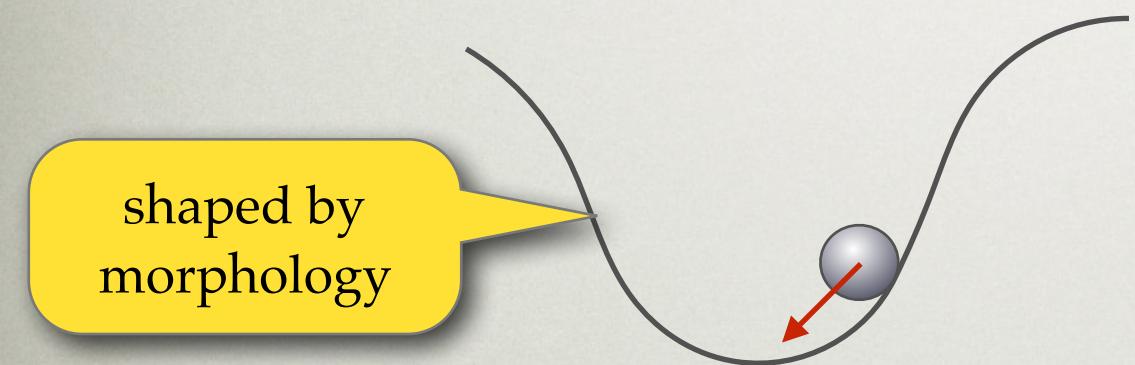
ATTRACTOR LANDSCAPE



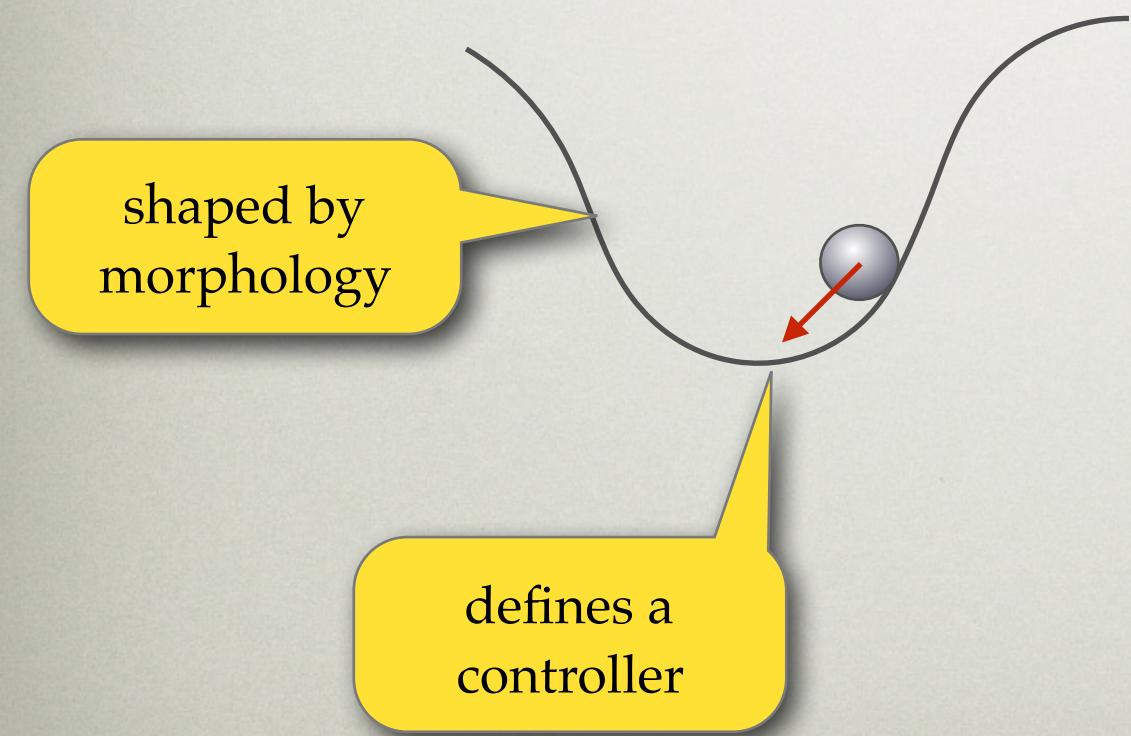
ATTRACTOR LANDSCAPE



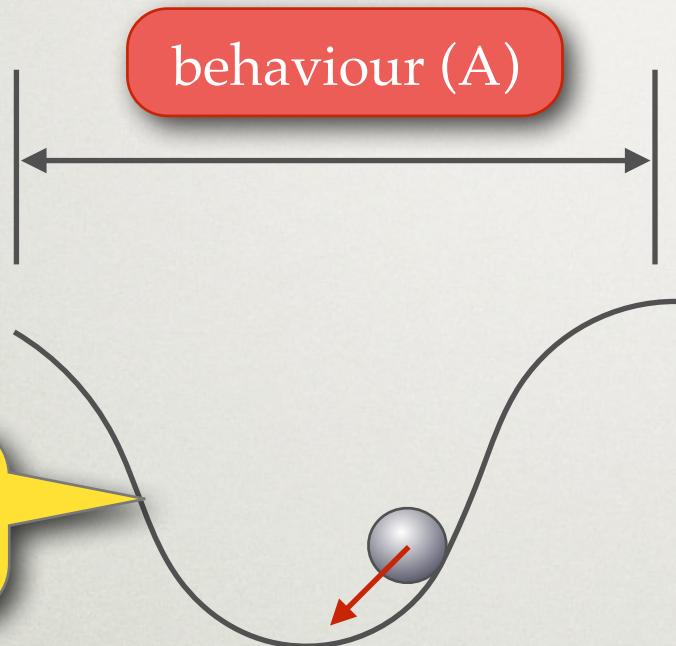
ATTRACTOR LANDSCAPE



ATTRACTOR LANDSCAPE



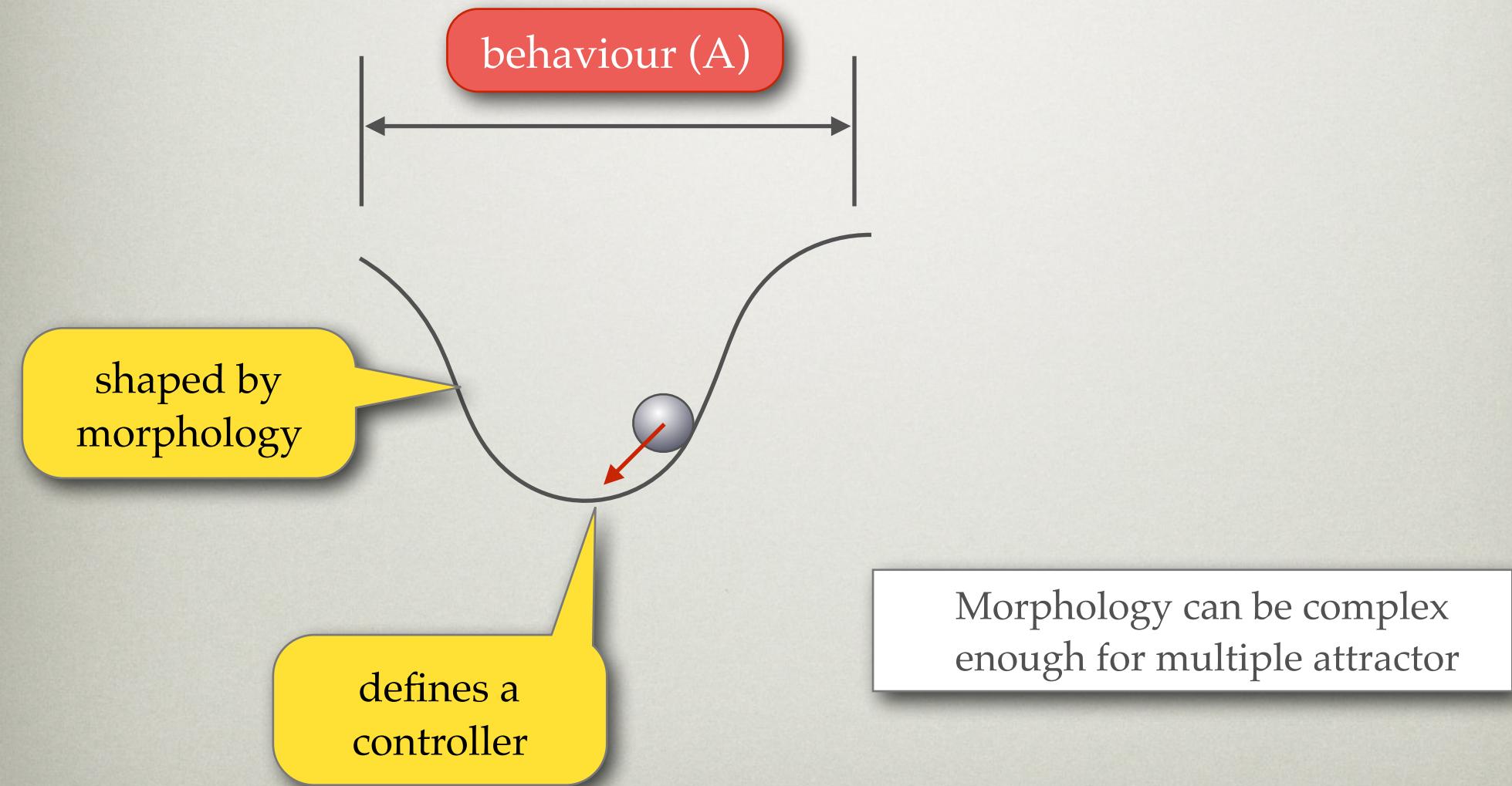
ATTRACTOR LANDSCAPE



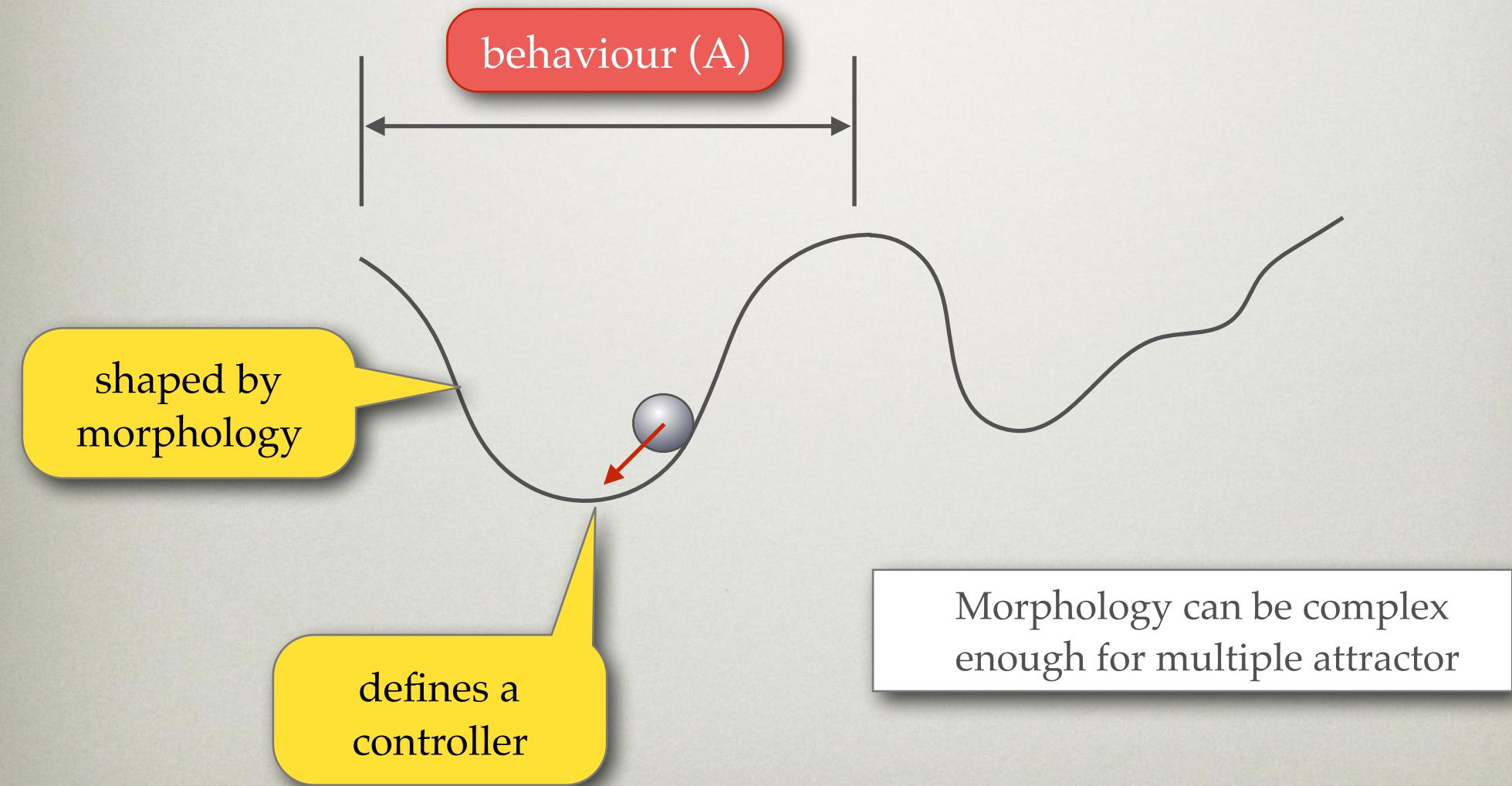
shaped by
morphology

defines a
controller

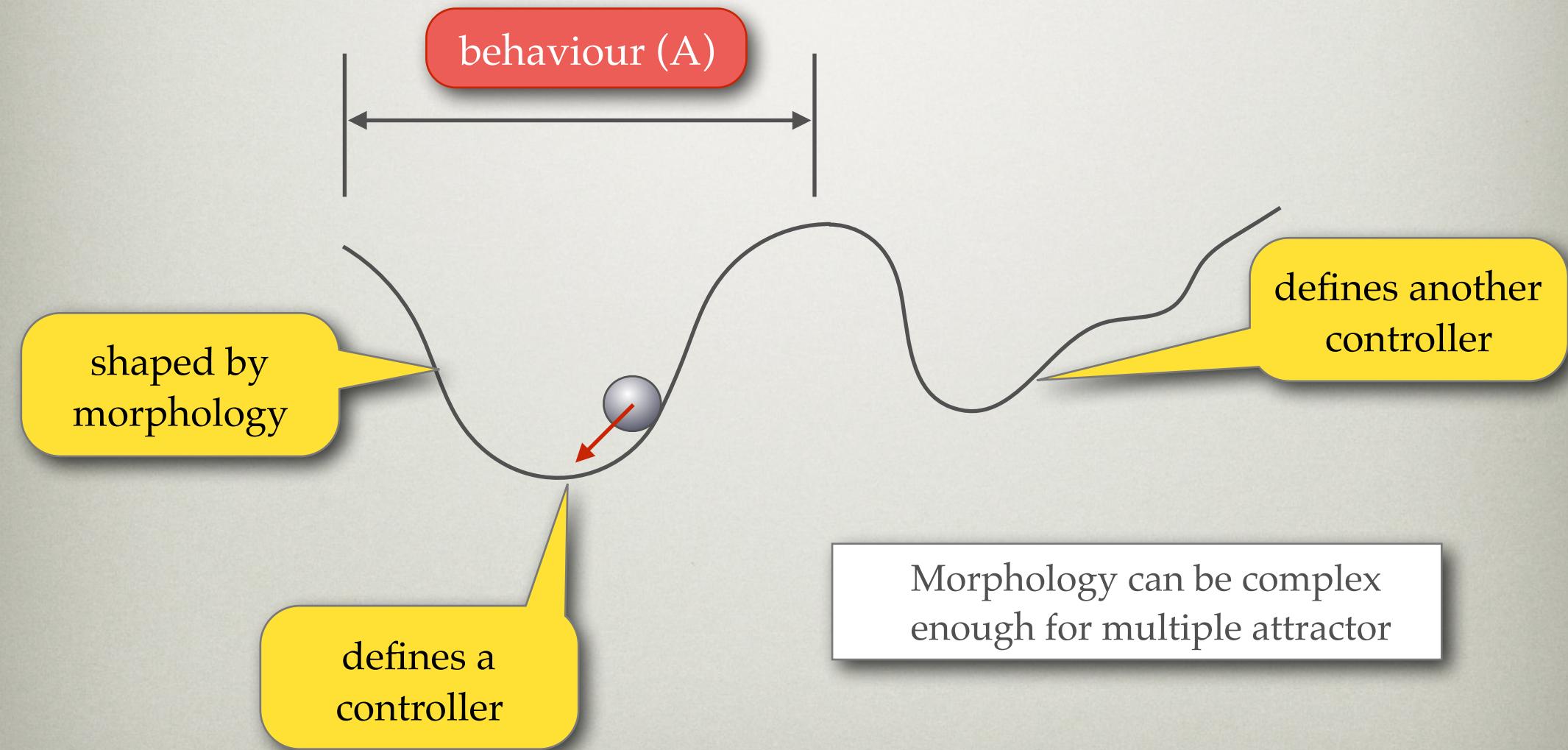
ATTRACTOR LANDSCAPE



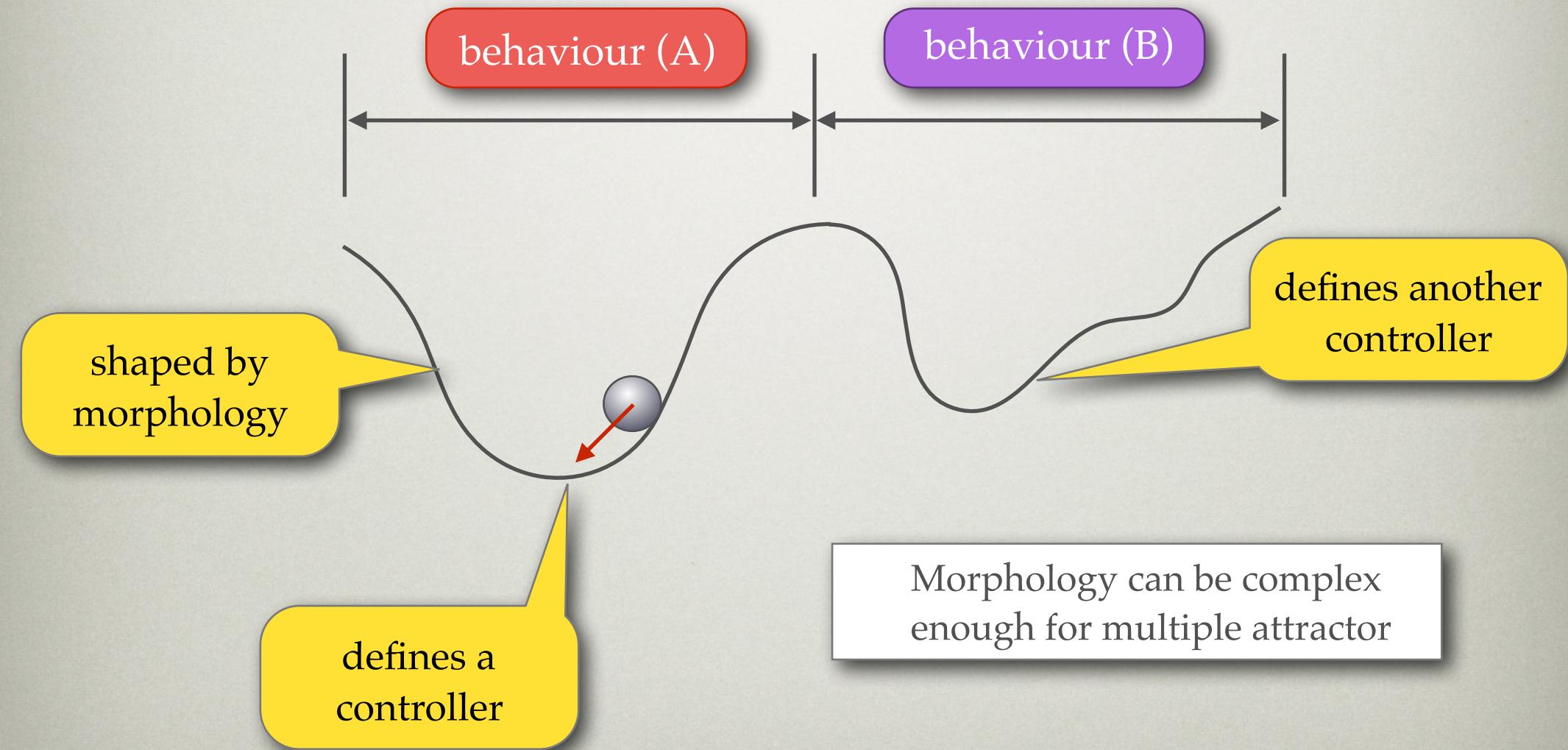
ATTRACTOR LANDSCAPE



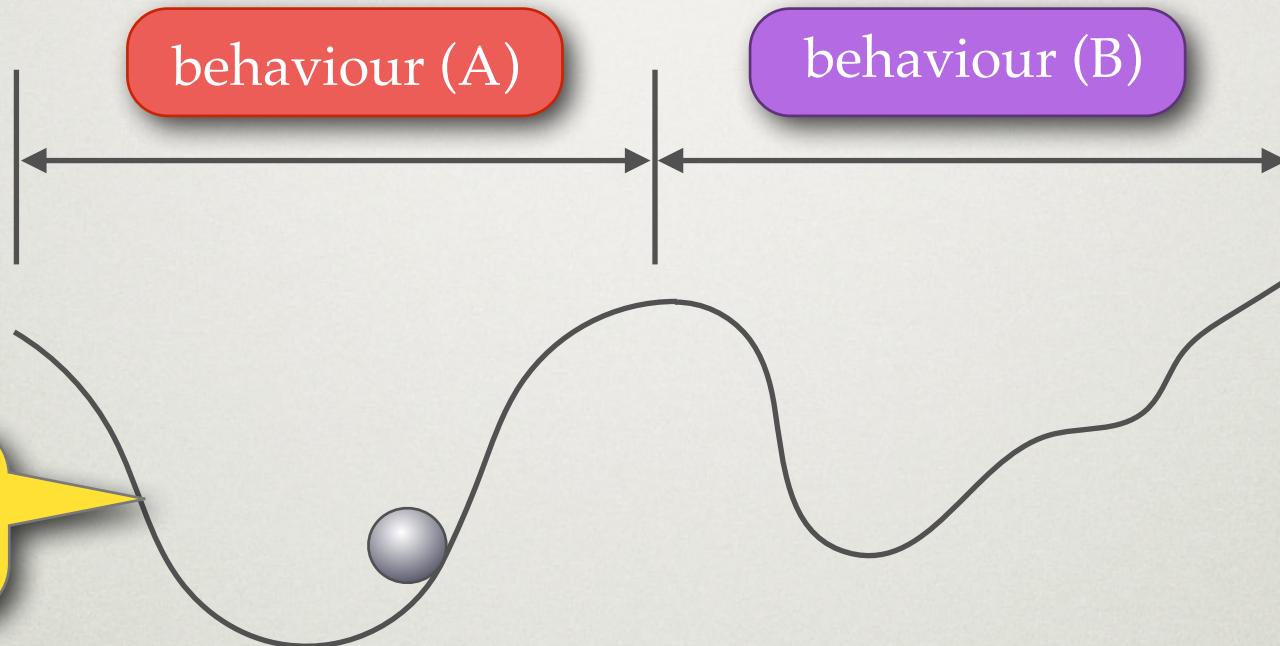
ATTRACTOR LANDSCAPE



ATTRACTOR LANDSCAPE

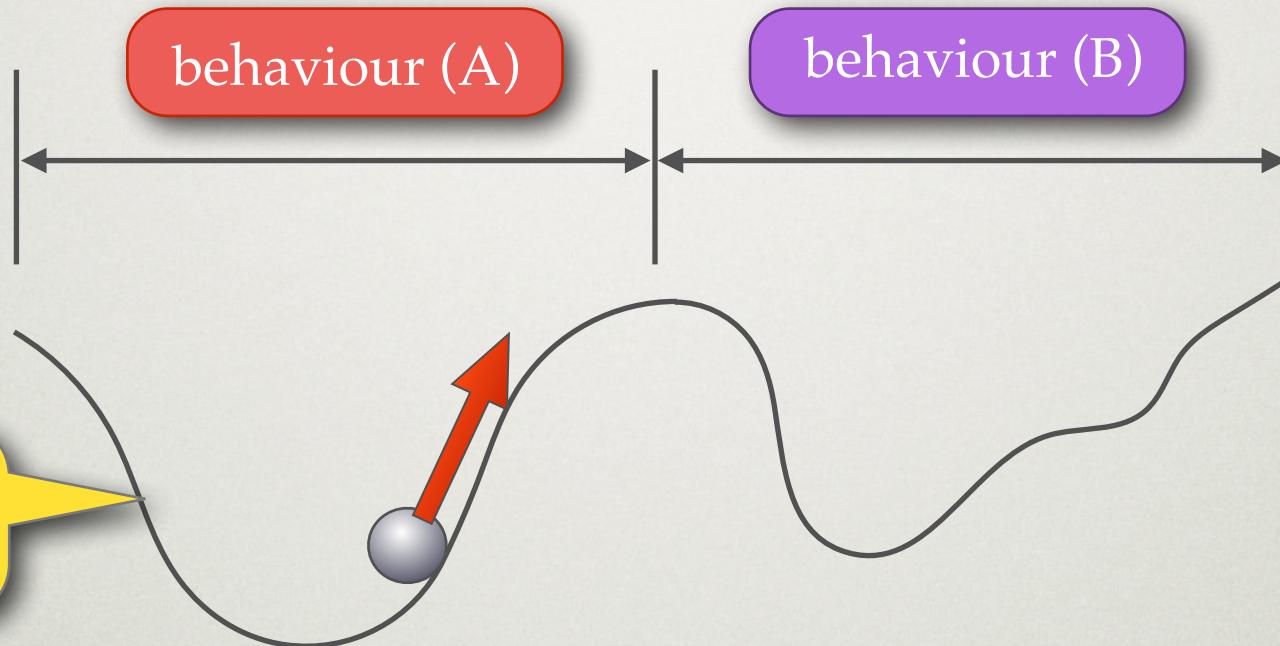


ATTRACTOR LANDSCAPE



How do we change from (A) to (B)?

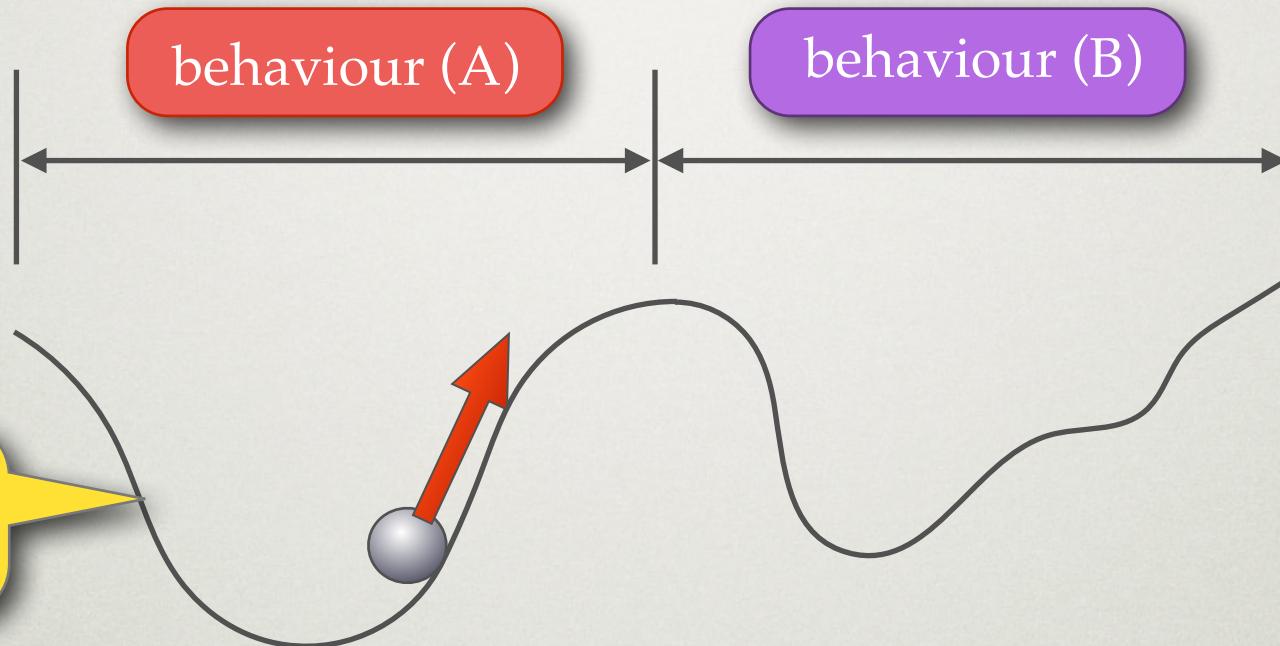
ATTRACTOR LANDSCAPE



How do we change from (A) to (B)?

- Push it into the right direction

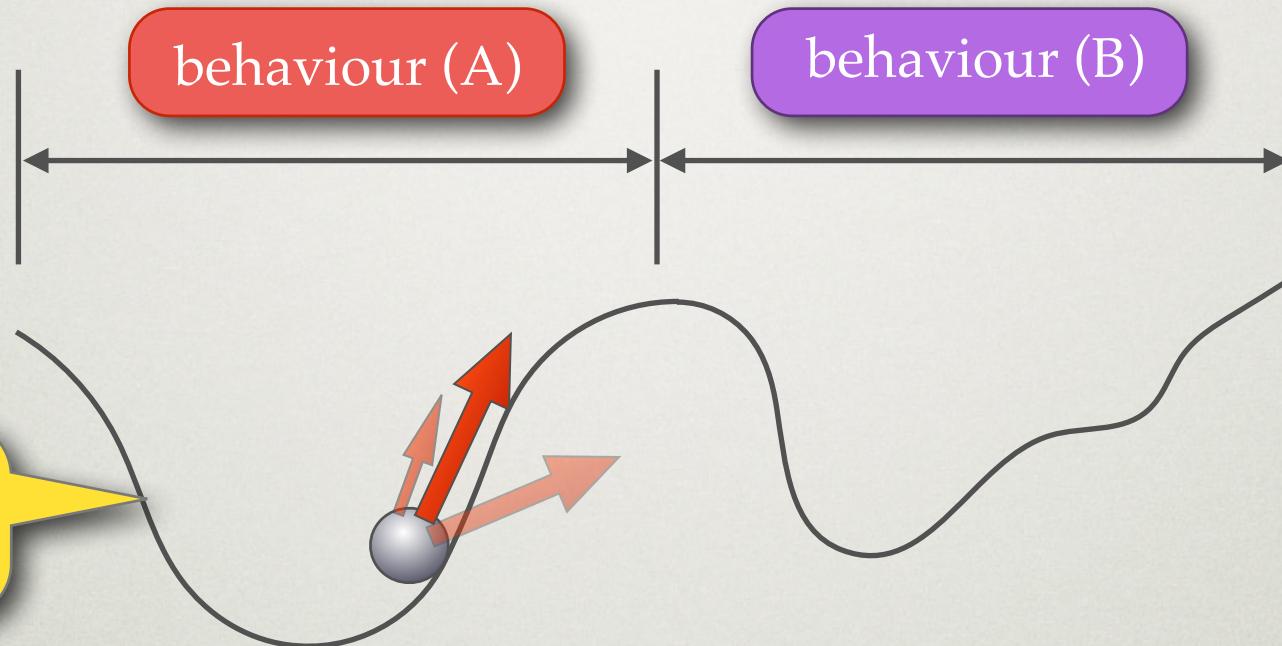
ATTRACTOR LANDSCAPE



How do we change from (A) to (B)?

- Push it into the right direction
- Very simple!

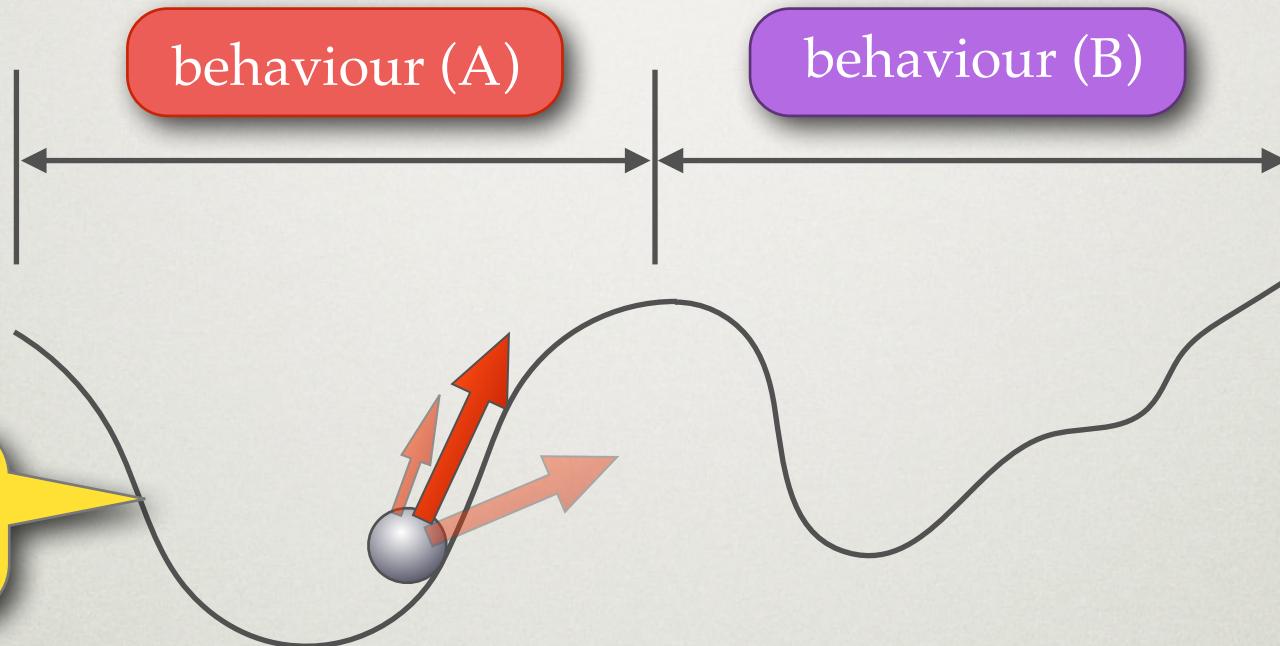
ATTRACTOR LANDSCAPE



How do we change from (A) to (B)?

- Push it into the right direction
- Very simple!
- No precision is needed!

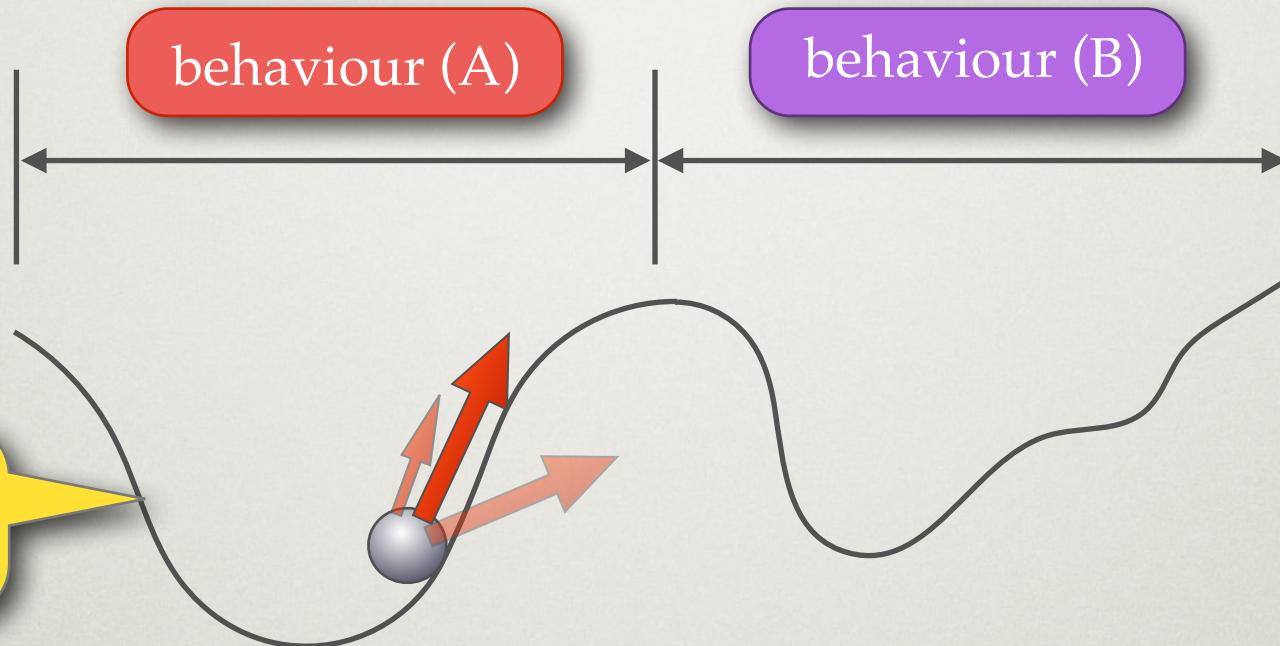
ATTRACTOR LANDSCAPE



How do we change from (A) to (B)?

- Push it into the right direction
- Very simple!
- No precision is needed!
- The rest is done by the morphology

ATTRACTOR LANDSCAPE



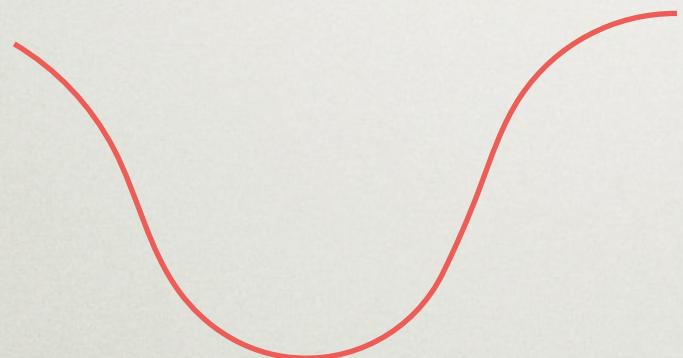
How do we change from (A) to (B)?

- Push it into the right direction
- Very simple!
- No precision is needed!
- The rest is done by the morphology

controller can be
simple and
temporary

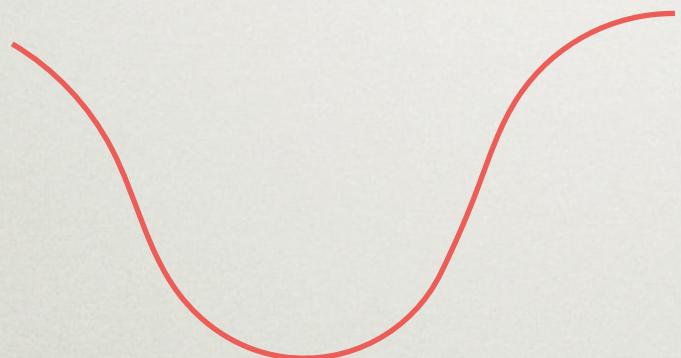
ATTRACTOR LANDSCAPE

behaviour (A)



ATTRACTOR LANDSCAPE

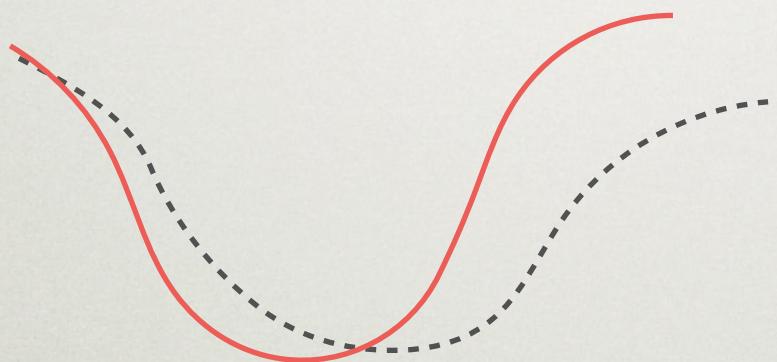
behaviour (A)



Changing morphology!

ATTRACTOR LANDSCAPE

behaviour (A)



Changing morphology!

ATTRACTOR LANDSCAPE

behaviour (A)

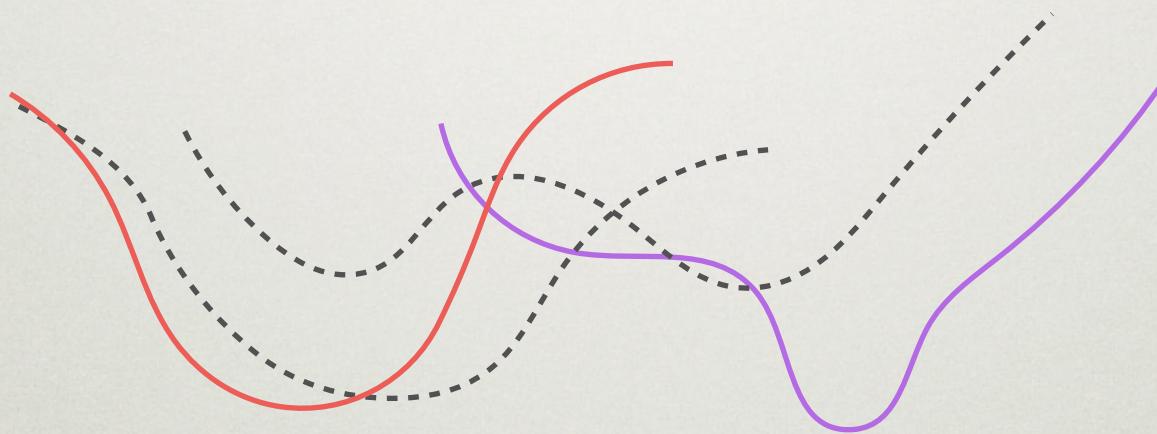


Changing morphology!

ATTRACTOR LANDSCAPE

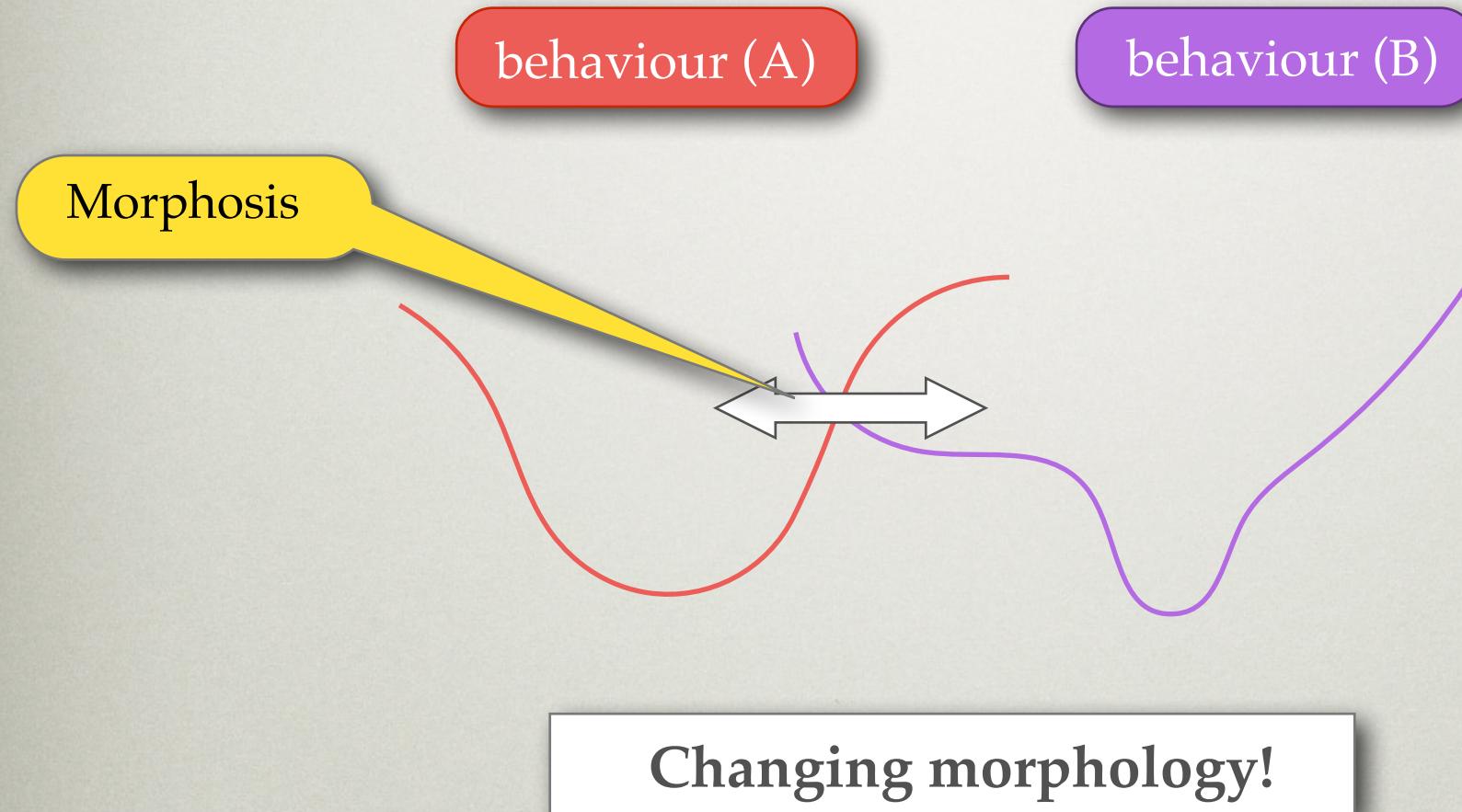
behaviour (A)

behaviour (B)

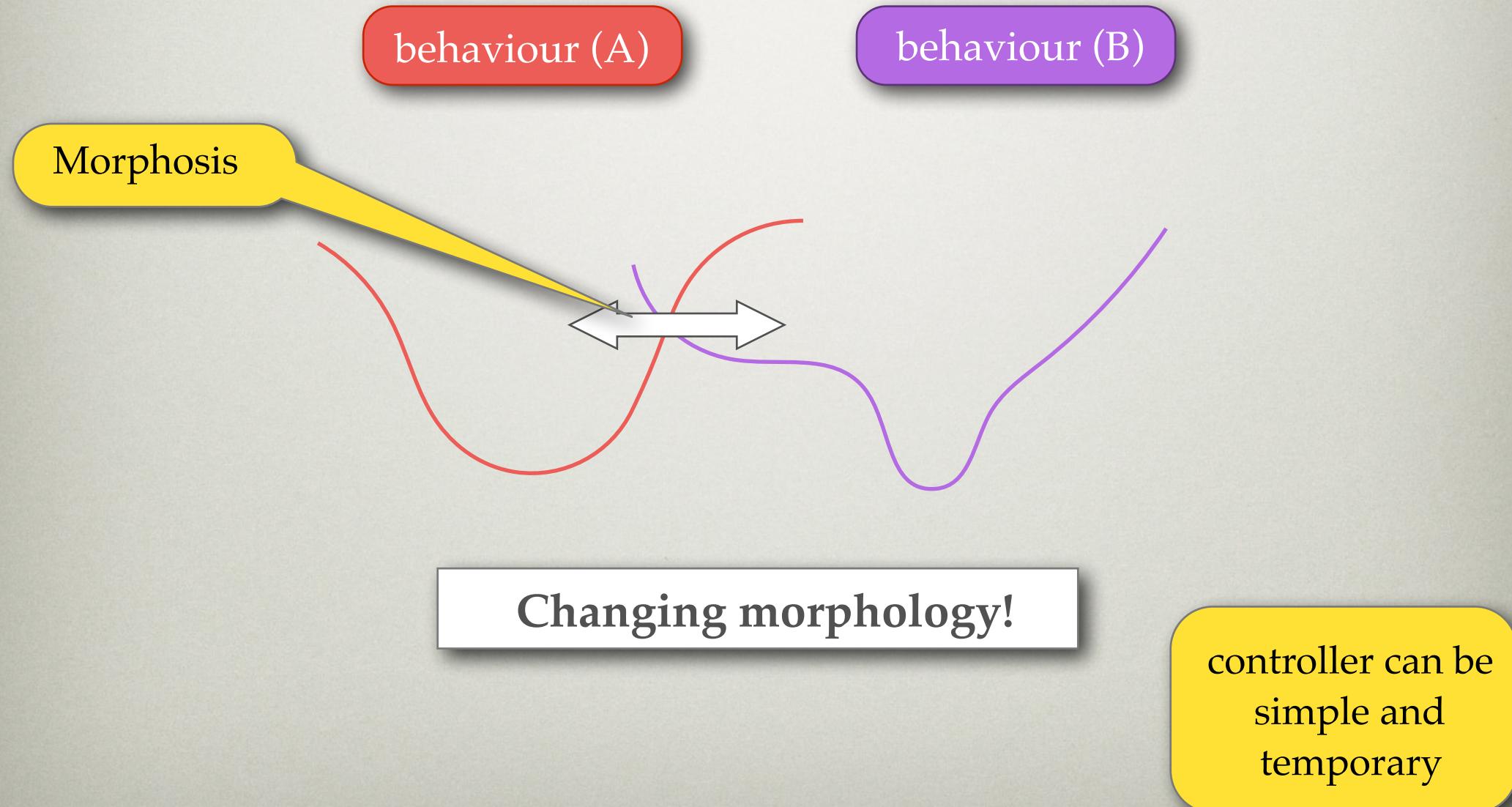


Changing morphology!

ATTRACTOR LANDSCAPE



ATTRACTOR LANDSCAPE



ATTRACTOR LANDSCAPE

behaviour (A)

behaviour (B)

ATTRACTOR LANDSCAPE

behaviour (A)

behaviour (B)

controller (A)

controller (B)

ATTRACTOR LANDSCAPE

behaviour (A)

behaviour (B)



controller (A)

controller (B)



ATTRACTOR LANDSCAPE

behaviour (A)

behaviour (B)



controller (A)

controller (B)



limit cycle (A)

limit cycle (B)

ATTRACTOR LANDSCAPE

behaviour (A)

behaviour (B)

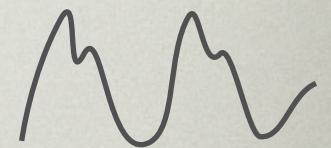
controller (A)

controller (B)



limit cycle (A)

limit cycle (B)



ATTRACTOR LANDSCAPE

behaviour (A)

behaviour (B)

controller (A)

controller (B)

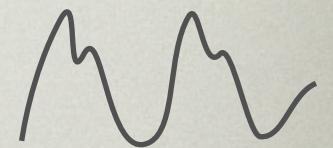


limit cycle (A)

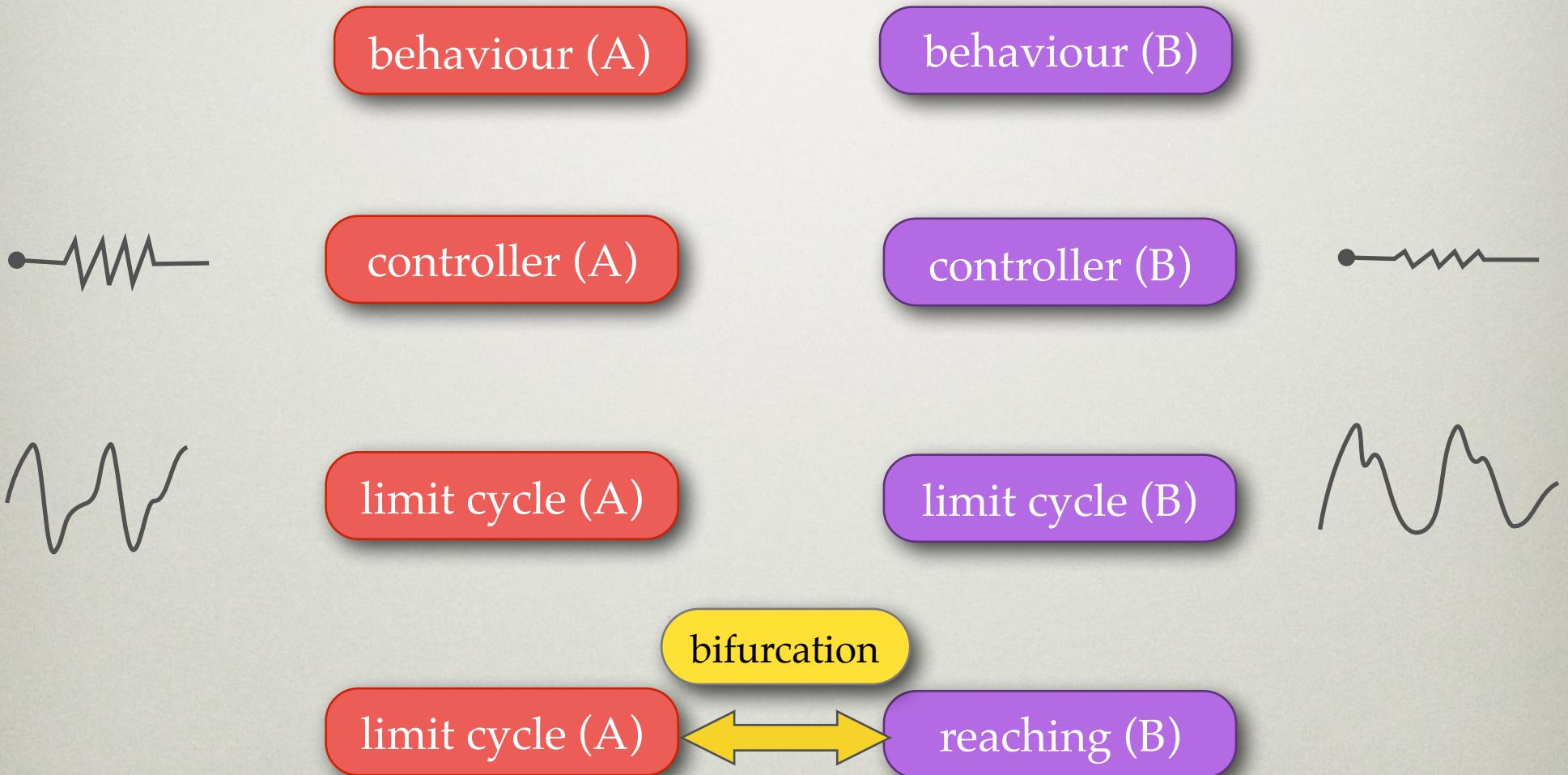
limit cycle (B)

limit cycle (A)

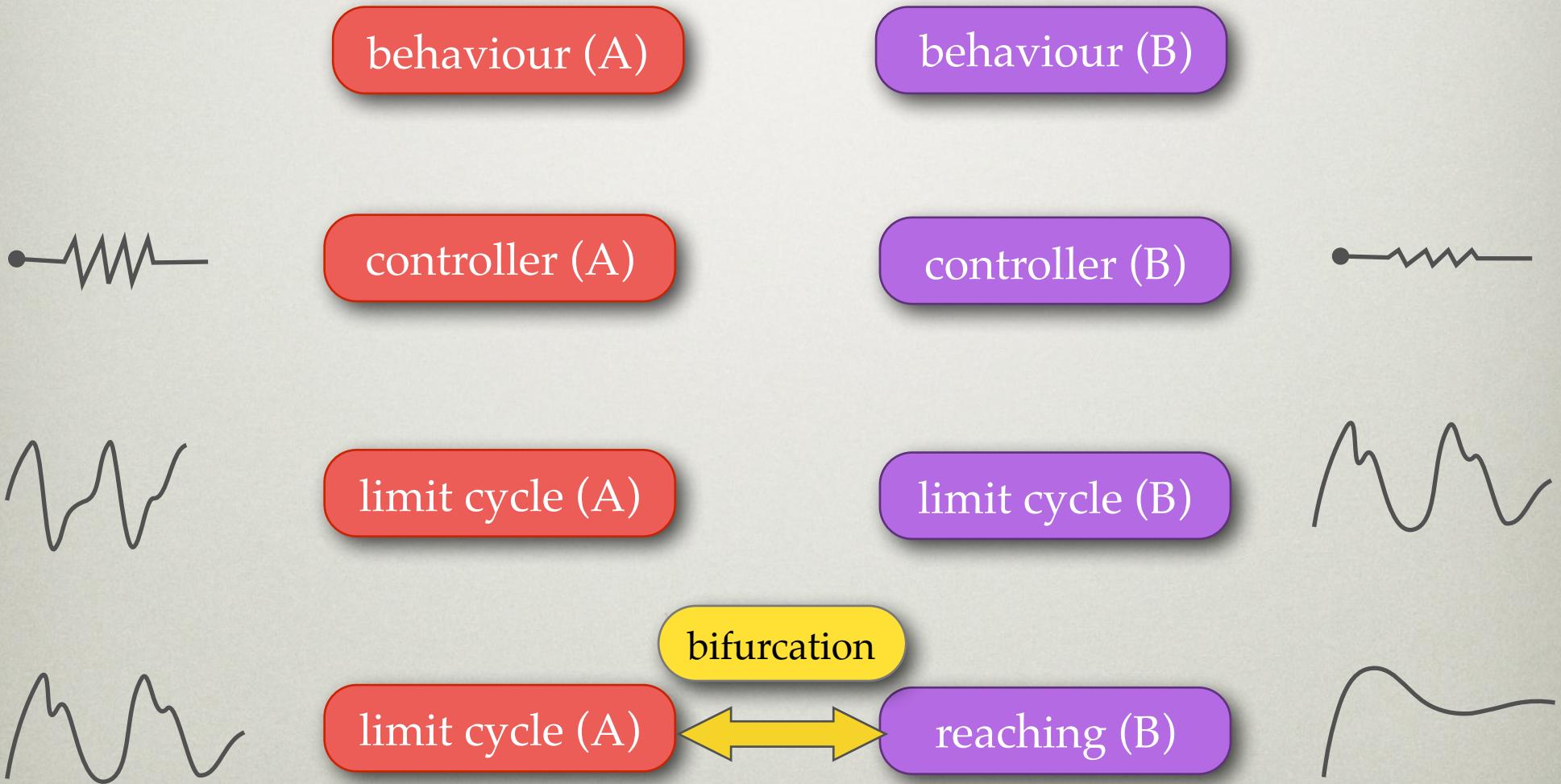
reaching (B)



ATTRACTOR LANDSCAPE

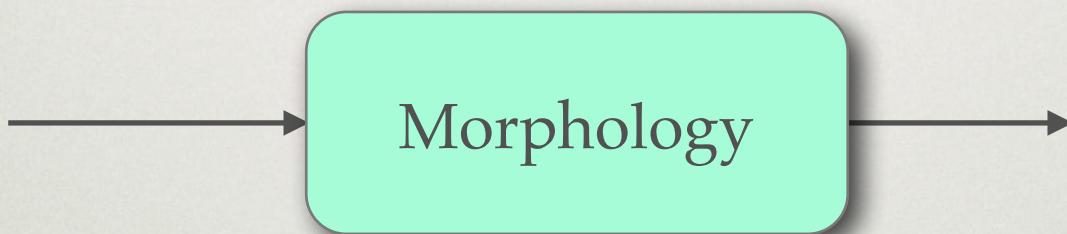


ATTRACTOR LANDSCAPE

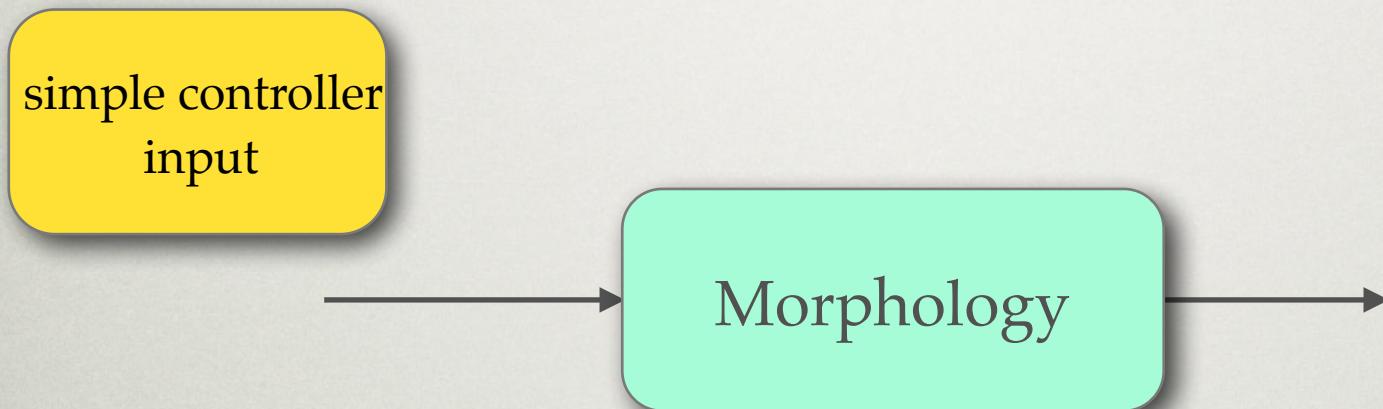


ATTRACTOR LANDSCAPE WITH INPUT

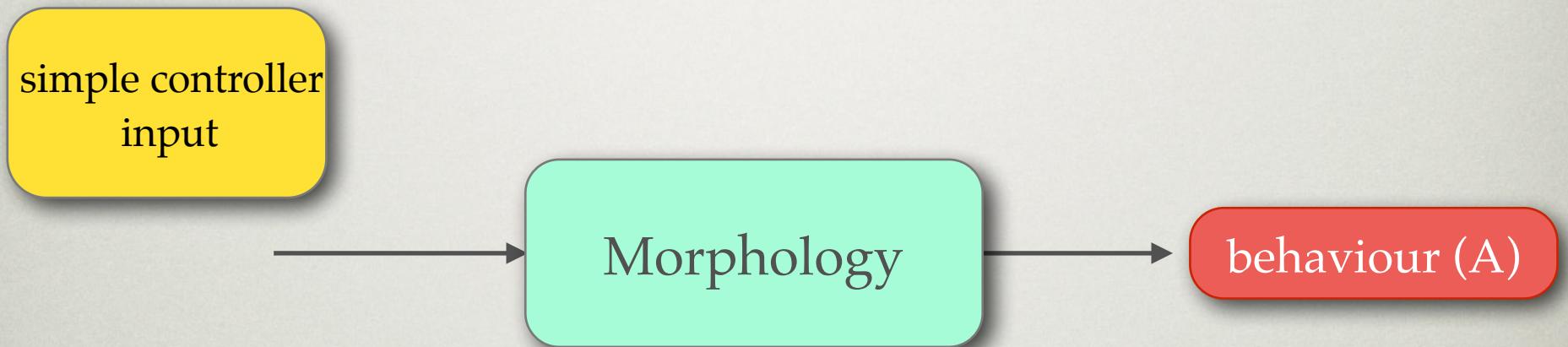
ATTRACTOR LANDSCAPE WITH INPUT



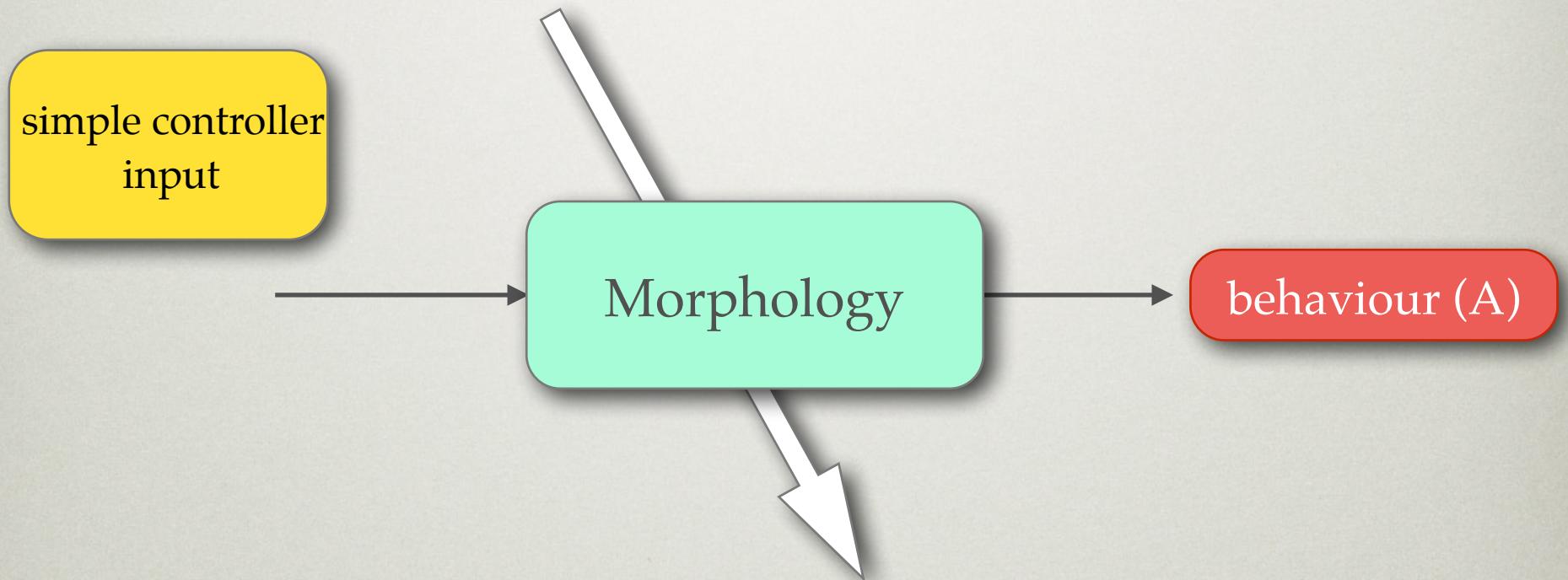
ATTRACTOR LANDSCAPE WITH INPUT



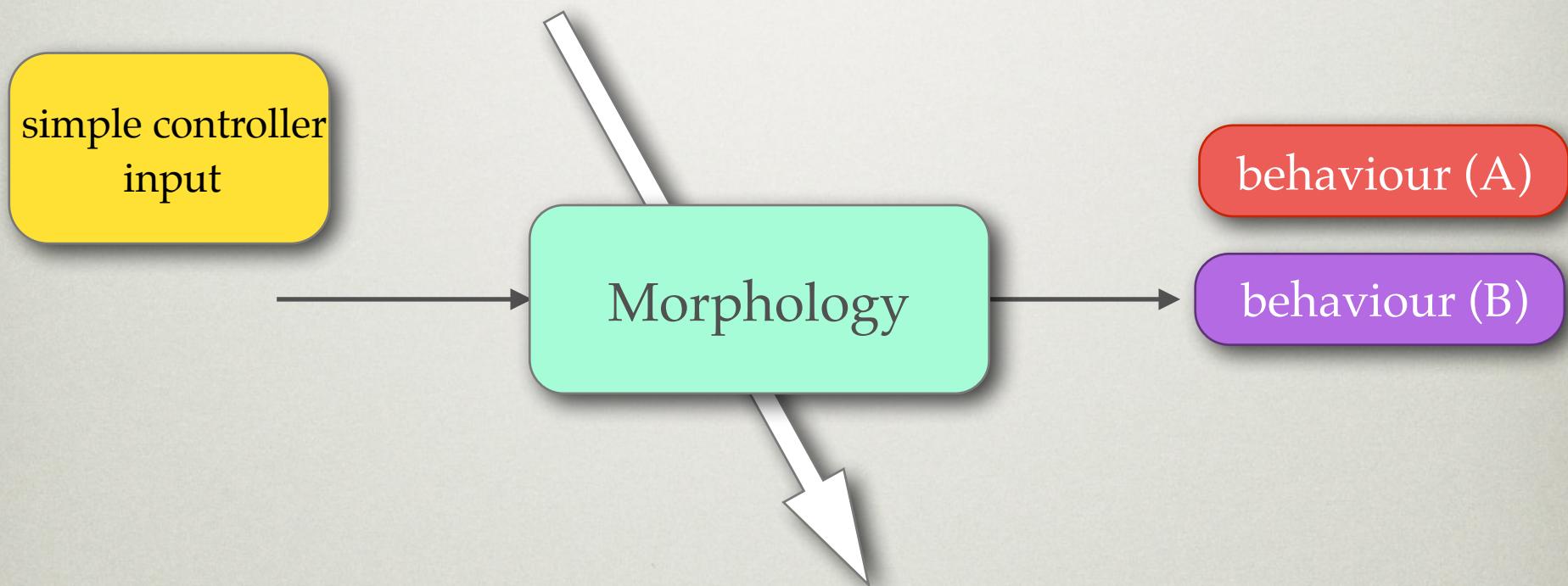
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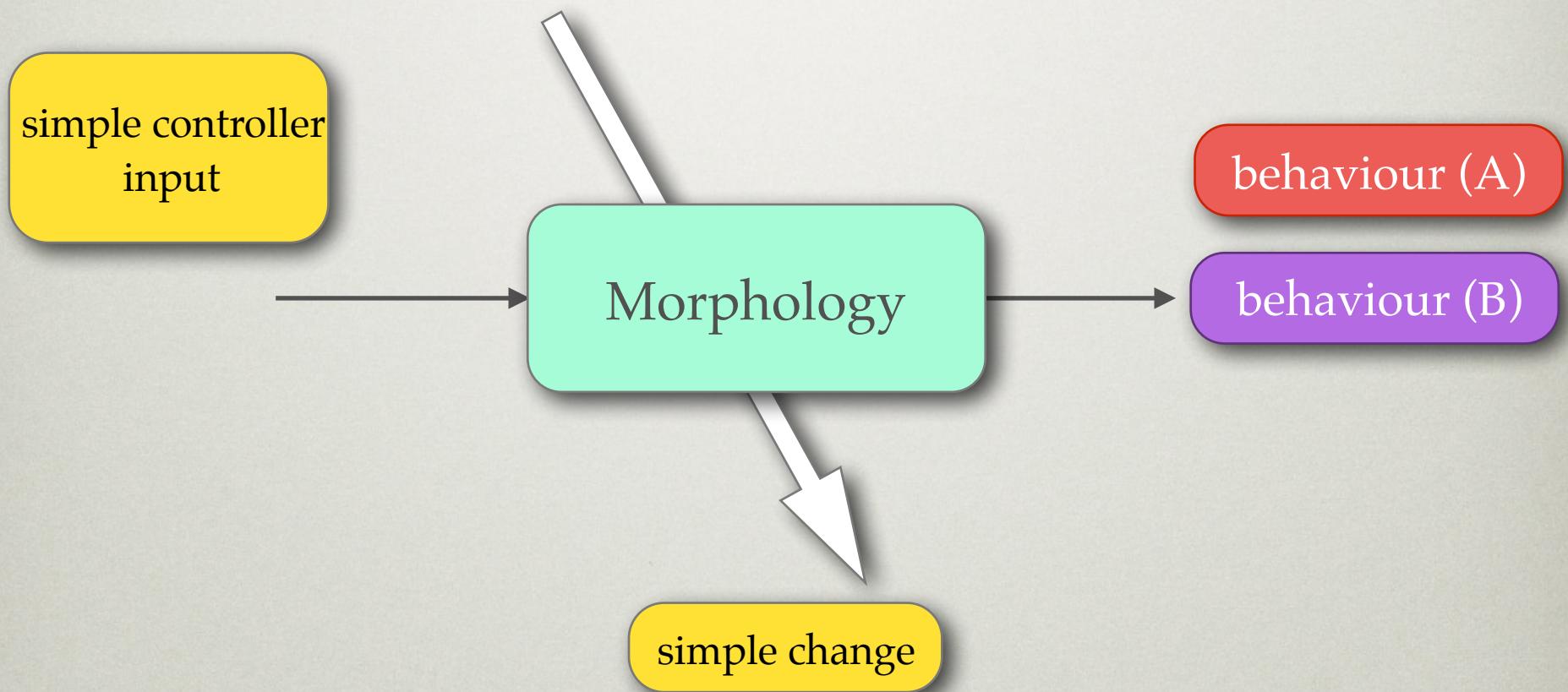
ATTRACTOR LANDSCAPE WITH INPUT



ATTRACTOR LANDSCAPE WITH INPUT



ATTRACTOR LANDSCAPE WITH INPUT



ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE

Francesco Corucci

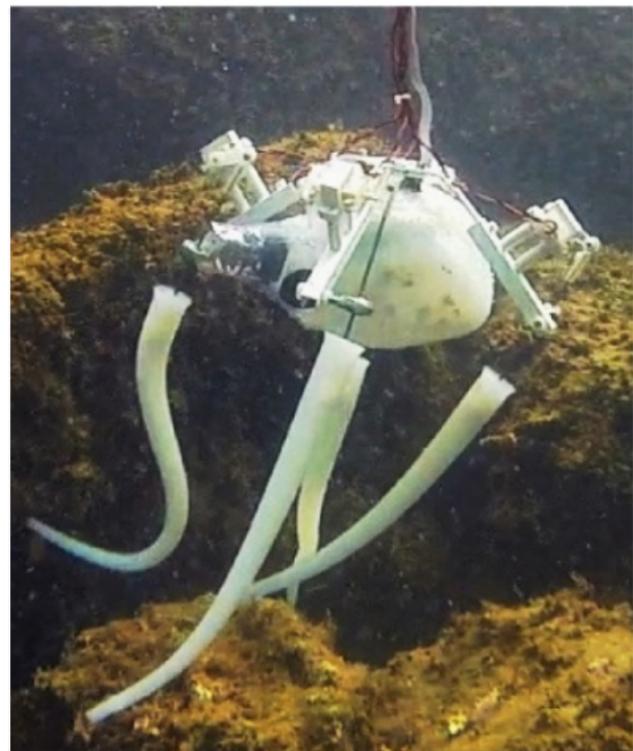


Corucci, Francesco; Calisti, Marcello; Hauser, Helmut and Laschi, Cecilia
"Novelty-based evolutionary design of morphing underwater robots." GECCO 2015

ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE



Francesco Corucci



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ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE



Francesco Corucci



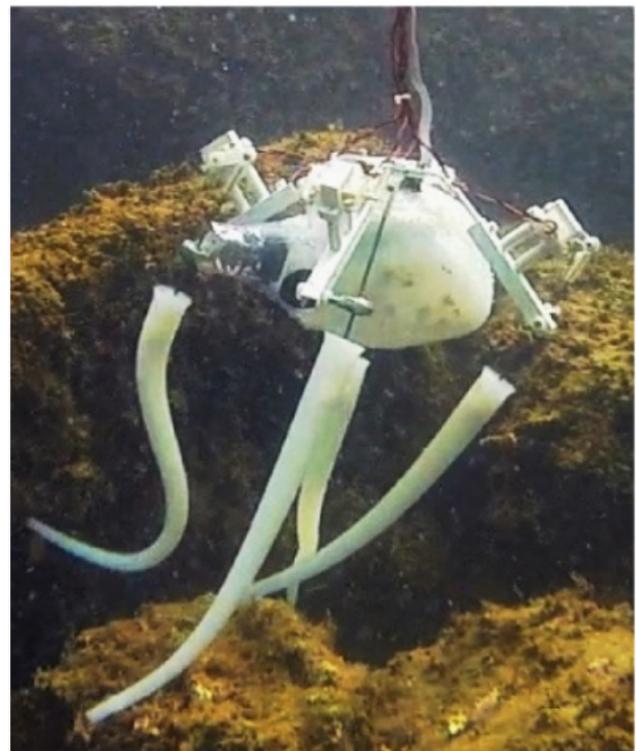
- Bio-inspired octopus robot

Corucci, Francesco; Calisti, Marcello; Hauser, Helmut and Laschi, Cecilia
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ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE



Francesco Corucci



- Bio-inspired octopus robot
- Morphology not optimal

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ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE



Francesco Corucci



- Bio-inspired octopus robot
- Morphology not optimal
- Simple control, find clever morphology

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ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE



Francesco Corucci



- Bio-inspired octopus robot
- Morphology not optimal
- Simple control, find clever morphology
- Morphology-induced behaviour

ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE



Francesco Corucci

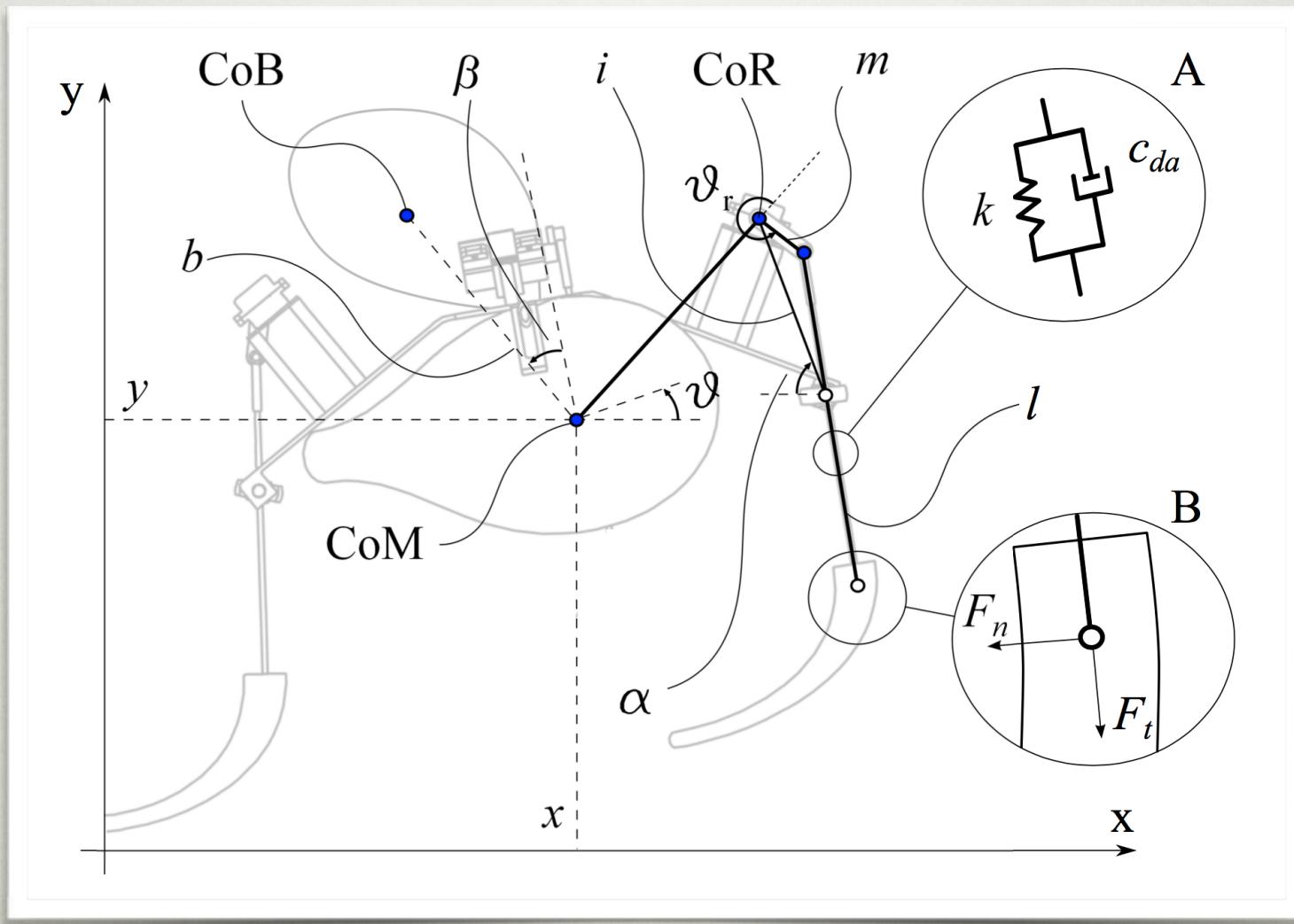


- Bio-inspired octopus robot
- Morphology not optimal
- Simple control, find clever morphology
- Morphology-induced behaviour

Using Genetic Algorithms to
optimize the body

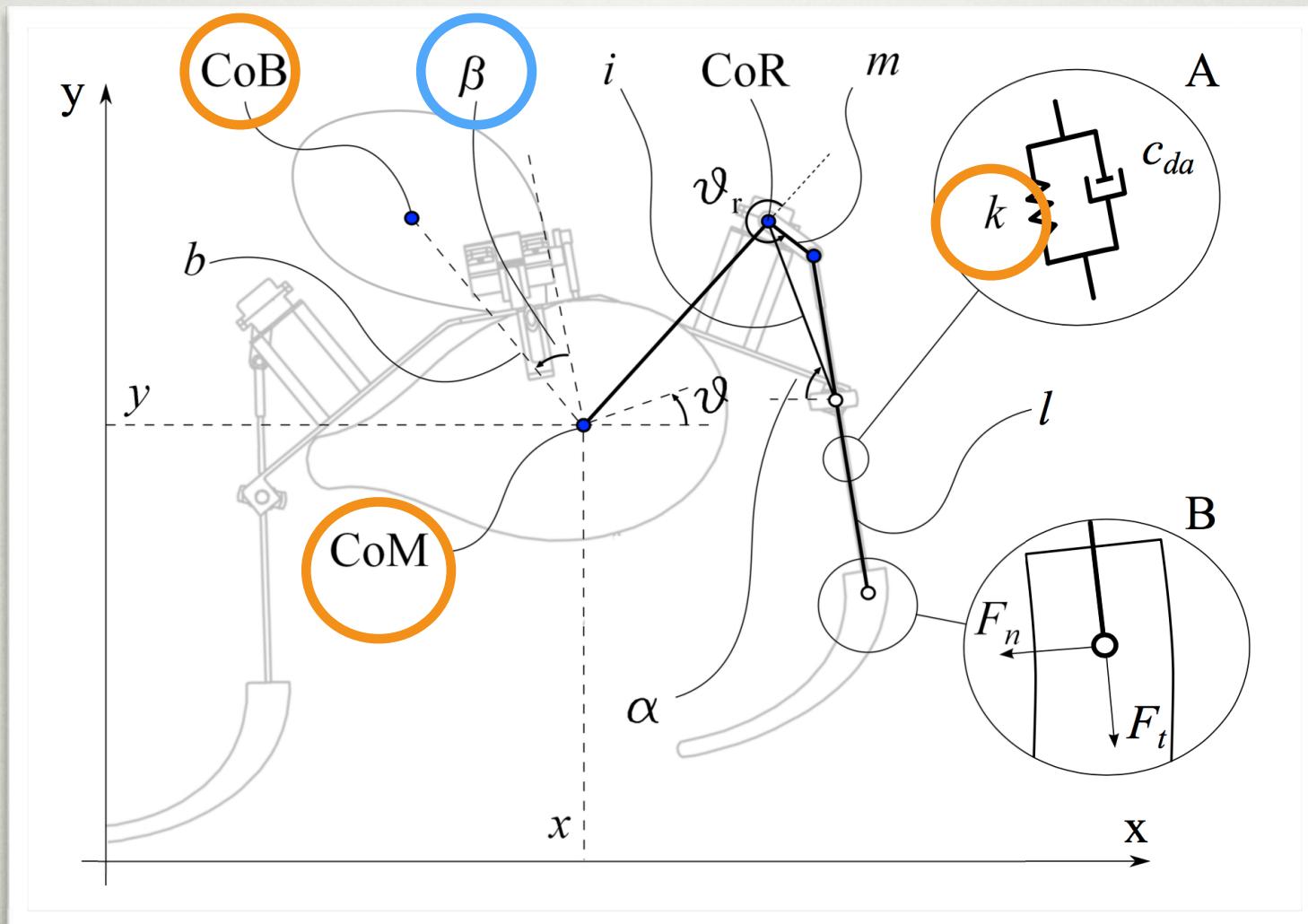
ATTRACTOR LANDSCAPE

OCTOPUS EXAMPLE



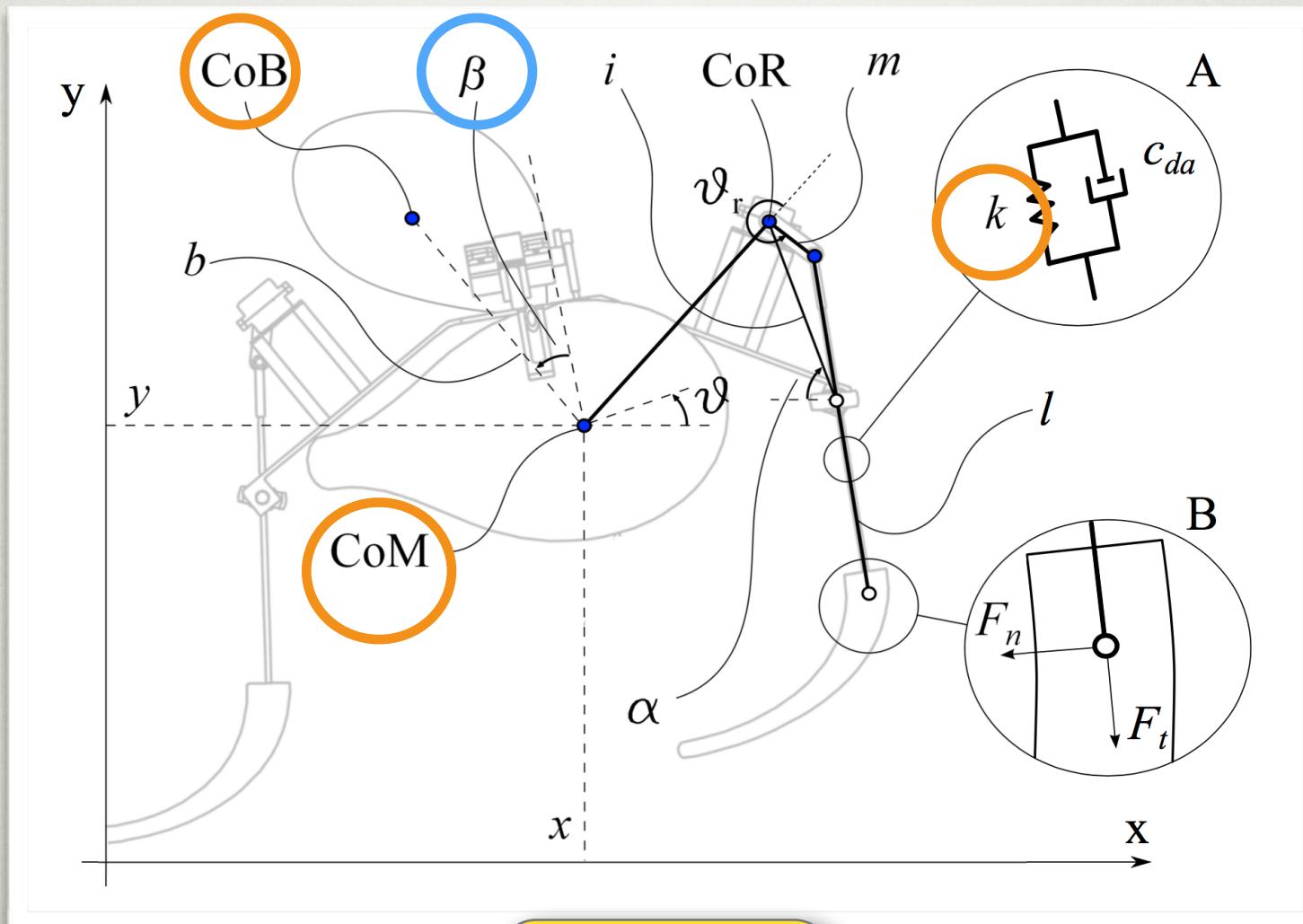
ATTRACTOR LANDSCAPE

OCTOPUS EXAMPLE



ATTRACTOR LANDSCAPE

OCTOPUS EXAMPLE



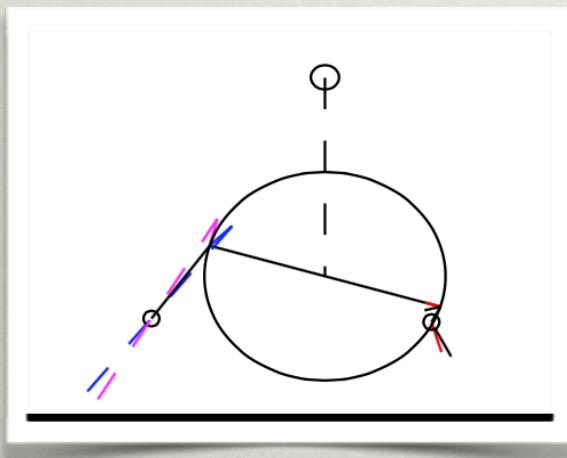
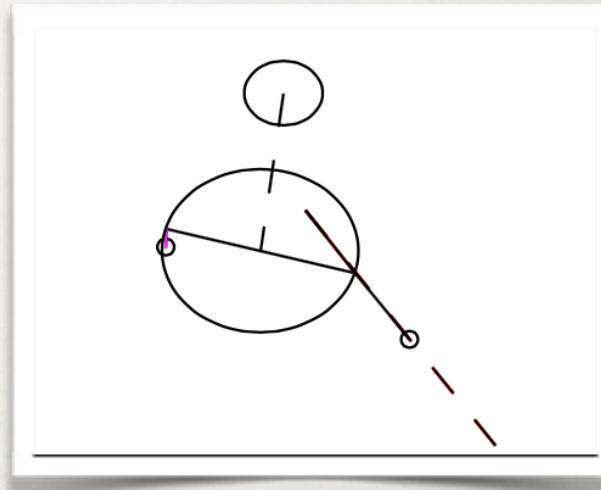
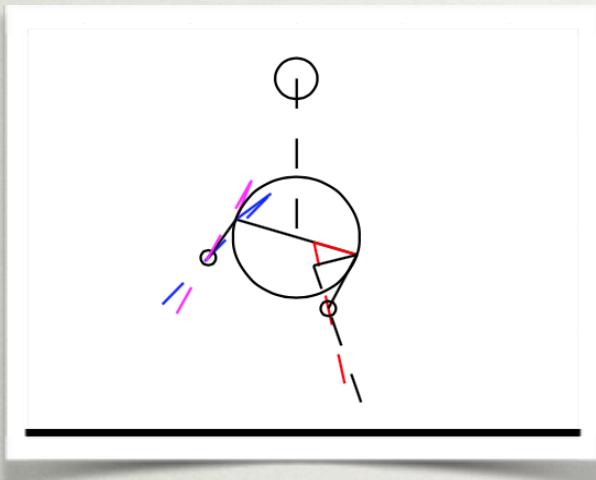
novelty search

ATTRACTOR LANDSCAPE

OCTOPUS EXAMPLE

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ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE

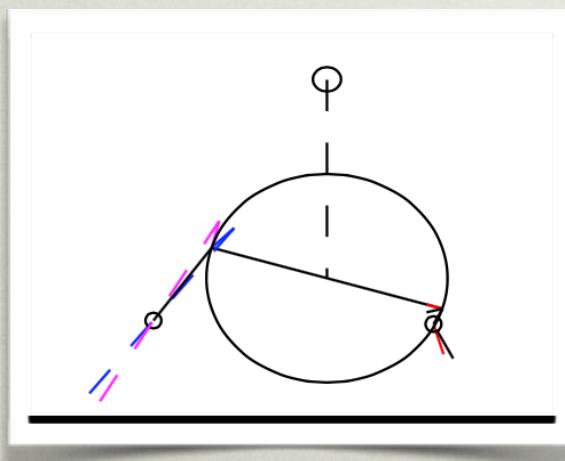
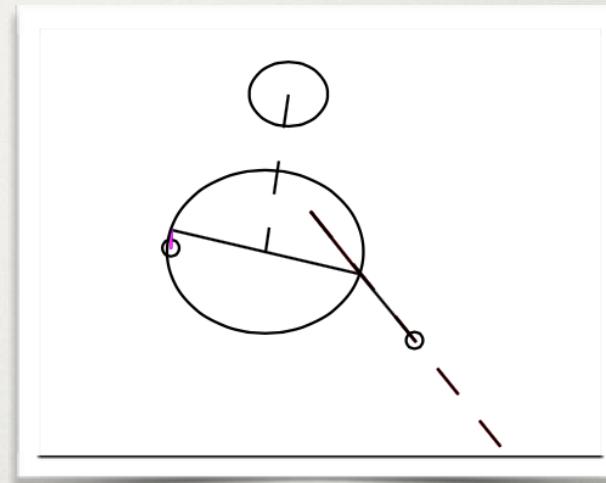
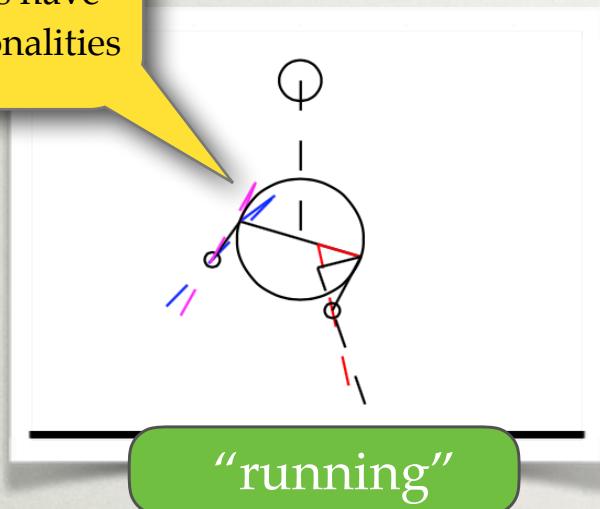


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ATTRACTOR LANDSCAPE

OCTOPUS EXAMPLE

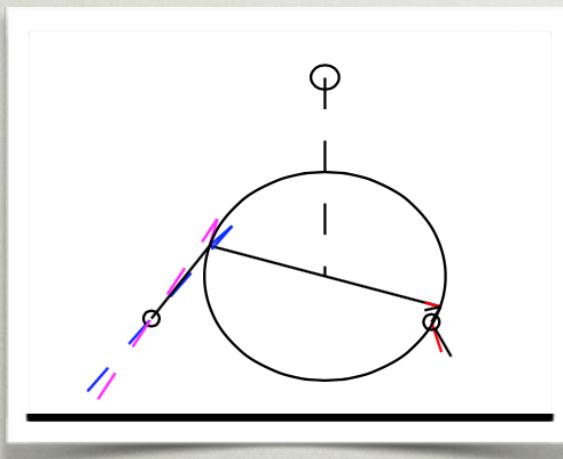
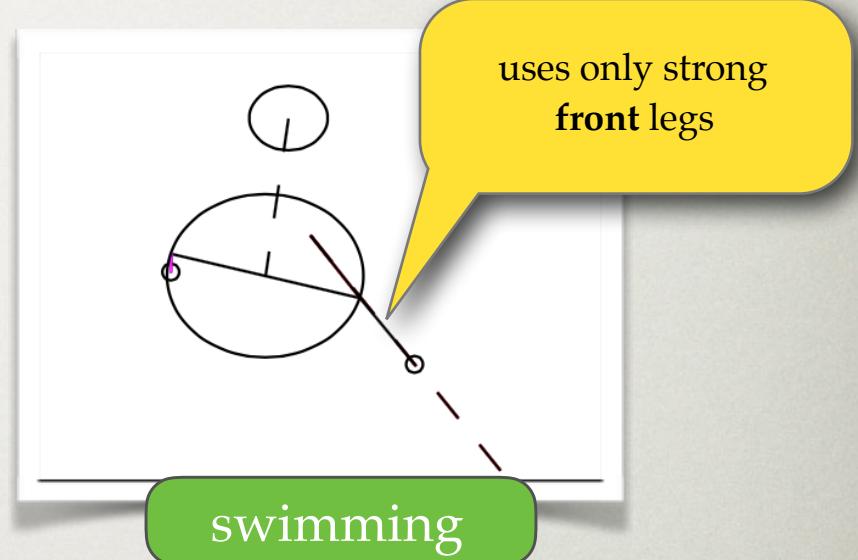
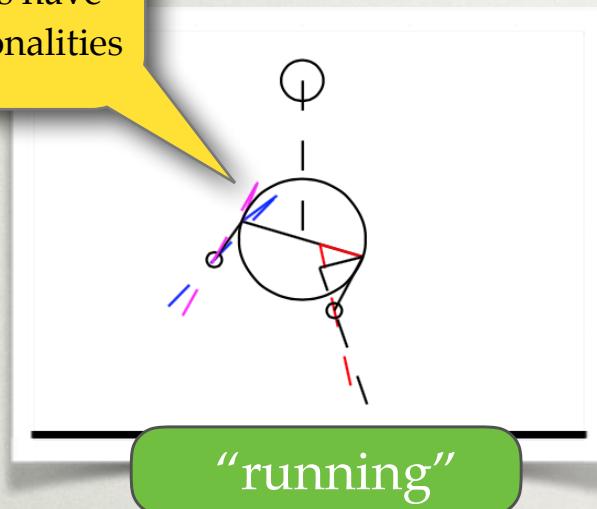
front/hind legs have
different functionalities



ATTRACTOR LANDSCAPE

OCTOPUS EXAMPLE

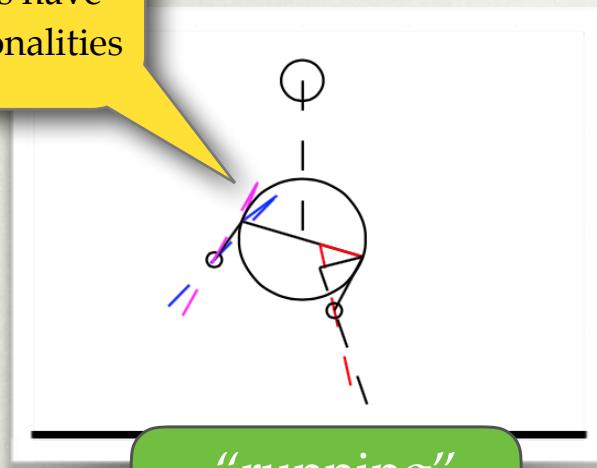
front/hind legs have different functionalities



ATTRACTOR LANDSCAPE

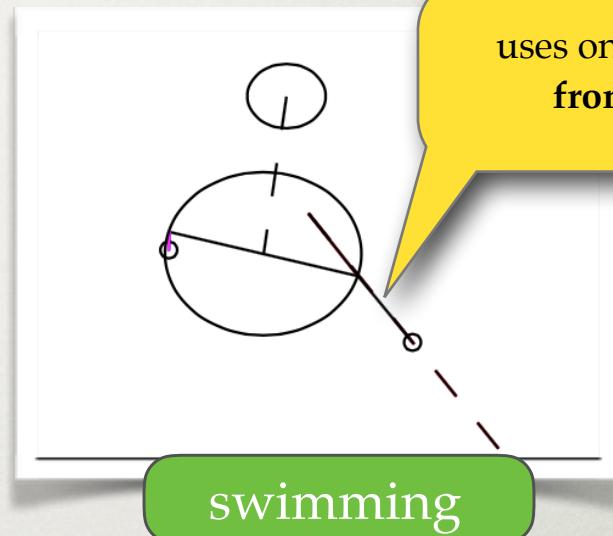
OCTOPUS EXAMPLE

front/hind legs have different functionalities



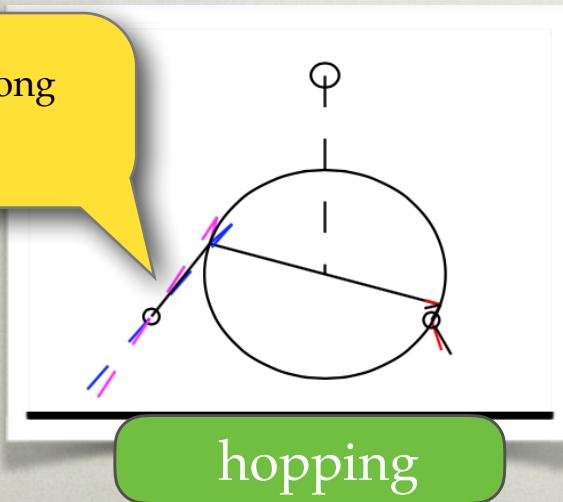
“running”

uses only strong
front legs



swimming

uses only strong
hind legs

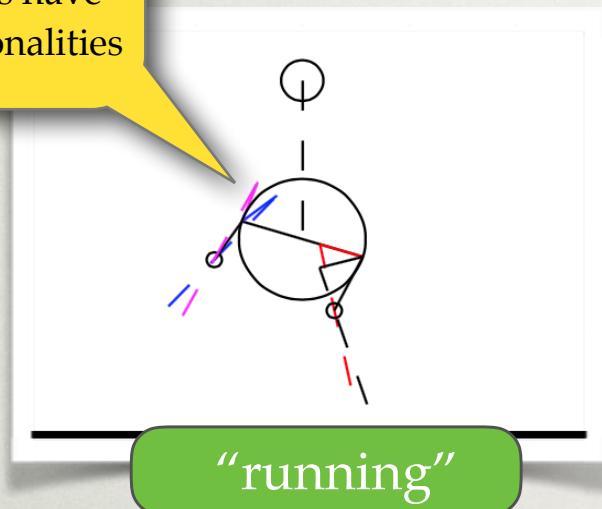


hopping

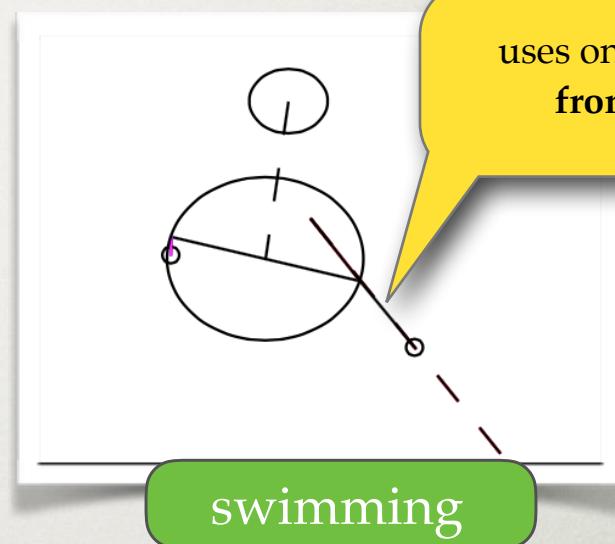
ATTRACTOR LANDSCAPE

OCTOPUS EXAMPLE

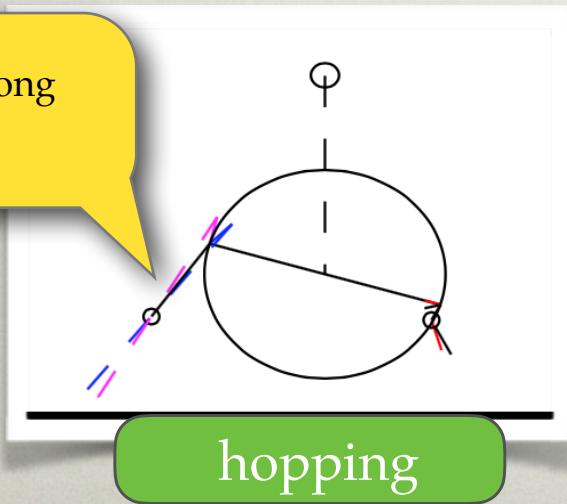
front/hind legs have different functionalities



uses only strong front legs

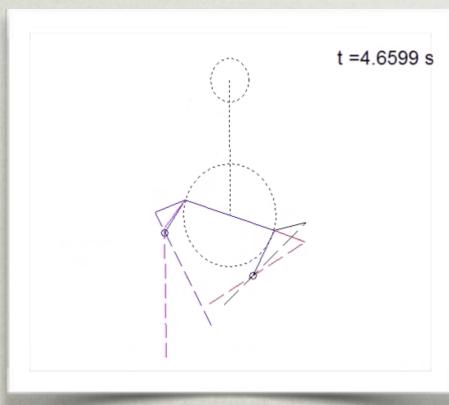
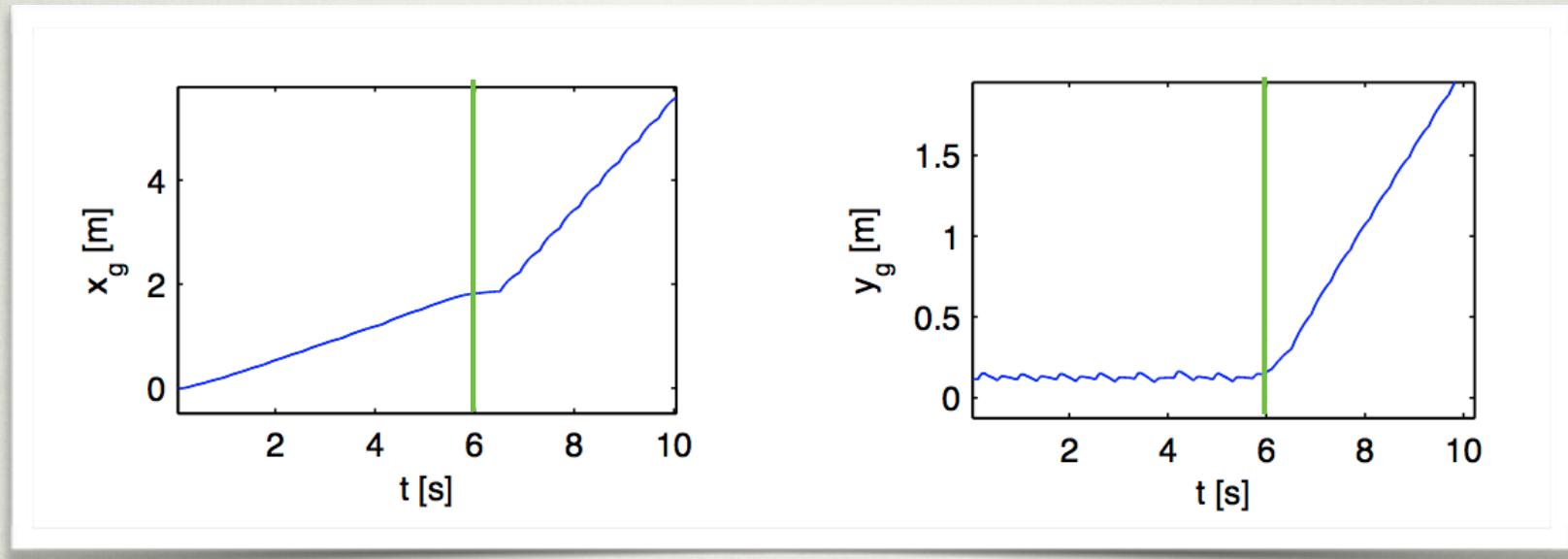


uses only strong hind legs



How can we switch between behaviours?

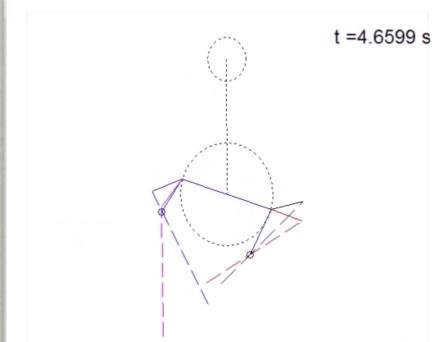
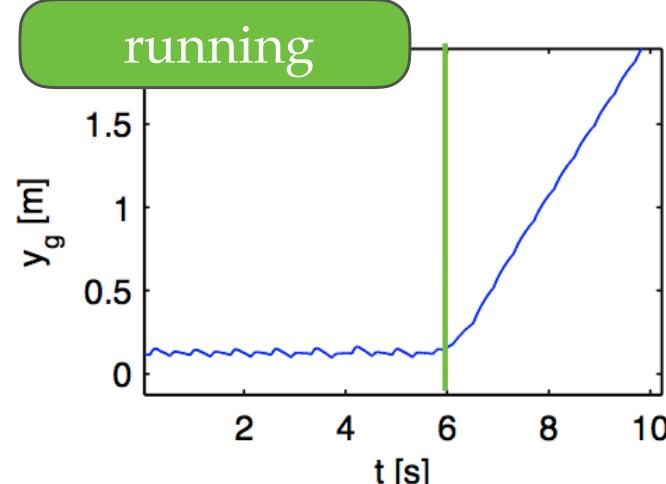
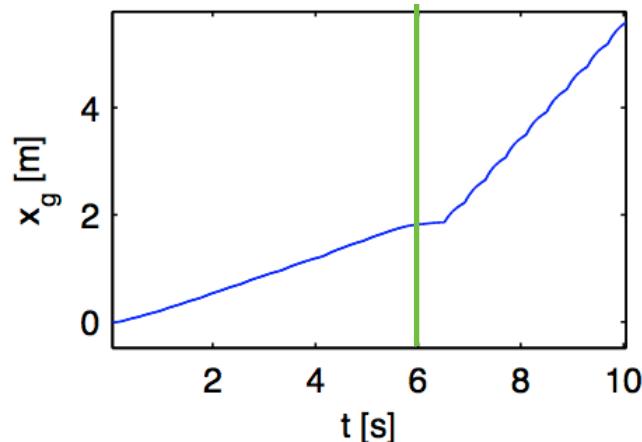
ATTRACTOR LANDSCAPE OCTOPUS EXAMPLE



How can we switch between behaviours?

ATTRACTOR LANDSCAPE

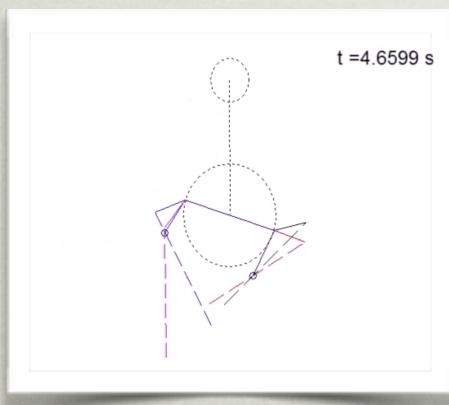
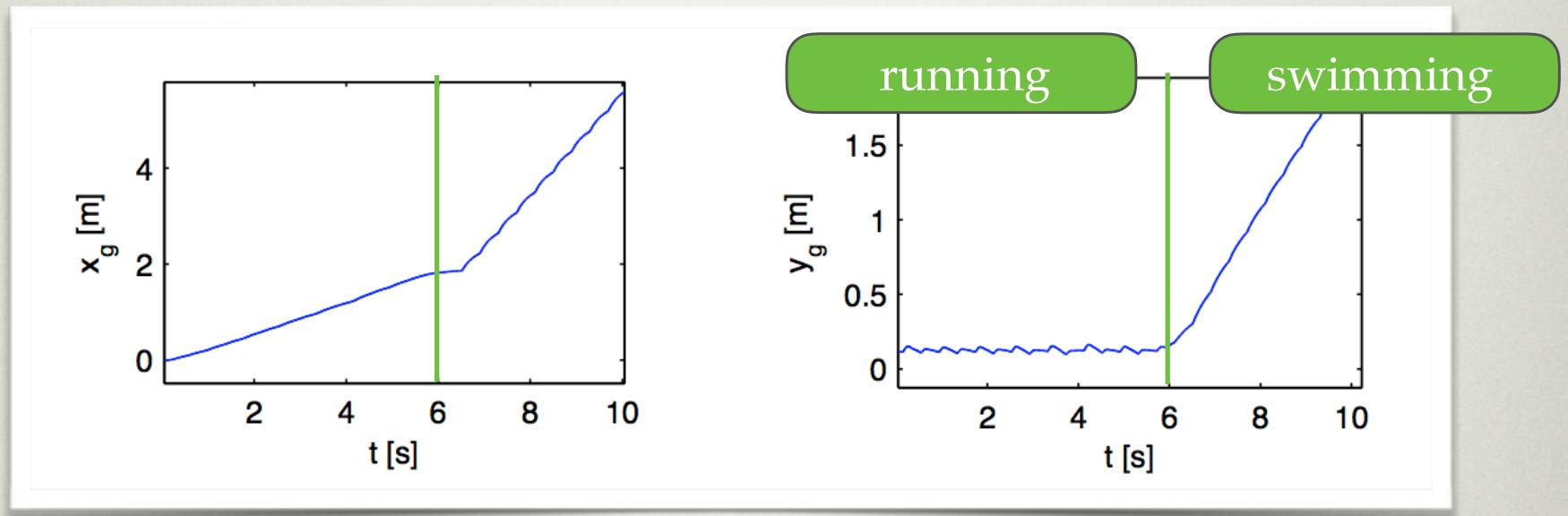
OCTOPUS EXAMPLE



How can we switch between behaviours?

ATTRACTOR LANDSCAPE

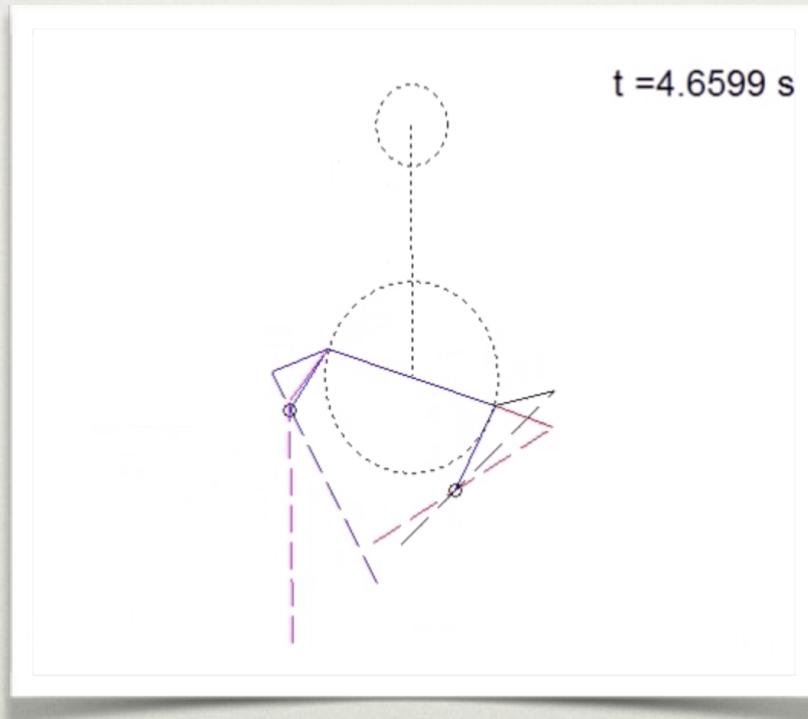
OCTOPUS EXAMPLE



How can we switch between behaviours?

ATTRACTOR LANDSCAPE

OCTOPUS EXAMPLE



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THANK YOU VERY MUCH FOR YOUR ATTENTION!



Francesco
Corucci

- Corucci, Francesco; Calisti, Marcello; Hauser, Helmut and Laschi, Cecilia
"Novelty-based evolutionary design of morphing underwater robots." GECCO 2015
- Corucci, Francesco; Calisti, Marcello; Hauser, Helmut and Laschi, Cecilia
"Evolutionary discovery of self-stabilized dynamic gaits for a soft underwater legged robot" International Conference on Advanced Robotics (ICAR), pp 337-344,
- Corucci, Francesco; Calisti, Marcello; Hauser, Helmut and Laschi, Cecilia
"Shaping the body to shape the behavior: a more active role of the morphology in the brain-body trade-off." ECAL, 2015