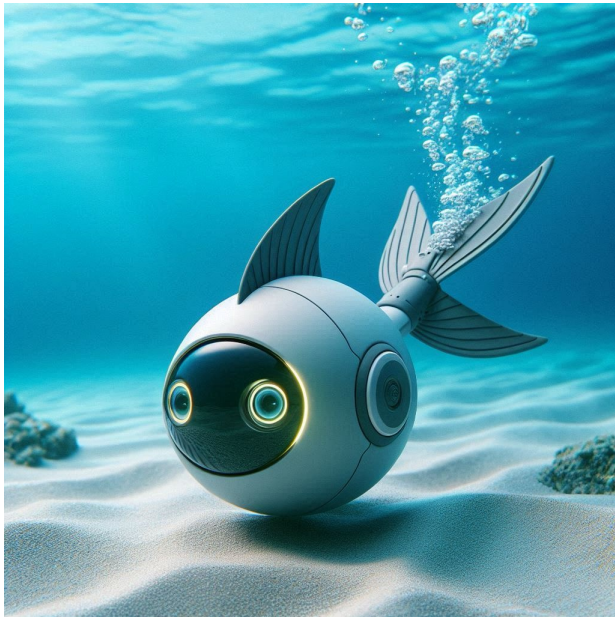


# ***Ethology and Robotics ..... Biomimetics as a consortium :***



# Robotics ...

Copyright free 😊



*Fish*



*Bird*



*Bee*



*Goupil*

DALL-E 3 interpretations in response to the query : « Design a *name* robot »



# Biomimetics ... for scientific purposes

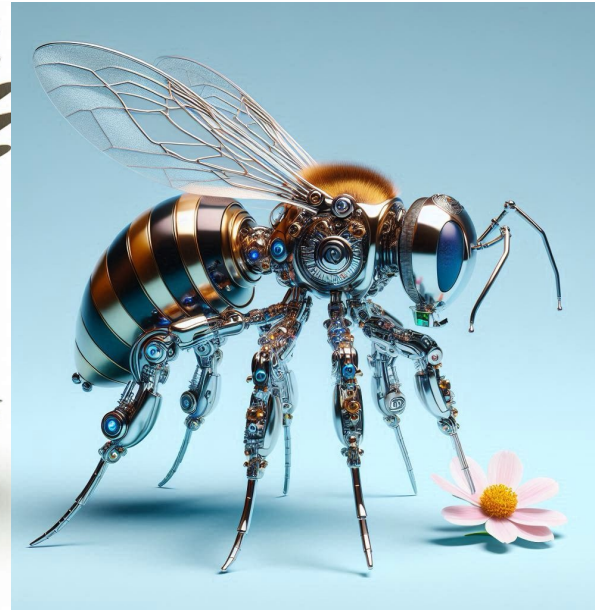
Copyright free 😊



*Zanclus cornutus*



*Columba*



*Apis mellifera*



*Vulpes vulpes*

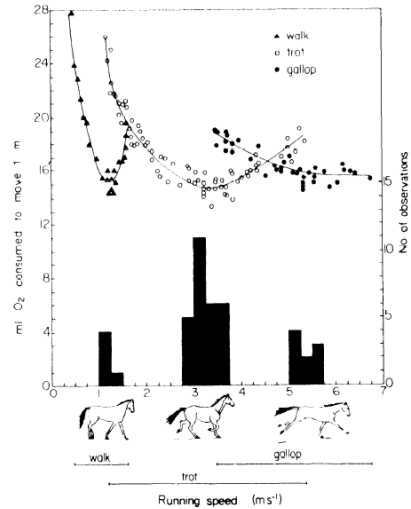
DALL-E 3 interpretations in response to the query « Design a **scientific-name** **biomimetic** robot »

# From Ethology to Robotics ....

- How can Ethology contribute biomimetic arguments in Robotics ?
  - ▣ If a living organism survives, it may have developed behaviours that solve problems
    - What kind of solutions ... in what contexts (i.e. scale, mechanical, physical, chemical) ?
    - If this is the case, what kind of behaviours are involved ? and how do they emerge ?
      - Are they related to structural materials or mechanics ?
      - Do they involve sensory-motor organisation ?
      - How are these behaviours regulated and organised (from « cells » to network and cognition) ?
      - Are the emergent behaviours optimal ?
      - ....
- Some examples ....

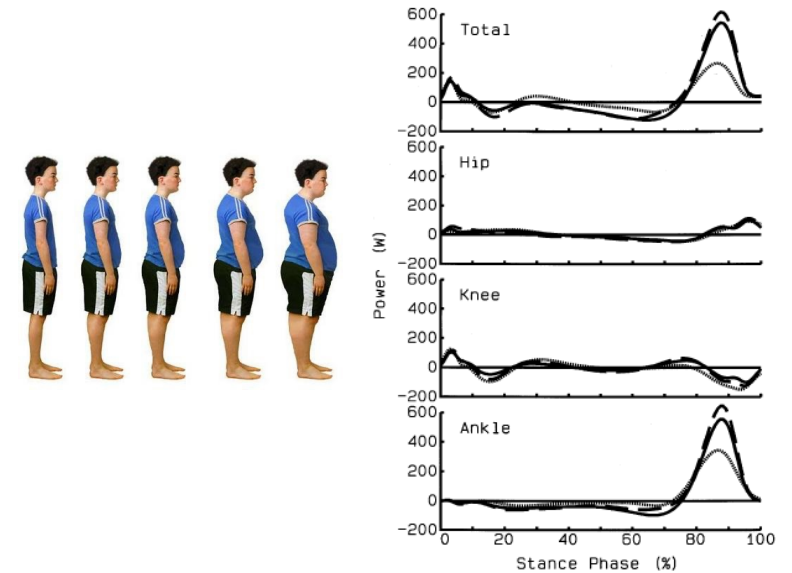
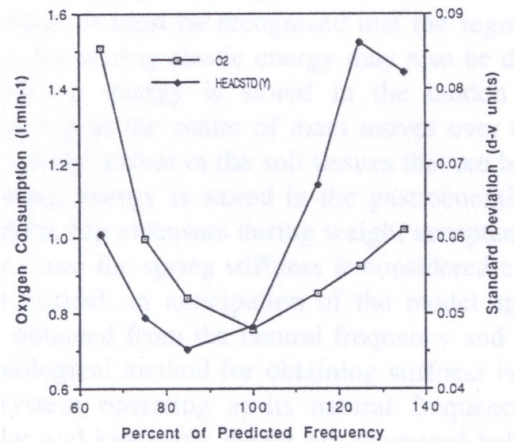
# Auto-optimization of locomotion pattern in vertebrates ..... criteria identification

Hoyt and Taylor (Nature Lond) 1981



Walking and running patterns so as the switch from one to the other are in accordance with the optimization of :

- Energy cost,
- Head stability ,
- Symetry and balance,
- Joints constraints,
- ...



- Holt (Physical Therapy Practice) 1993
- Holt et al. (Hum Mov Science) 1996
- Breniere (J Mot Behavior) 1996
- \* De Vita and Hortoblagyi (J of Biomech) 2003
- \* Lai et al (Clin Biomech) 2008
- Faria et al (Clin Biomech) 2009

# From Ethology to robots ....

*An inverse optimal control algorithm*

**A goal : running speed 11"/100m**

Stack of constraint priorities

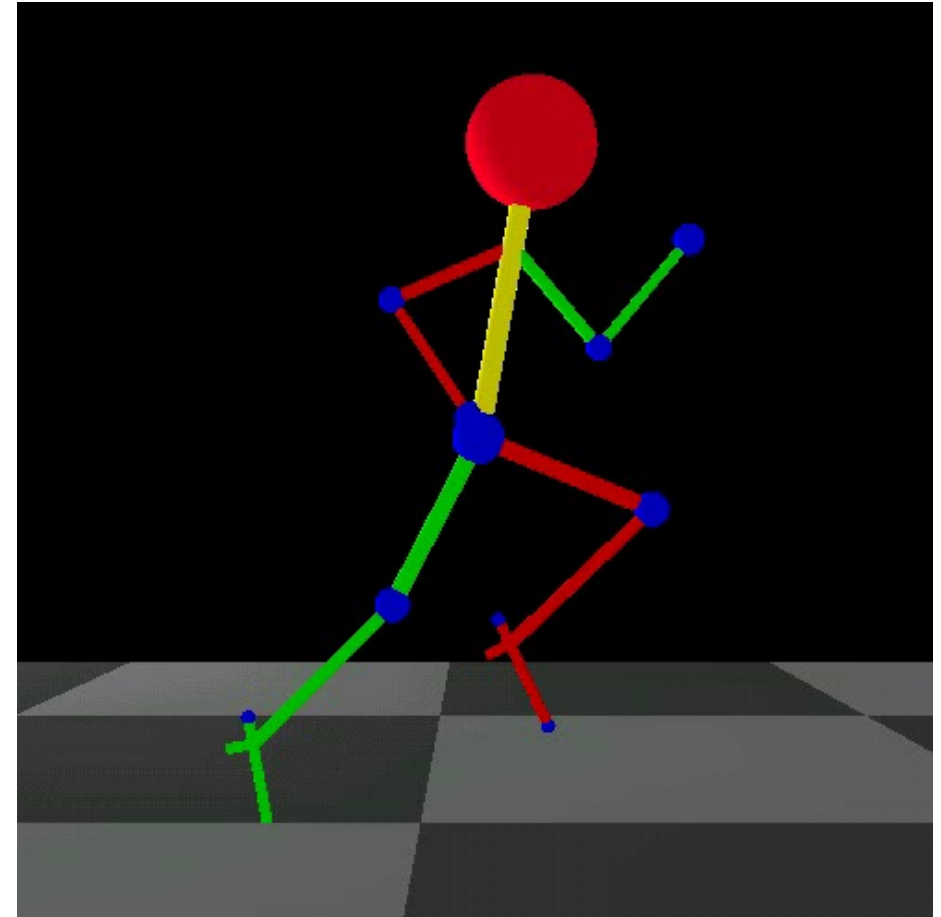
Minimal joints moments

Head stability

Balance and symmetry

Energy cost

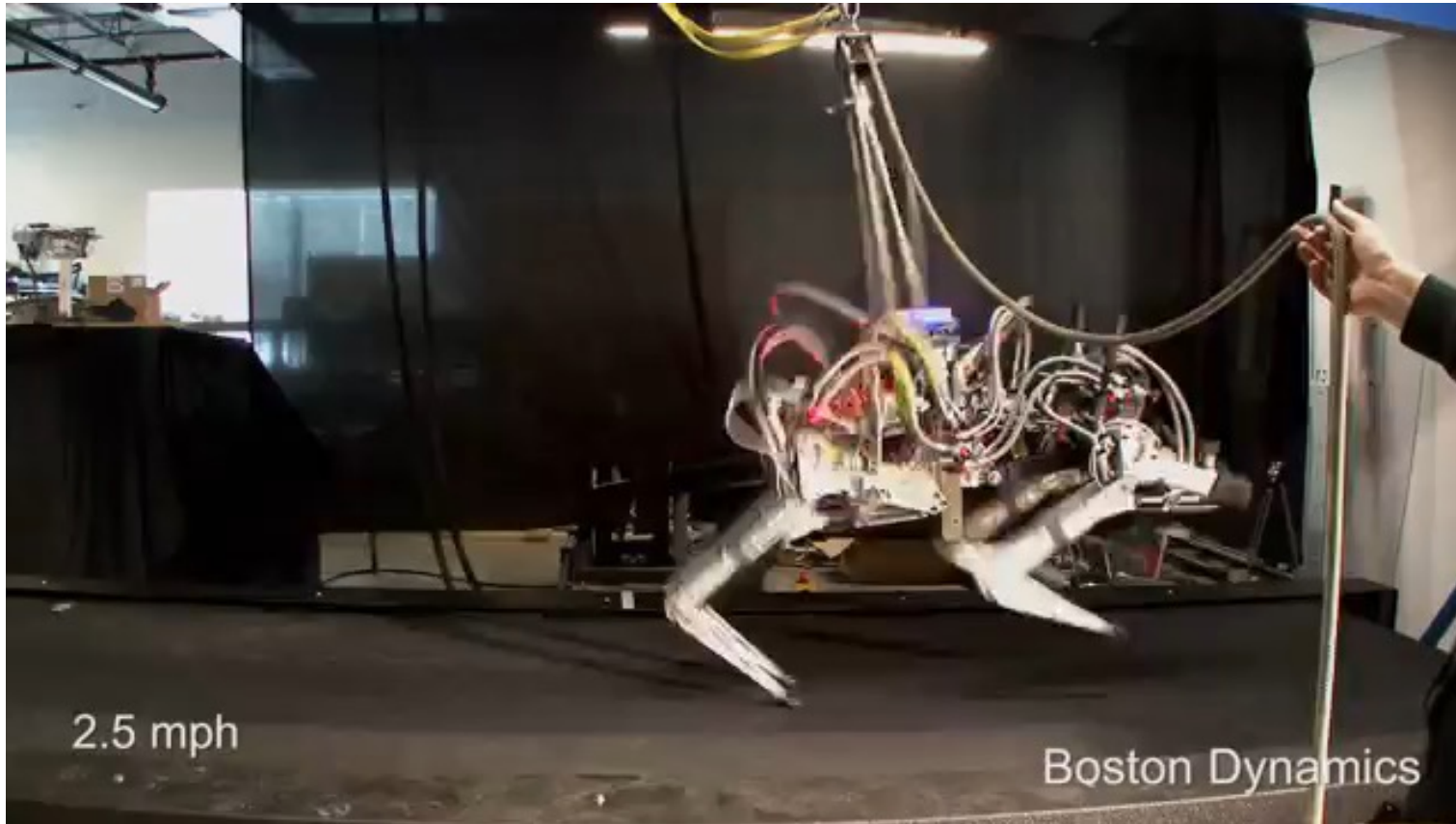
**Running pattern generation**





# From Ethology to robots .... *An inverse optimal control algorithm*

- « Cheetah » asymmetric pattern emerges at 30 km/h to optimize stability and energy transfer at high speed.



# From Robotics to Ethology....

- How can robots be used to test Ethology's hypothesis ?
  - ▣ If a robot behaves correctly, it is the physical demonstration that a solution has been identified and correctly implemented (Physical proof of concept).
  - ▣ Biomimetics approach can be apply at many levels
    - Structure mechanics and materials ?
    - Sensors and engine ?
    - Biomimetic algorithms to address regulation and organisation
      - Inverse optimal control, deep learning etc ...
  - ▣ Sometimes, the robot reveals an unlikely solution



# From Robotics to Ethology .... An inverse optimal control algorithm find an unlikely solution

**A goal : running speed 11"/100m**

Stack of constraint priorities

Minimal joint moments

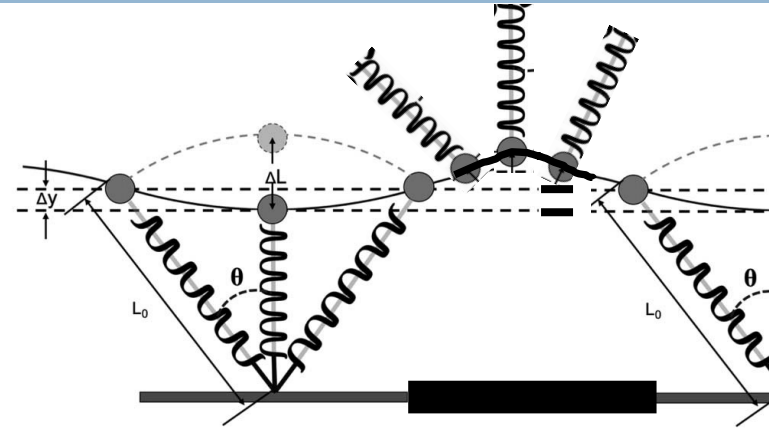
Head stability

Balance and symmetry

Energy cost

A 2<sup>nd</sup> solution arises ....

**Vaulting pattern generation**



# From Robotics to Ethlogy ....

*An inverse optimal control algorithm explains the behaviour*

## Vaulting pattern generation

Stack of constraint priorities

Minimal joint moments

Energy cost

Balance and symmetry

Head stability (?!)

Survival advantages :

High speed : 2m/s

Avoid contacts with sand (60-70°C)

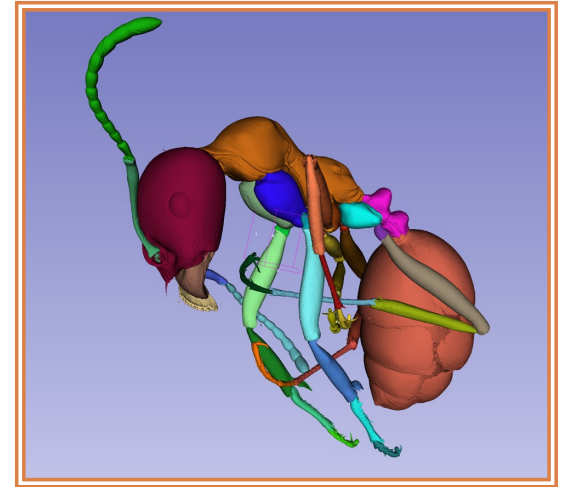
*Cebrennus rechenbergi* vaulting pattern matches with Mombaur's robotic simulation



# Inverse engineering biomimetic approach



- Inverse engineering biomimetic approach to address Ethology.....
  - ▣ Division of labour, Heavy loads
  - ▣ Trunk and legs structures, functions
  - ▣ Collaborative load to carrying,



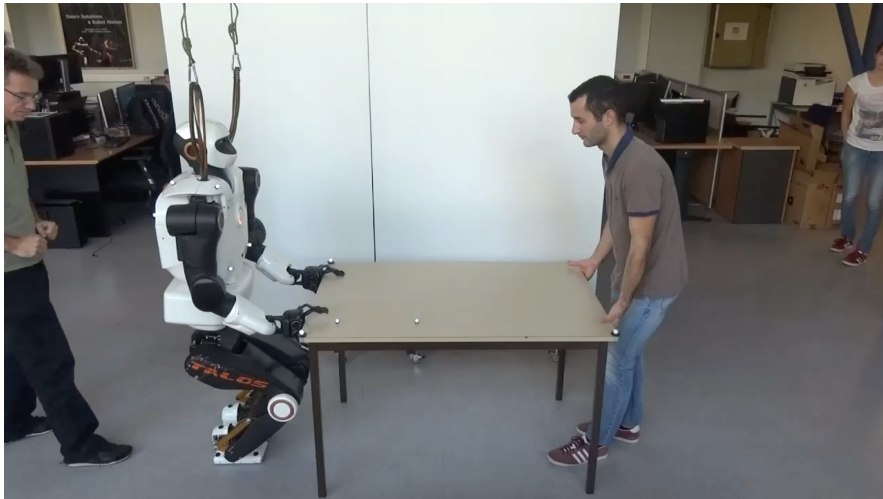
Drapin J. et al. , 2021 ->



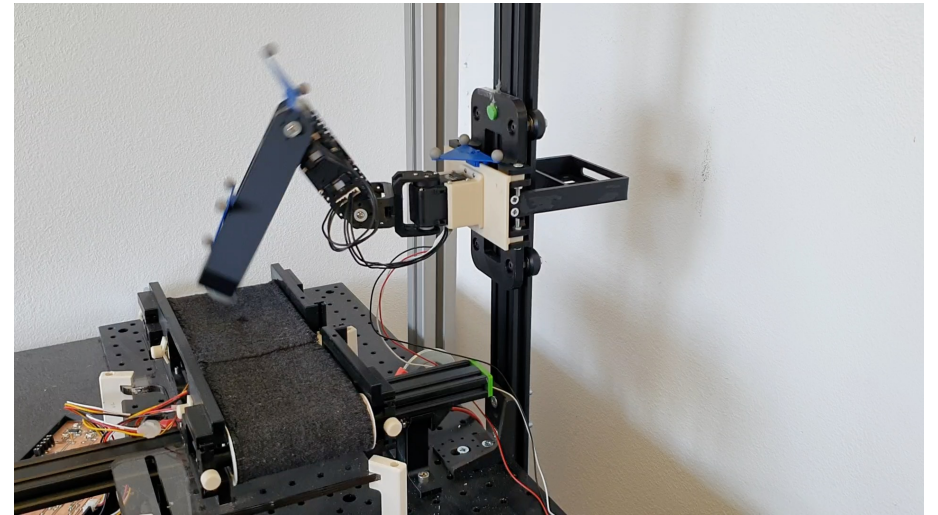
Serres J. et al. , 2019 ->

# Collective load carrying

## □ Collaborative robot (CoBot)



## □ AO MITI Barbarus – Mimic-Ant







***Biomimetics as a consortium***

GDR 2088 : Biomimétisme, Bioinspiration