Movement data in biomedical research

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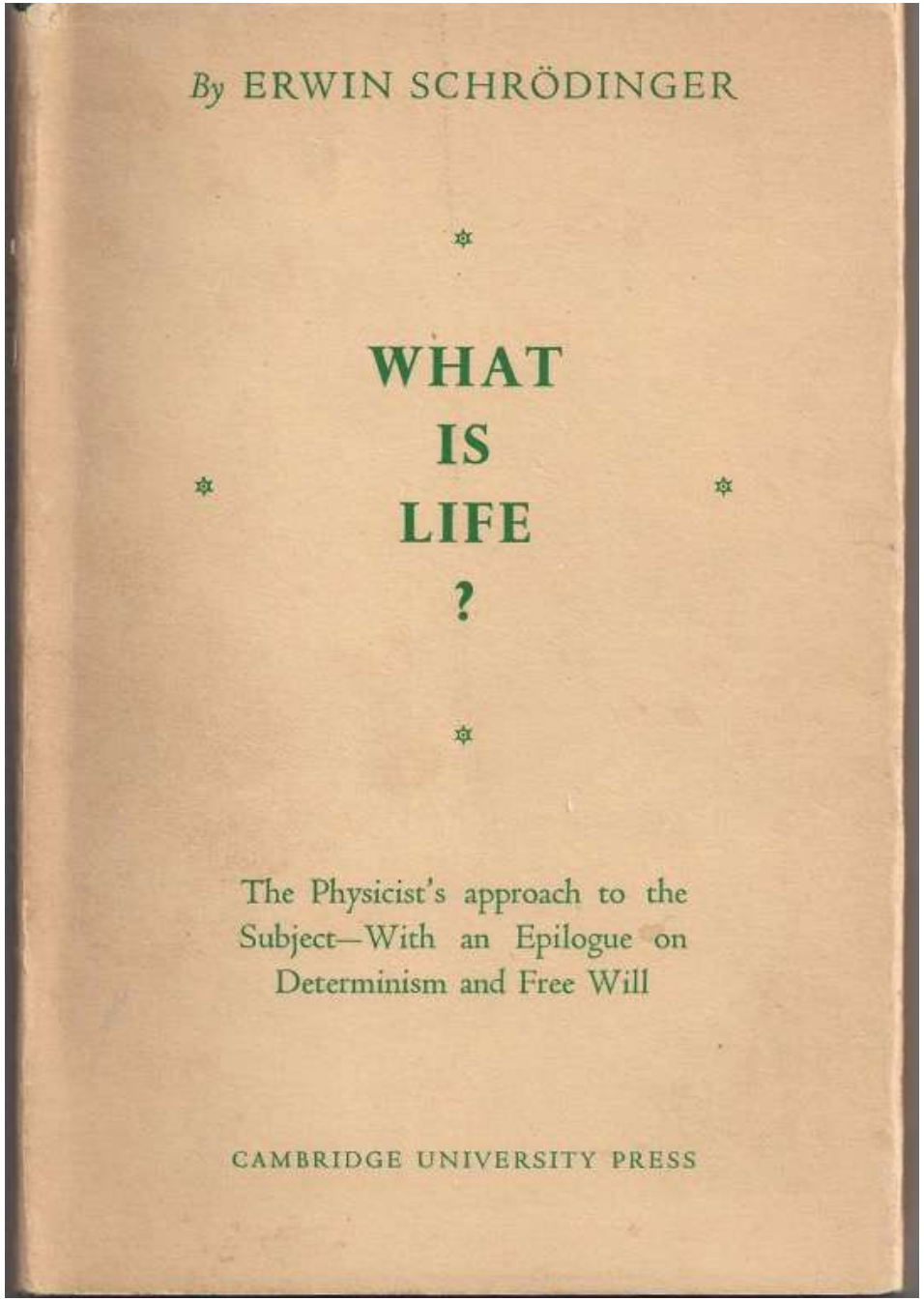
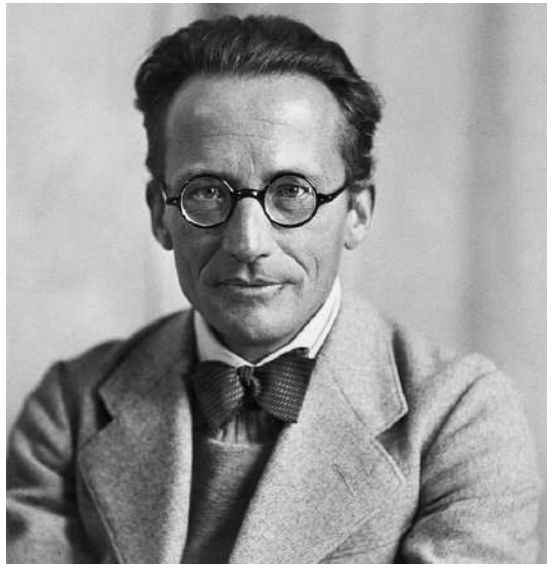


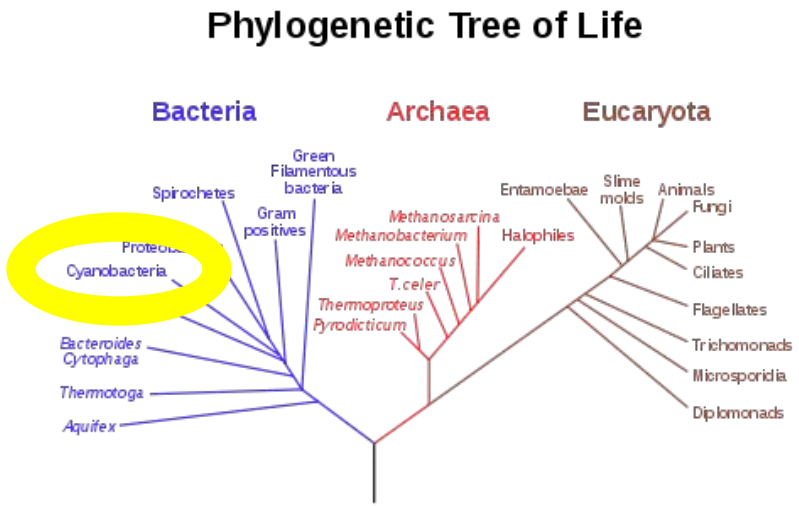


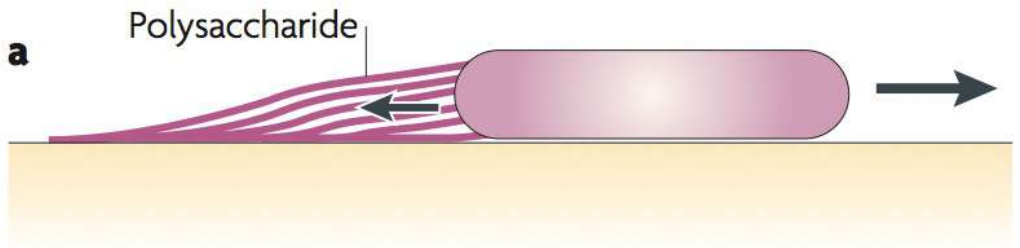
Life = movement

Gliding of filamentous cyanobacteria

Blue-green algae:

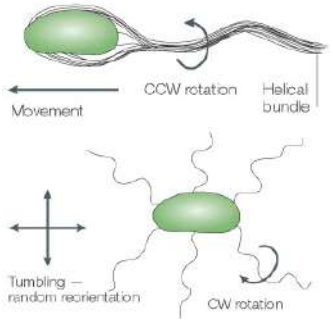
No organelles or appendages
Gliding by slime propulsion



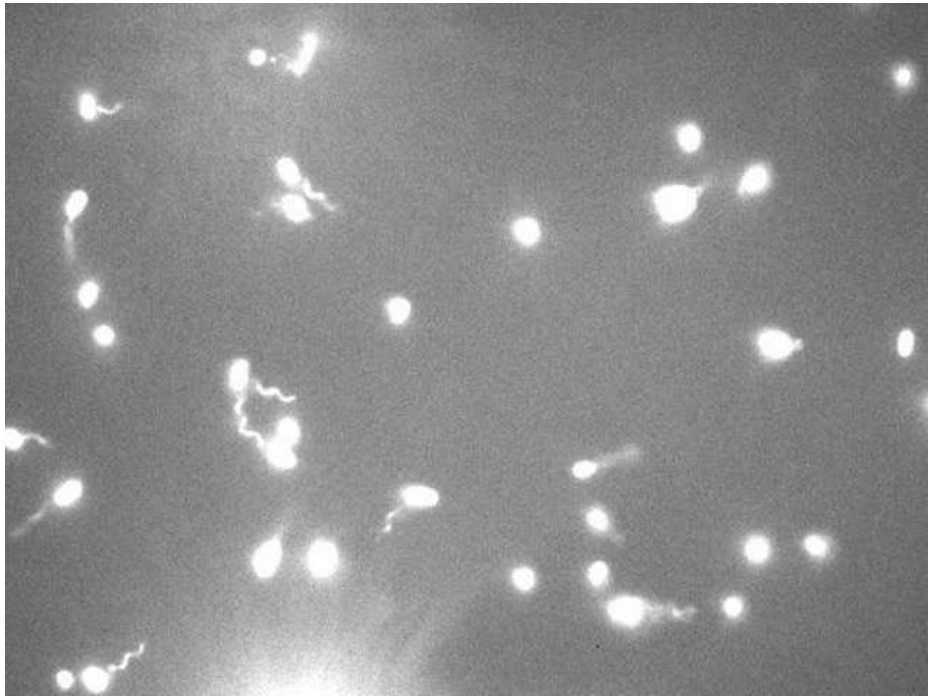


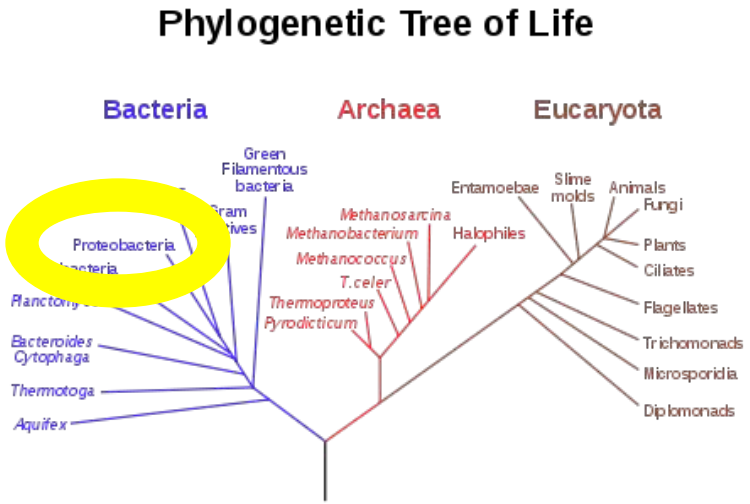
http://www.youtube.com/watch?v=lCm_UZd8IKk
Jarrell and McBride, Nature Reviews Microbiology (2008)

Swimming of bacteria



E. coli:
Run and tumble



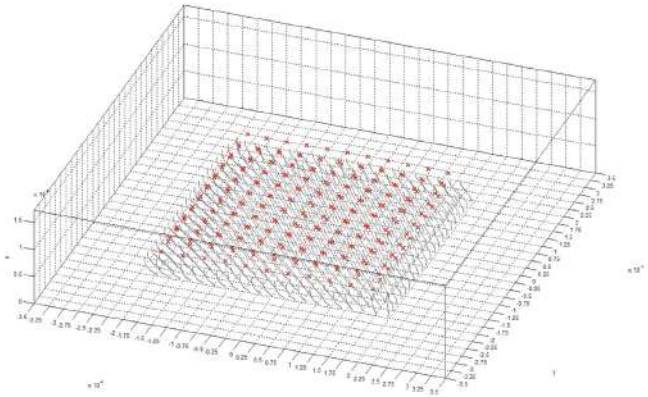


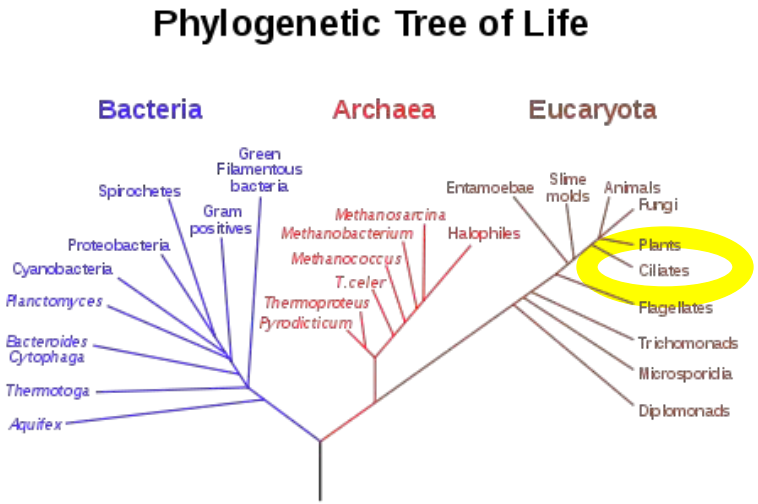
Alberts *et al.*, *Molecular Biology of the Cell*, 3ed., 1994

Swimming of ciliates

Paramecium:

Motility by propagation of ciliary metachronal waves

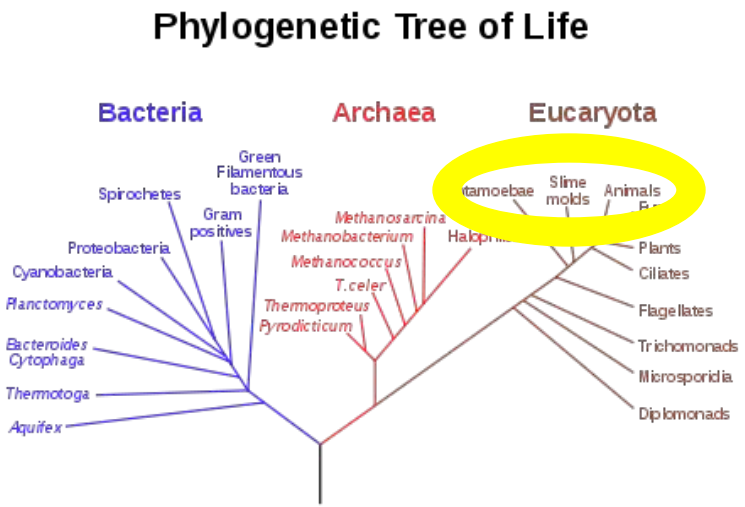




Crawling of amoeba

Slime mold:

Movement by shape changes

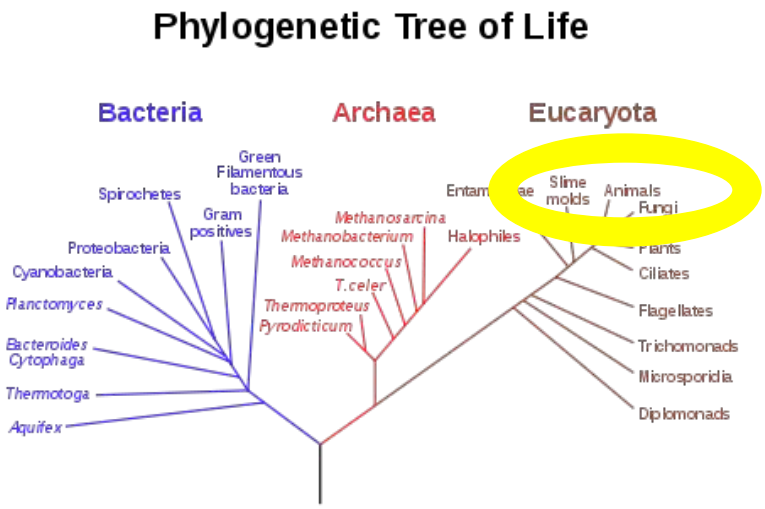


http://biology.ucsd.edu/~firtel/video/ax3single/video.htm

Crawling of mammalian cells

Human neutrophil:

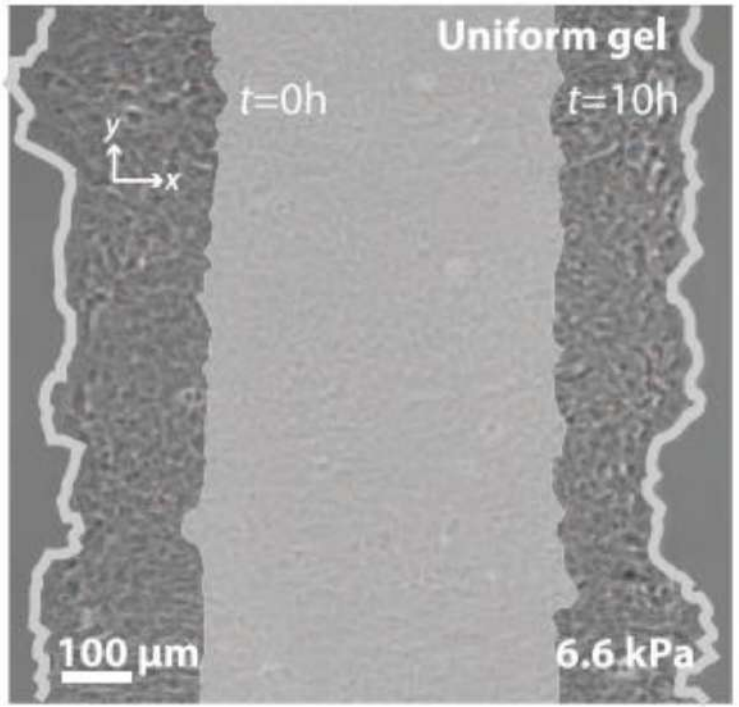
Movement by shape changes



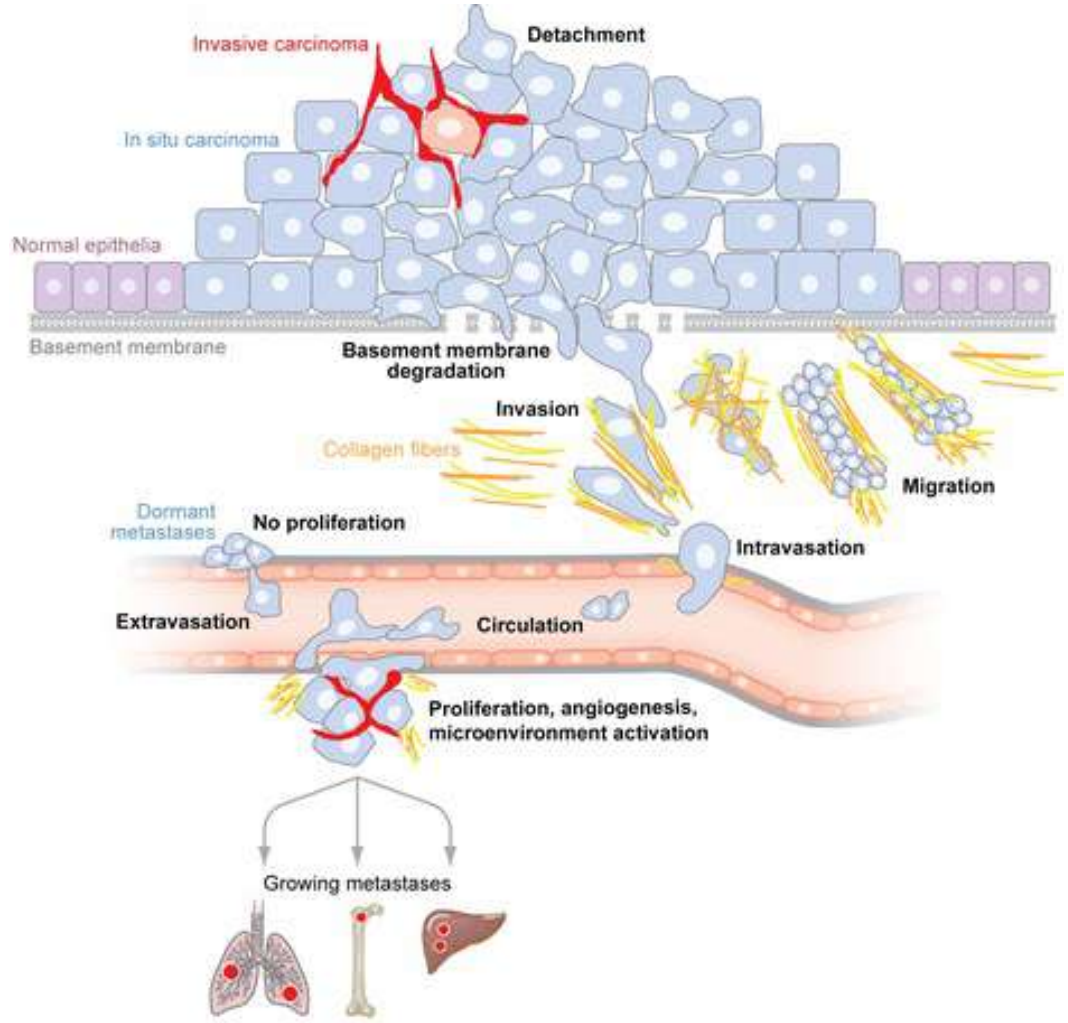
Rogers, 1950s

Cell migration

- Cancer metastasis
- Wound healing



Sunyer et al. Science (2016)



Bacac M, Stamenkovic I. 2008.
Annu. Rev. Pathol. Mech. Dis. 3:221–47

Diseases result in movement changes

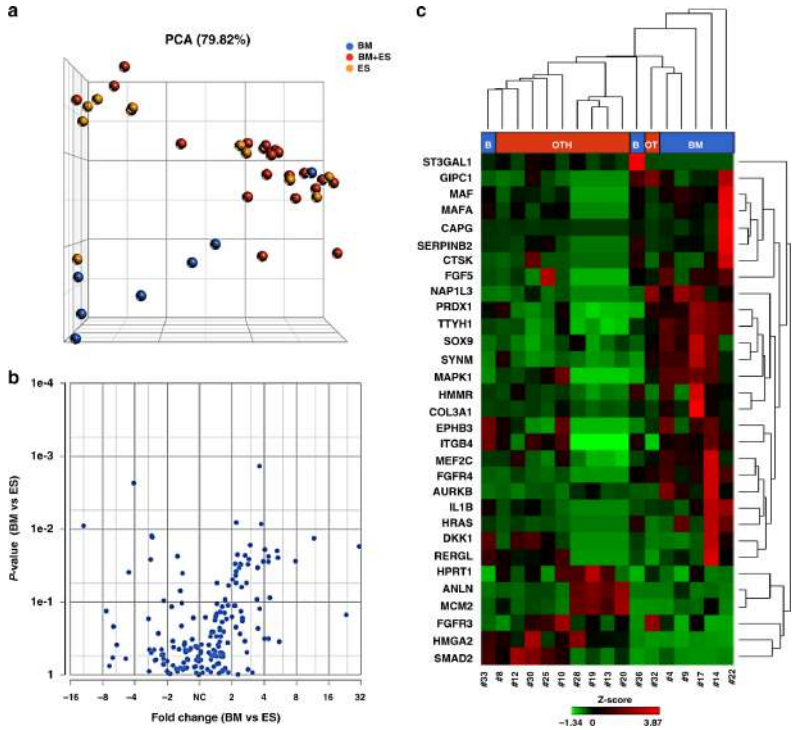
Parkinson’s disease

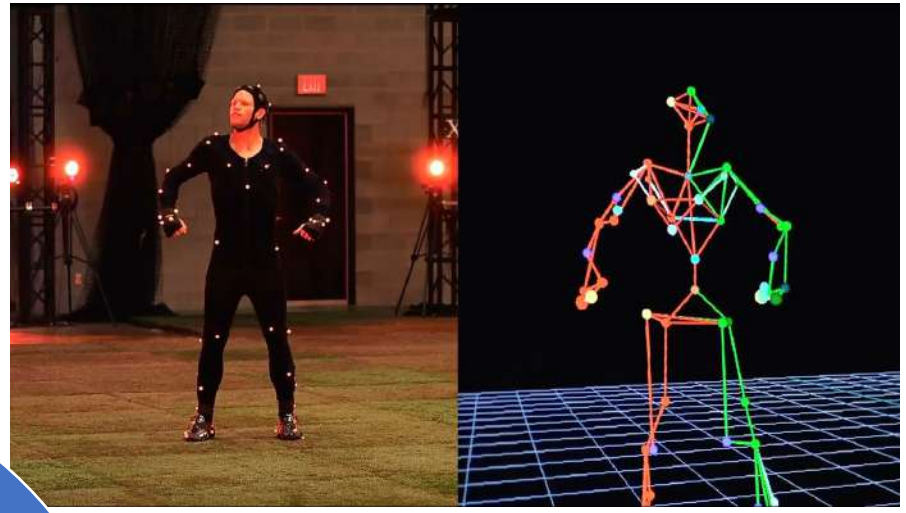
Dementia

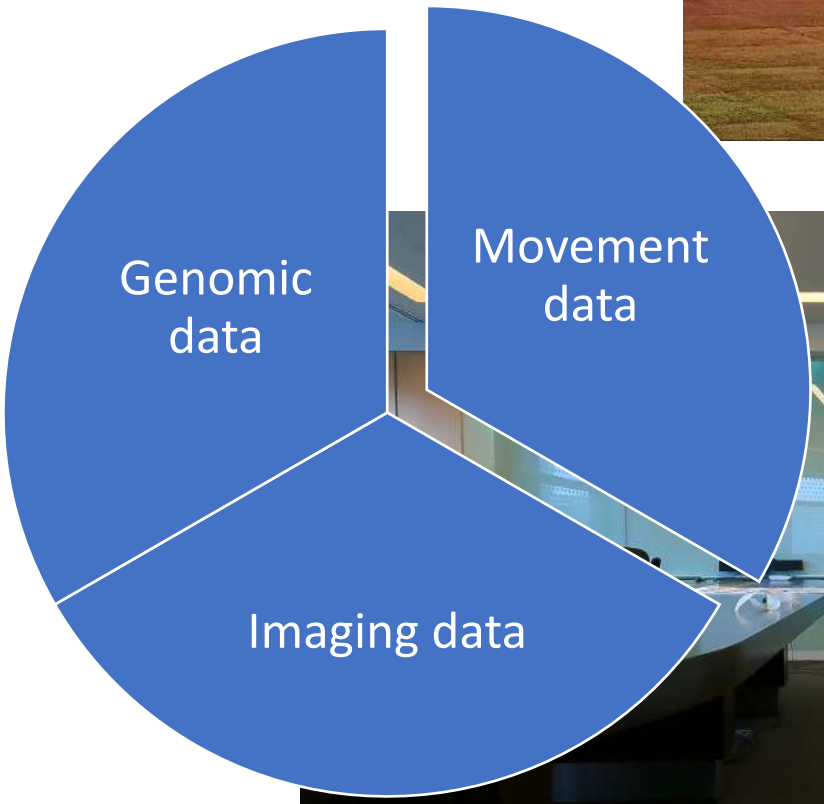
Diabetes-related lower limb amputations

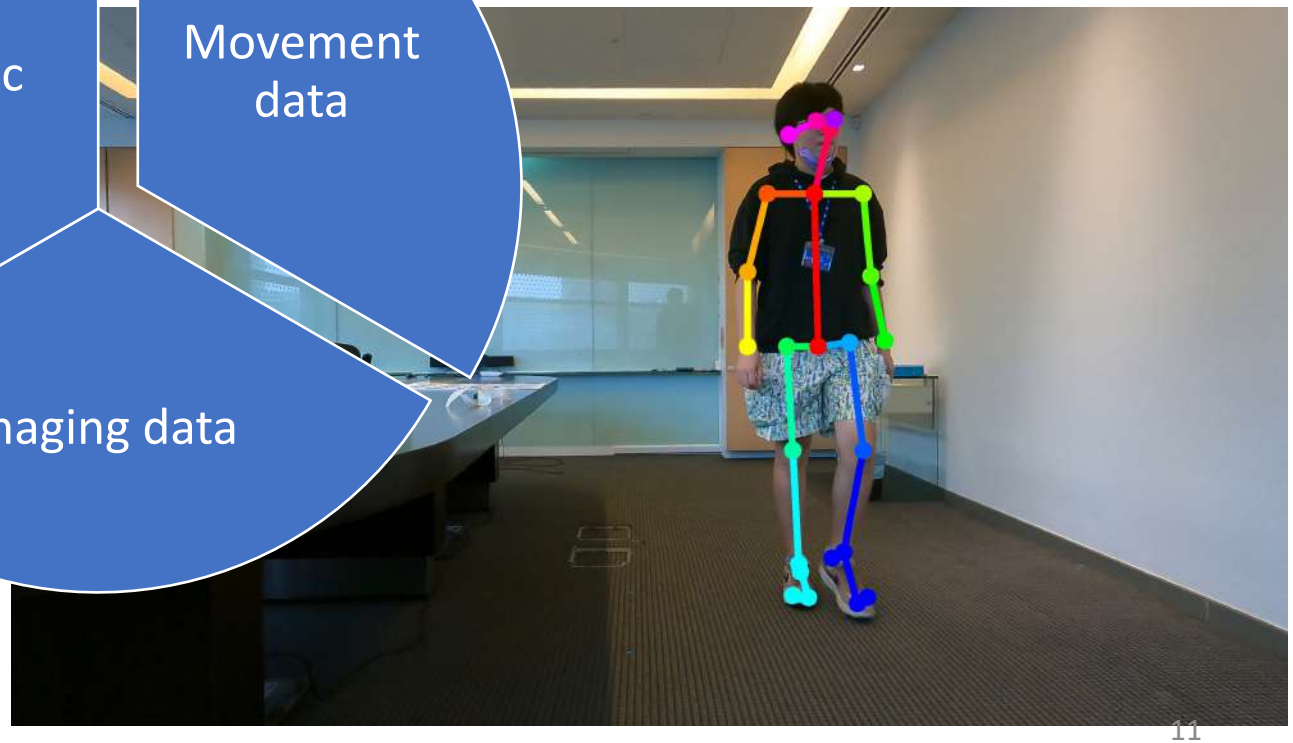
Objective

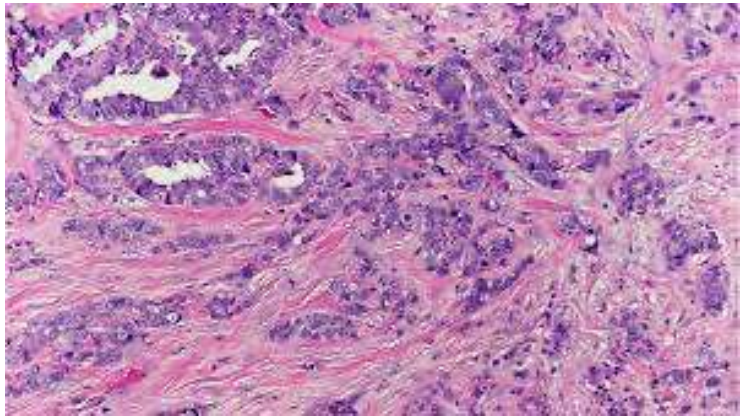
- Use movement data to inform us about disease progression


a
PCA (79.82%)
BM
BM+ES
ES
b
P-value (BM vs ES)
1e-4
1e-3
1e-2
1e-1
1
−16
−8
−4
−2
NC
2
4
8
16
32
Fold change (BM vs ES)
c
B
OTH
B
OT
BM
ST3GAL1
GIPC1
MAF
MAFA
CAPG
SERPINB2
CTSK
FGF5
NAP1L3
PRDX1
TTYH1
SOX9
SYNM
MAPK1
HMMR
COL3A1
EPHB3
ITGB4
MEF2C
FGFR4
AURKB
IL1B
HRAS
DKK1
RERGL
HPRT1
ANLN
MCM2
FGFR3
HMGA2
SMAD2
Z-score
−1.34
0
3.87




Genomic data
Movement data
Imaging data





Objective

- Use movement data to inform us about disease progression

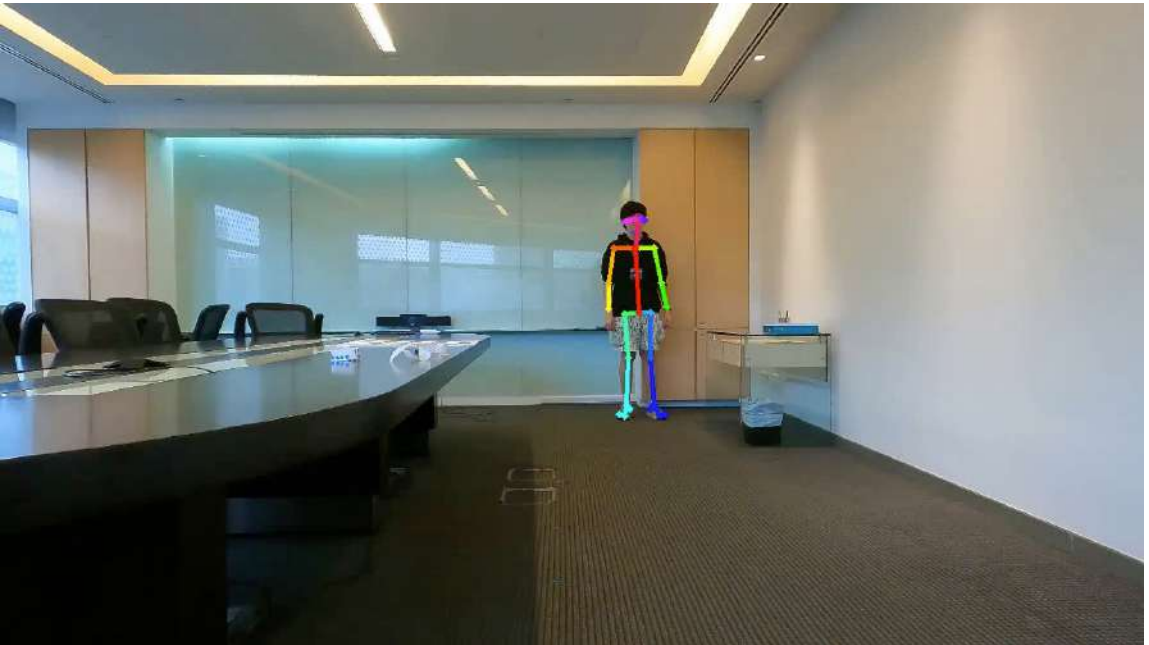
Advantages

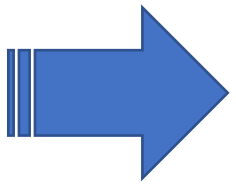
- Movement data can be captured:
  - Cheaply
  - Non-invasively
  - Continuously

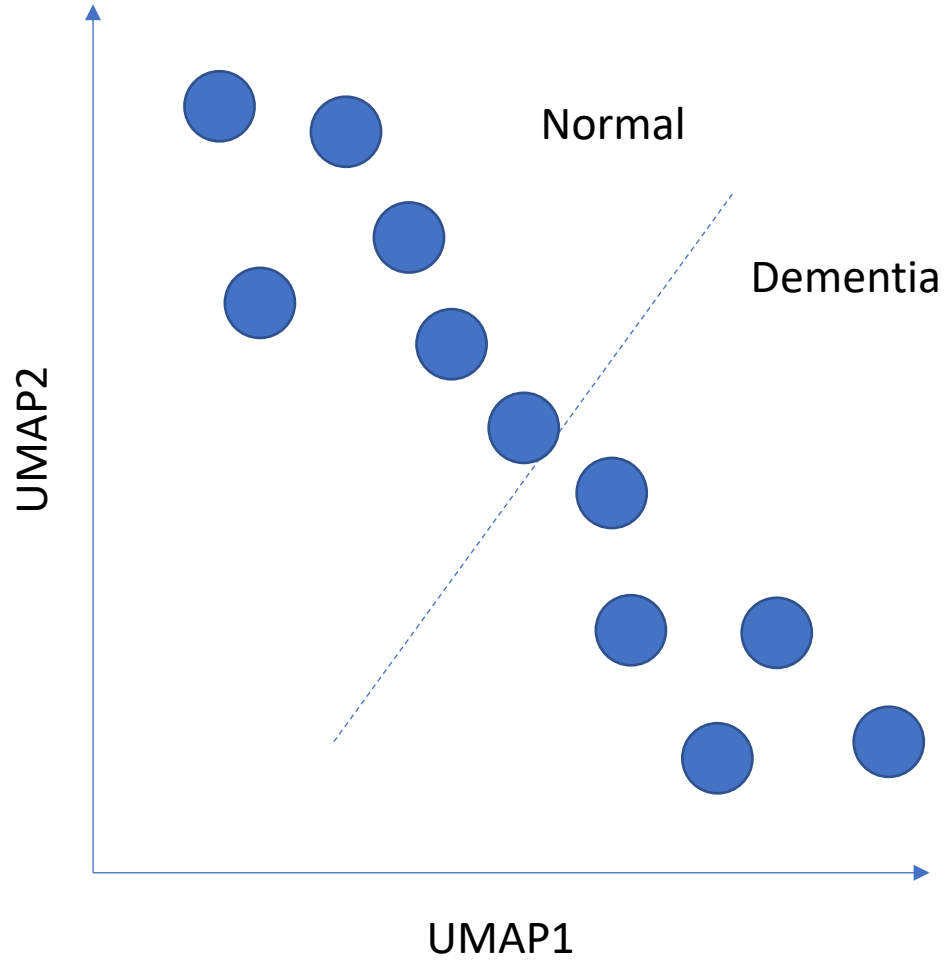
THE STRAITS TIMES SINGAPORE

Kebun Baru pilots tech-integrated facility for the elderly living alone

The facility has two cameras and a sound sensor that monitor the elderly. ST PHOTO: KUA CHEE SIONG

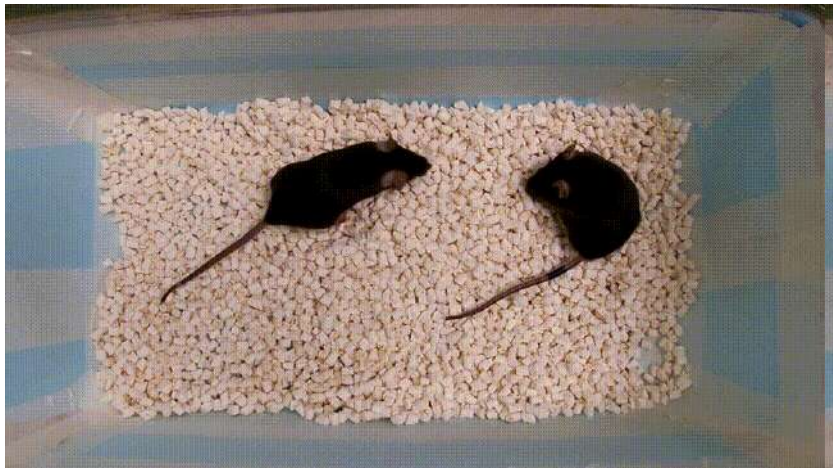




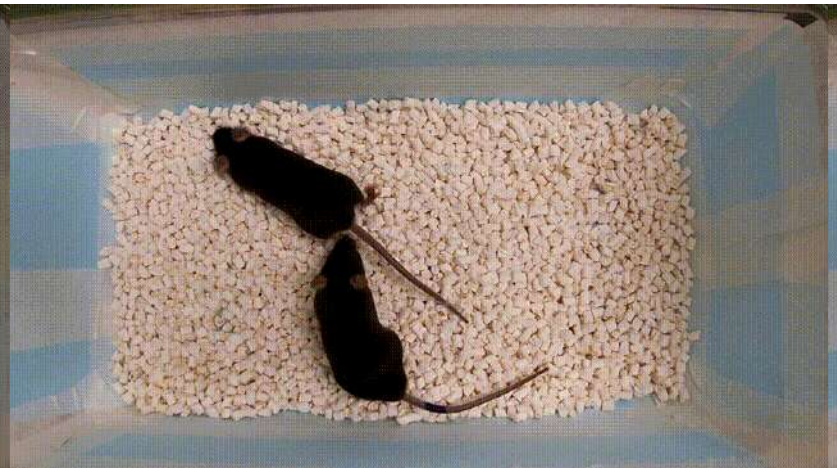

Normal
Dementia
UMAP2
UMAP1

Mouse models

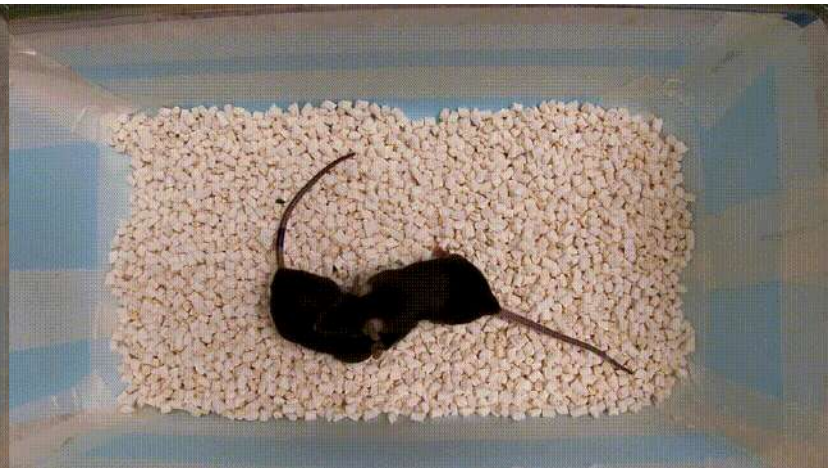
Nose-nose sniff



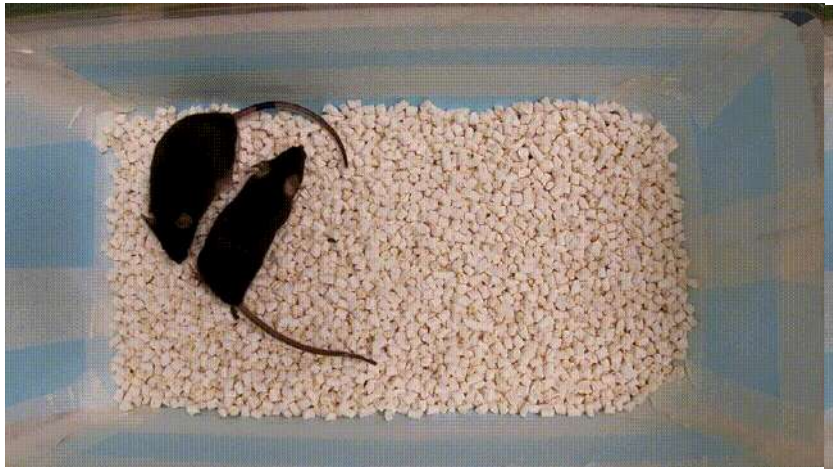
Anogenital sniff



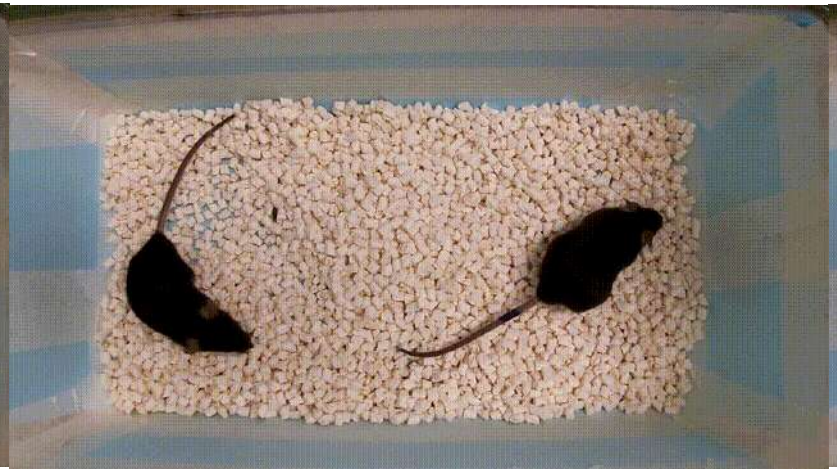
Body sniff



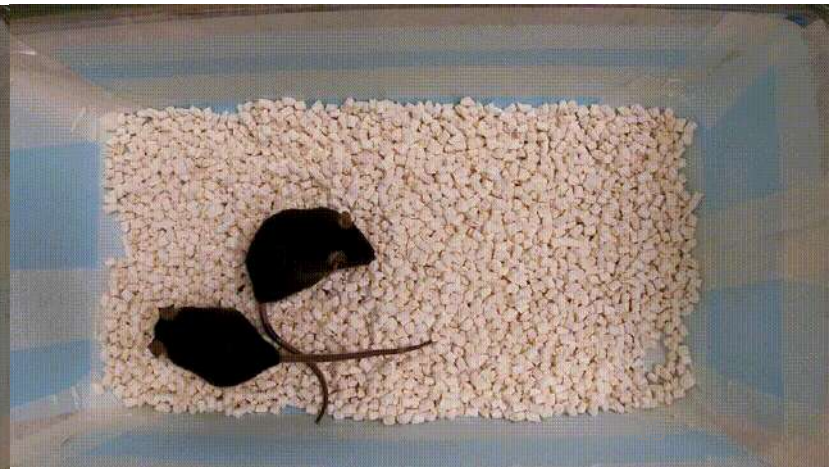
Affiliative



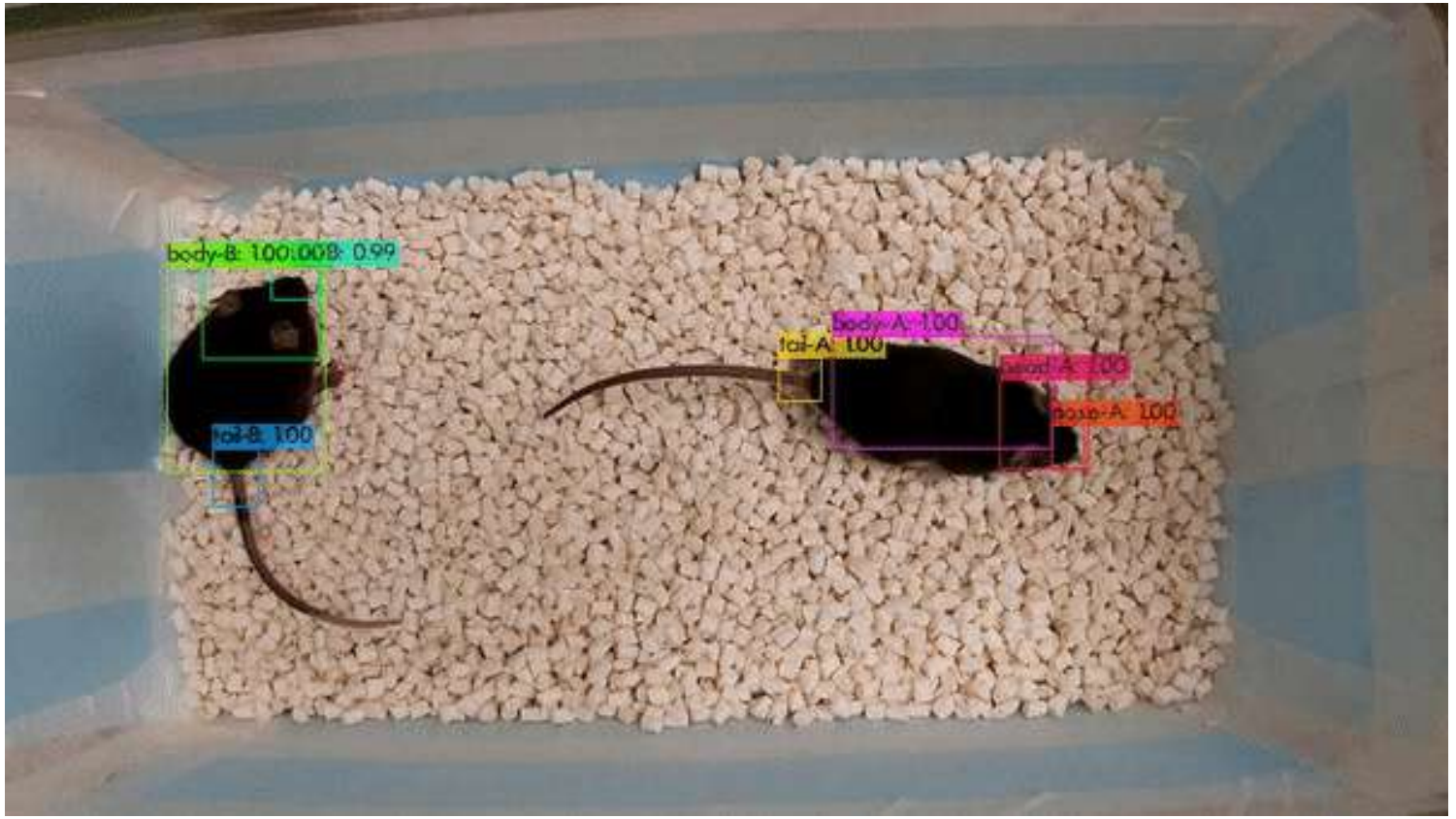
Following



Exploration



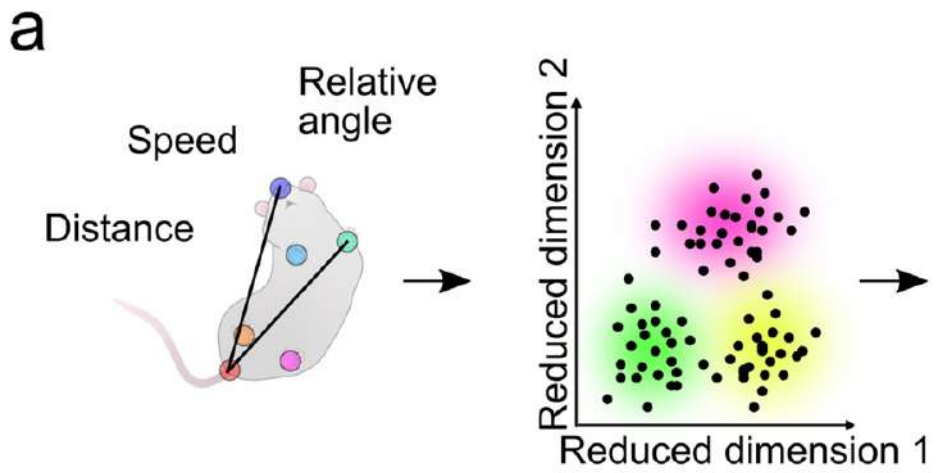
Mouse models



Unsupervised classification of behavior using pose information

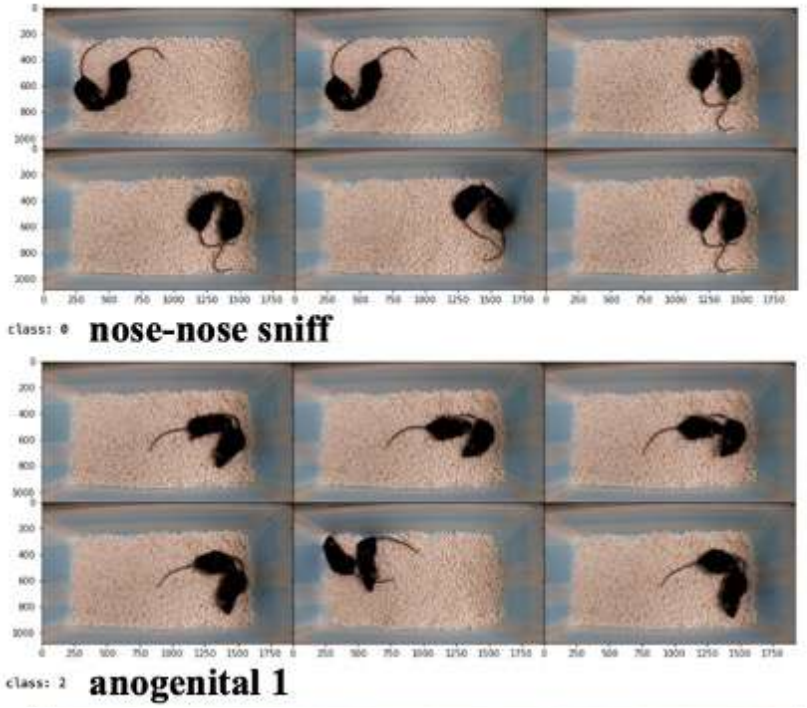
1. Calculation of features from pose estimation data
   - Distance between points, velocity, relative orientation etc.
2. Classification
   1. Dimensionality reduction and clustering
   2. Nonlinear dimensionality algorithms such as tSNE1, UMAP2
   3. Autoencoders type network that was trained with simulation data3, or on self-supervised task4

- Advantages of unsupervised learning
  - Remove potential biases introduced by humans in defining and labelling behavior



1. Berman et al. 2014. Mapping the stereotyped behaviour of freely moving fruit flies
2. Xu & Yttri 2021. B-SOiD, an open-source unsupervised algorithm for identification and fast prediction of behaviors
3. Batpurev et al. 2021. Automatic Identification of Mice Social Behavior through Multi-Modal Latent Space Clustering
4. Luxem et al. 2020. Identifying Behavioral Structure from Deep Variational Embeddings of Animal Motion

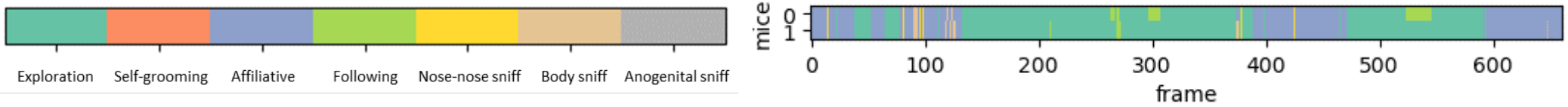
Unsupervised classification of behavior using pose information



Visual inspection of clusters

Assignment of behaviors to clusters

Unsupervised classification of behavior using pose information



Parkinson’s disease

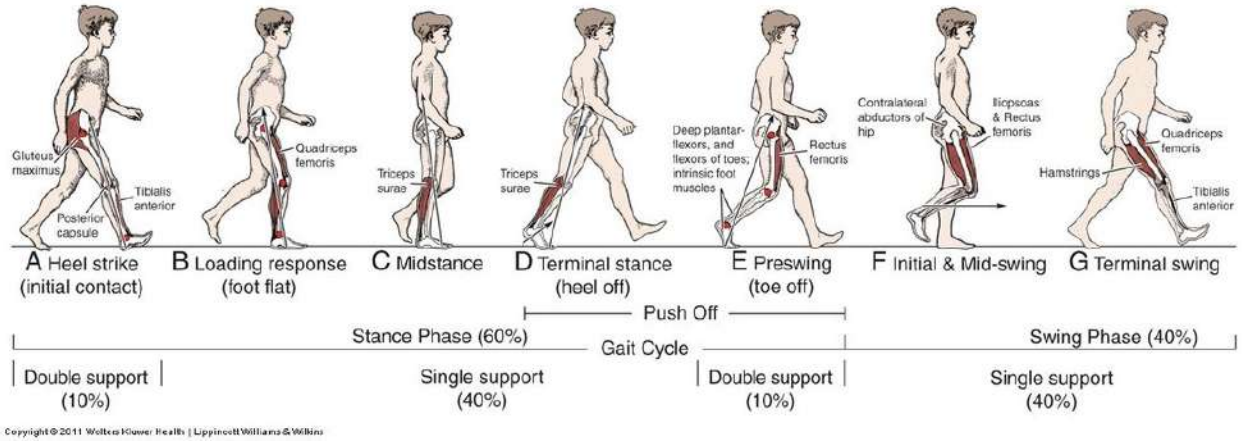
Dementia

Diabetes-related lower limb amputations

THE STRAITS TIMES SINGAPORE

War on diabetes: Amputation of limbs regarded as a last resort

Doctors try new ways to improve diabetics' blood circulation, help wounds heal better



Quantify amputee gait to aid in rehabilitation