universität**bonn**

# Data-Driven Mechanics: Constitutive Model-Free Approach

$$\inf_{y \in D} \inf_{z \in E} \|y - z\| = \inf_{z \in E} \inf_{y \in D} \|y - z\|$$

Michael Ortiz – Lecture 6
California Institute of Technology and
Rheinische Friedrich-Wilhelms Universität Bonn

Centre International des Sciences Mécaniques (CISM)
Udine (Italy), October 10-14, 2022

# Data-Driven Computing – Lecture plan

## TIME TABLE

| TIME | Monday | Tuesday | Wednesday | Thursday | Friday |
|------|--------|---------|-----------|----------|--------|
| | October 10 | October 11 | October 12 | October 13 | October 14 |
| 09.00 - 09.45 | Registration | Schönlieb | Stainier | Doblaré | Doblaré |
| 09.45 - 10.30 | Ortiz | Schönlieb | Stainier | Doblaré | Doblaré |
| 11.00 - 11.45 | Ortiz | Ortiz | Schönlieb | Stainier | Doblaré |
| 11.45 - 12.30 | Ortiz | Ortiz | Schönlieb | Stainier | Ortiz |
| 14.00 - 14.45 | Réthoré | Schönlieb | Reese | Stainier | |
| 14.45 - 15.30 | Réthoré | Schönlieb | Reese | Reese | |
| 16.00 - 16.45 | Réthoré | Réthoré | Stainier (DDCM) | Reese | |
| 16.45 - 17.30 | Réthoré (DIC) | Réthoré (DDI) | Poster Session | Reese | |
| 18.00 | Welcome aperitif | | | | |

# Data-Driven Computing – Lecture plan



- MD: Physically-informed neural networks in predictive physics
- MO: Fundamentals of (model-free) Data-Driven mechanics
- JR: Data-Driven material identification, experimental methods
- SR: Data structures, solvers, algorithmic strategies, plasticity
- CBS: Imaging, mathematical approaches, hybrid modeling
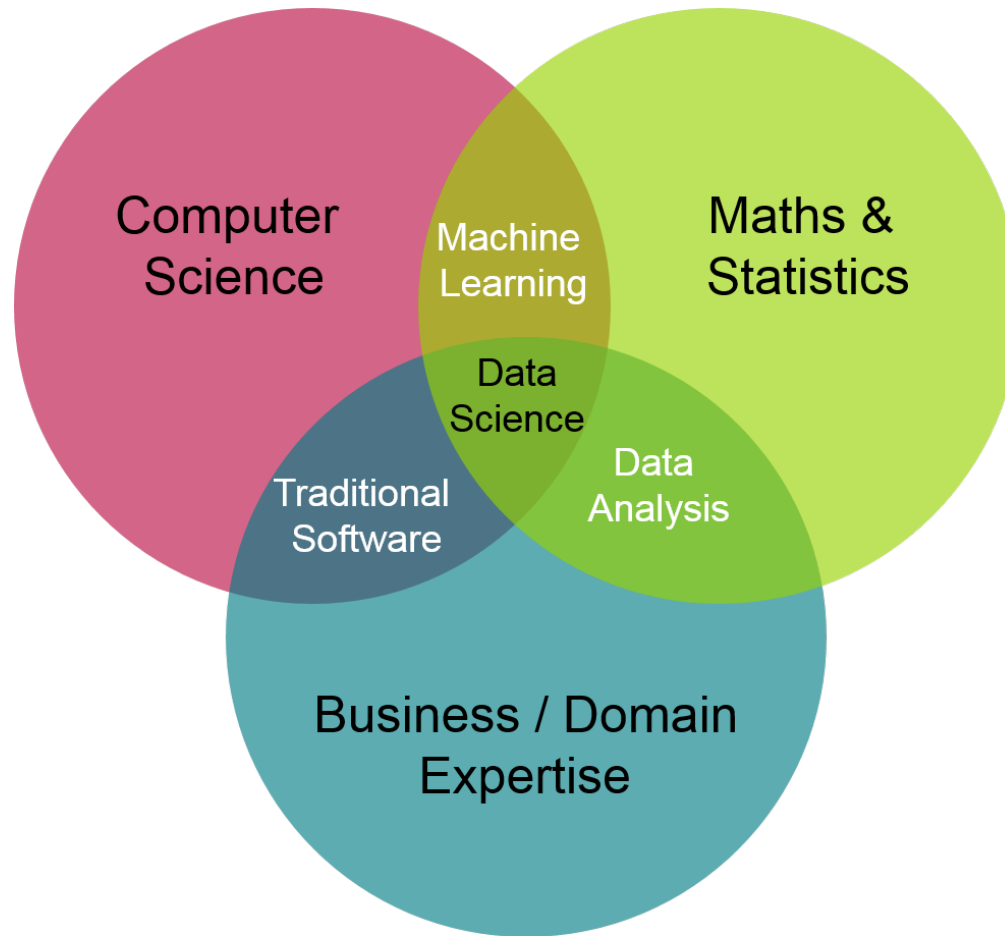- LS: Extensions to finite elasticity, multiscale analysis, design

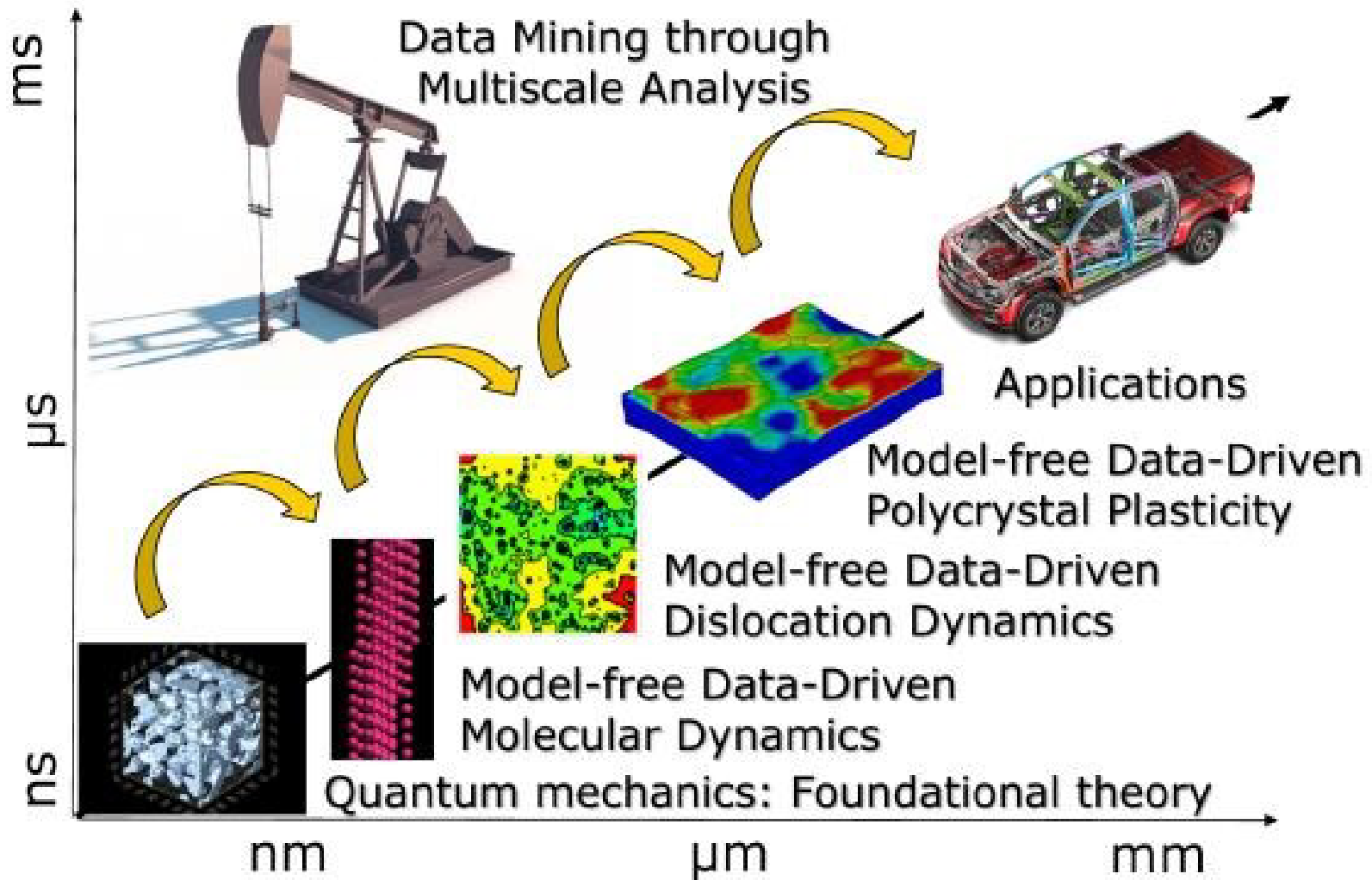# Data-Driven Computing – What have we learned, Palmer?

(from: Burn after reading)

# Data-Driven Computing – What have we learned?
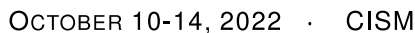
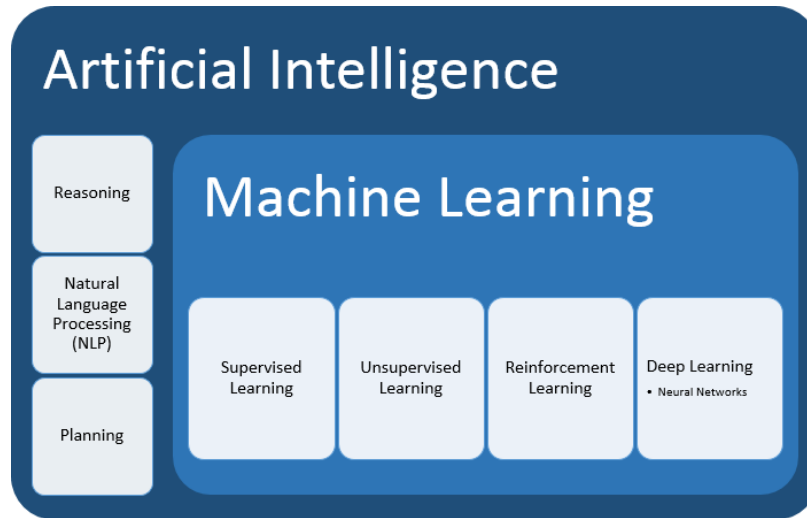# Data-Driven Computing – What have we learned?



**Great Learning Team**,
What is Data Science and How Does it Work:
A Complete Beginner's Guide, Jan 11, 2022.
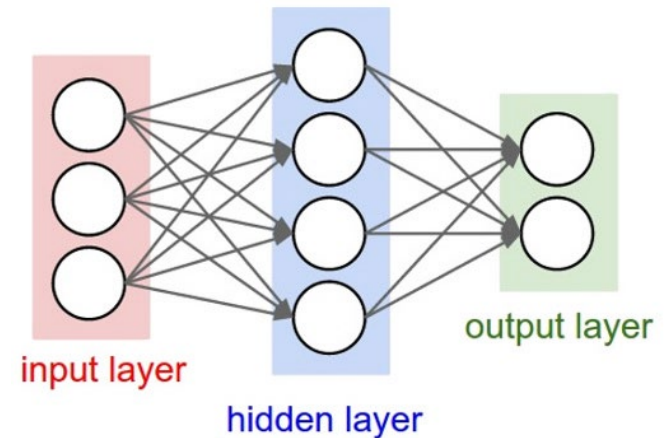
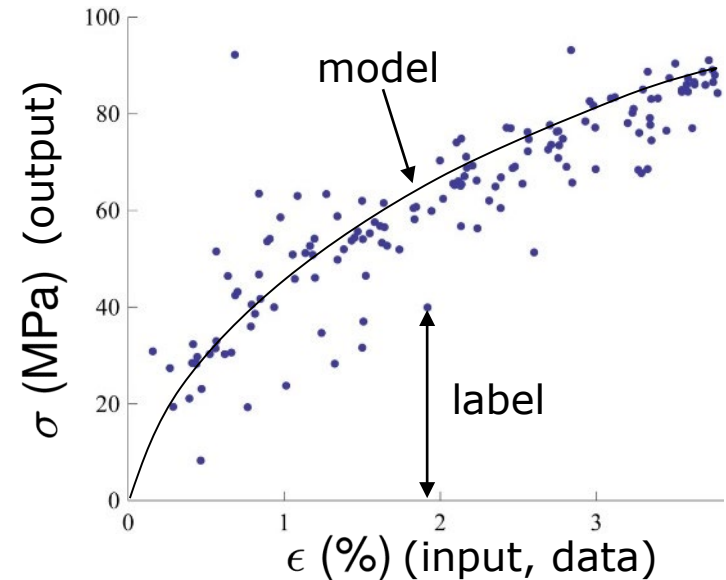# Data-Driven Computing – Where does the data come from?

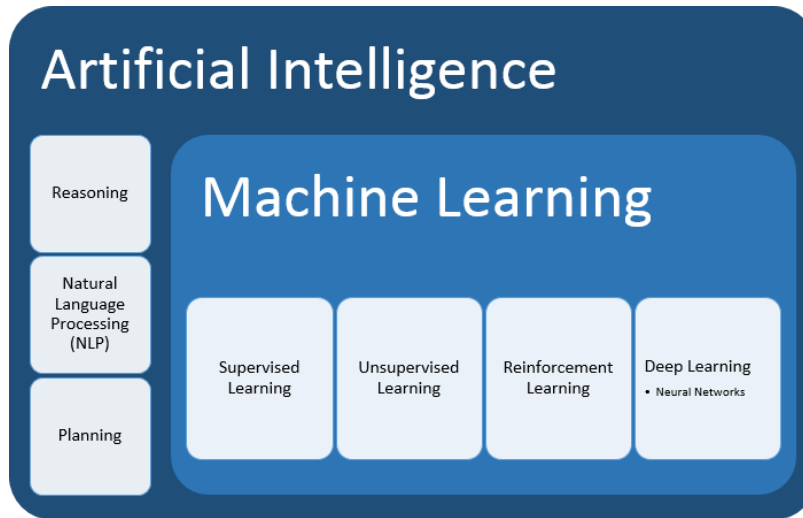# Data-Driven Computing – To fit or not to fit?



*Supervised learning*: Find (e.g., by *regression*) a function (e.g., *deep Neural Network*) from data containing both inputs and outputs (labels).

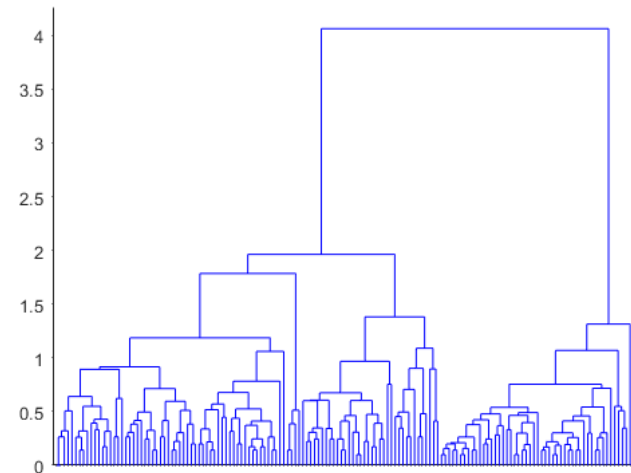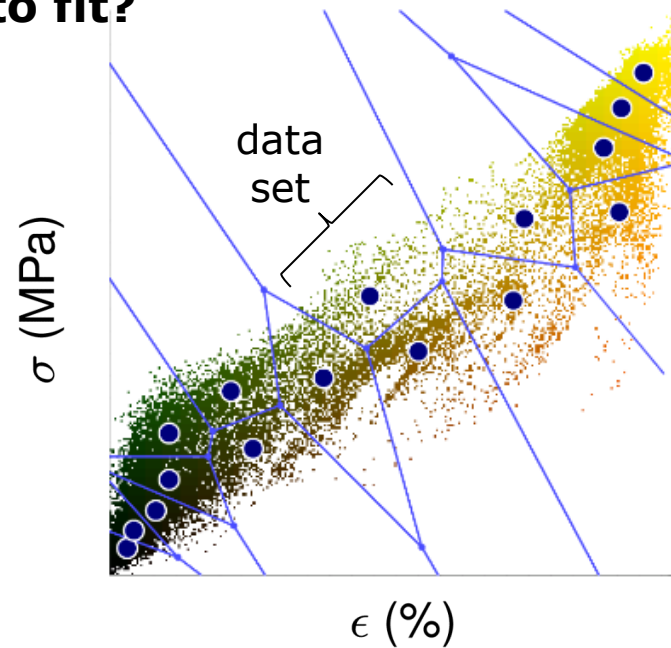J. Hurwitz & D. Kirsch, *Machine Learning*, John Wiley & Sons, 2018.

Deep Neural Network representation, regression

# Data-Driven Computing – To fit or not to fit?



*Unsupervised learning*: Find structure in *unlabeled data* sets (e.g., grouping, clustering, density), make predictions directly from *data structures*.

J. Hurwitz & D. Kirsch, *Machine Learning*, John Wiley & Sons, 2018.

Hierarchical k-means representation, set based

# Data-Driven Computing – Caveat emptor!

Technology makes it easier to generate information that does not constitute knowledge but is perceived as such

- Recipients of this information lack understanding of knowledge validation

[1]Avramides, K., *LGC Debate,* No. 2:28, January 2008.
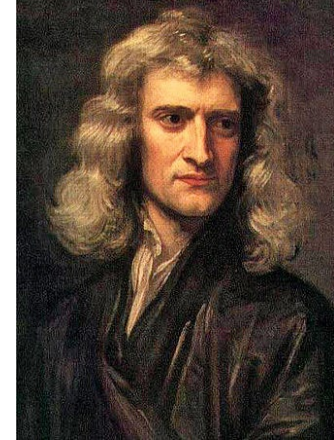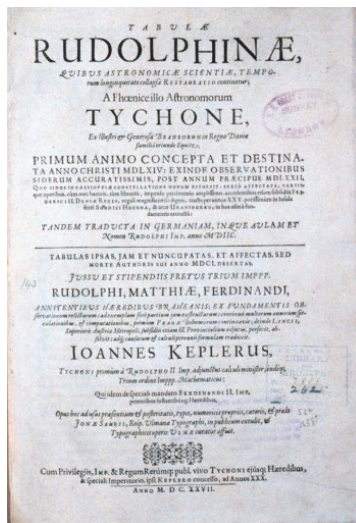
# Data-Driven Computing – Caveat emptor!



Tycho Brahe
(1546-1601)

Johannes Kepler
(1571-1630)

Sir Issac Newton
(1643-1727)

$$\frac{T^2}{a^3} = \frac{4\pi^2}{G(M+m)}$$

Kepler's laws
fit Brahe's data
Why?

$$\vec{F} = m\,\vec{a}$$

True epistemic
knowledge!

# Data-Driven Computing