

The Emerging Field of Plant Single-Cell Omics

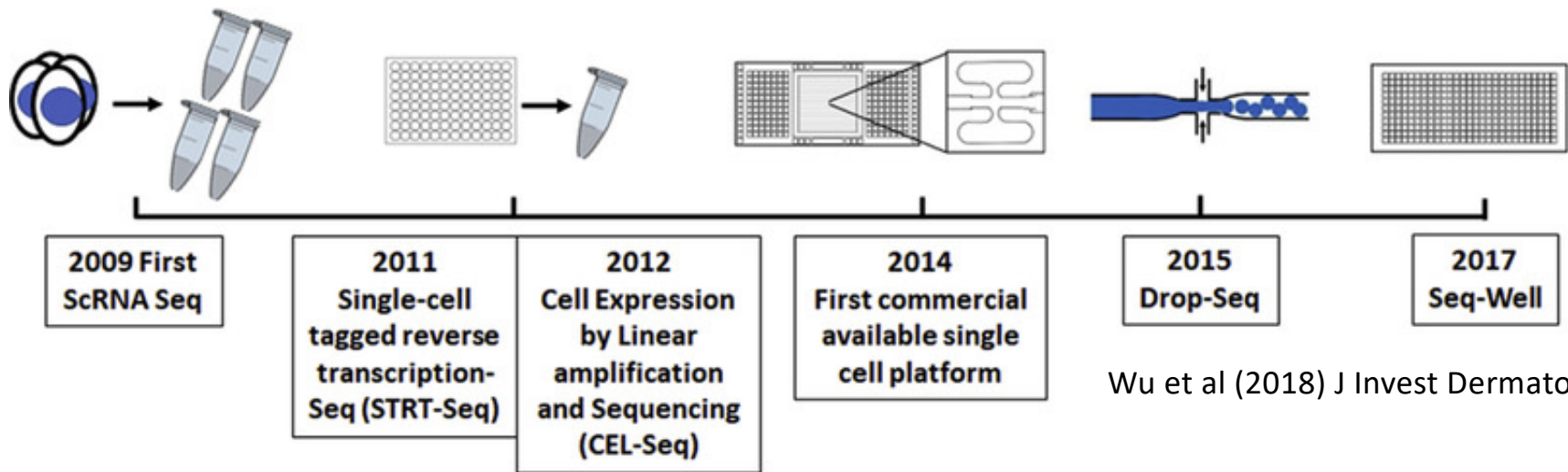
Impact, Status, Challenges, and Community

Sue Rhee

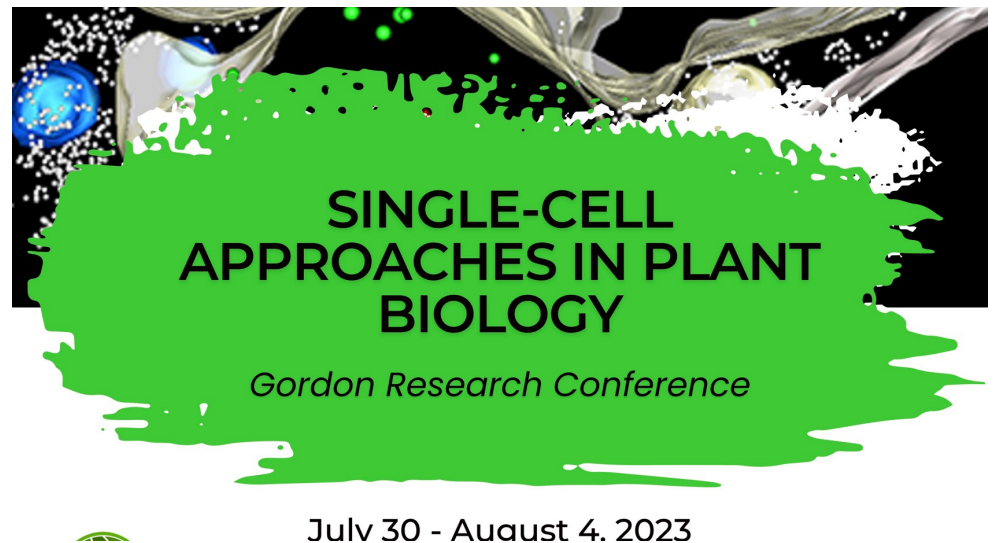
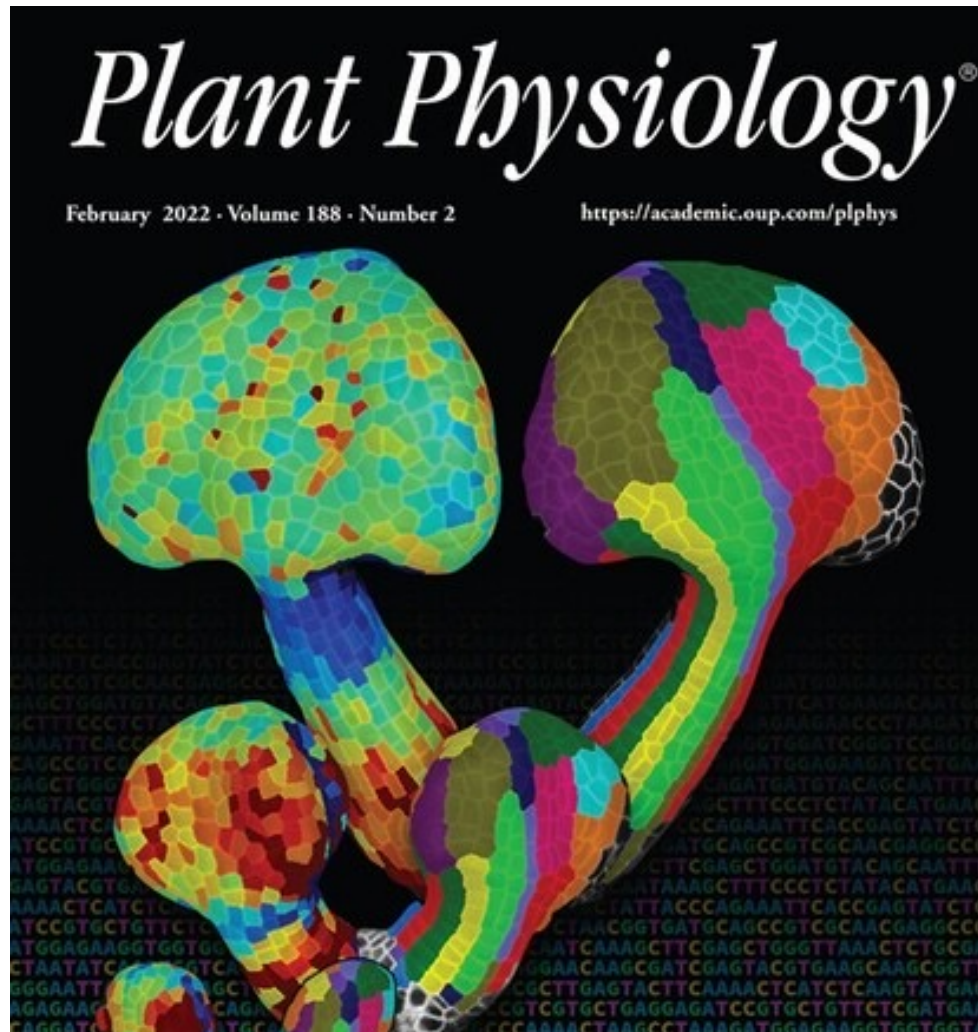
Carnegie Institution for Science

June 16, 2023

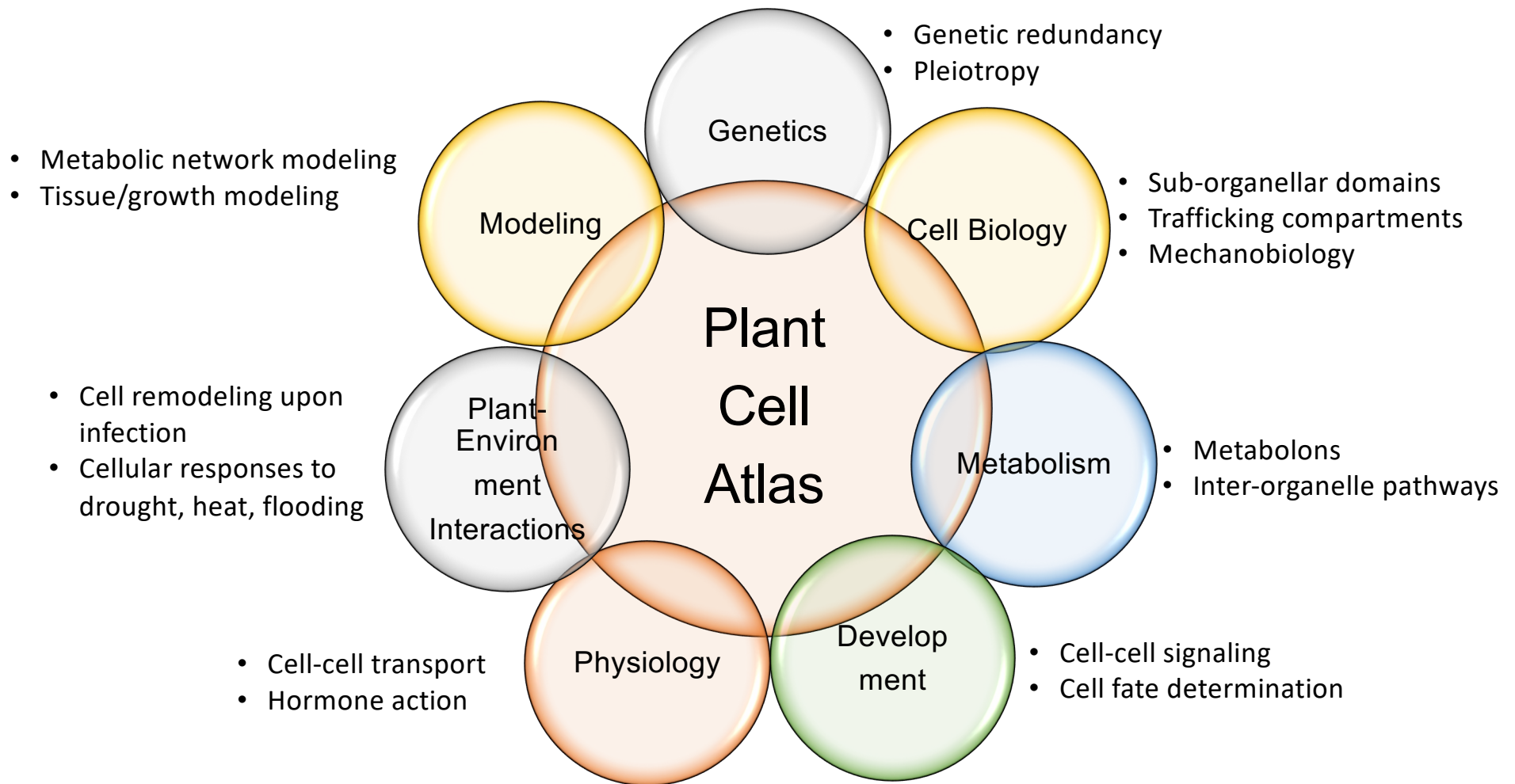
Single-cell RNAseq



2023: Initial technology mature, still expensive, lots of new technologies coming online that are increasing resolution and decreasing price



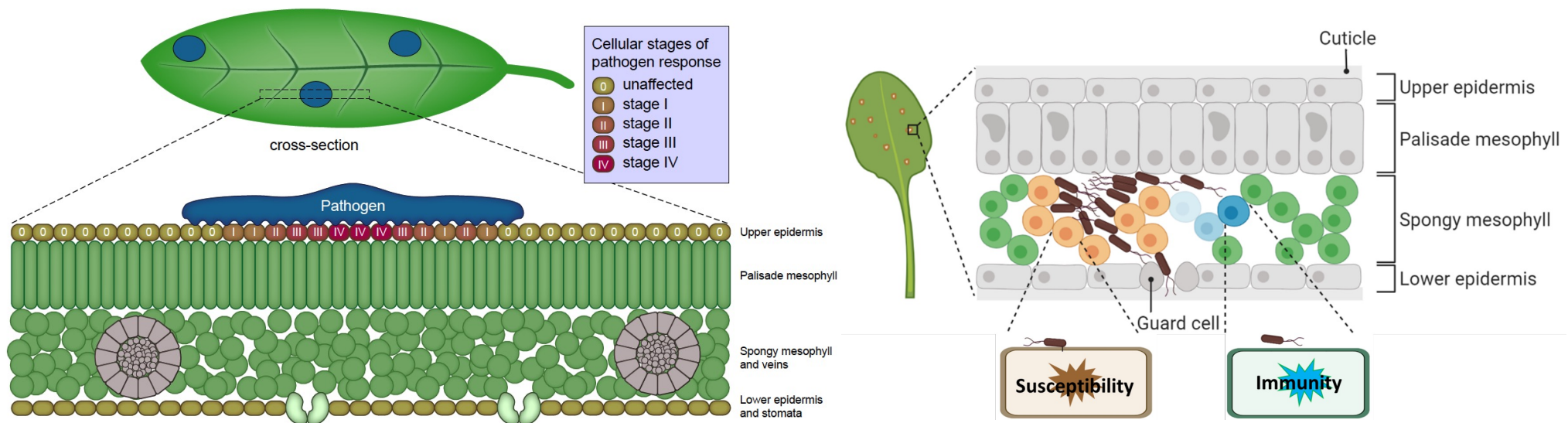
Single-cell approaches will impact many areas of plant science



Opportunities of single cell biology in plant-pathogen interactions

Each year, 20-40% crop loss due to pests
~\$220 Billion USD / year

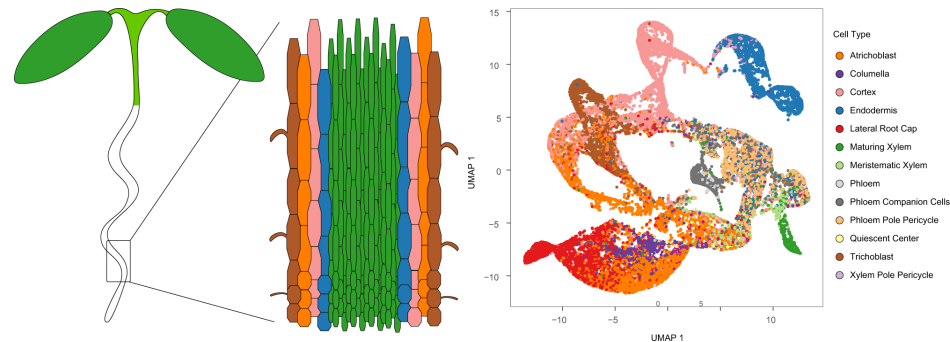
<http://www.fao.org/news/story/en/item/1187738/icode/>



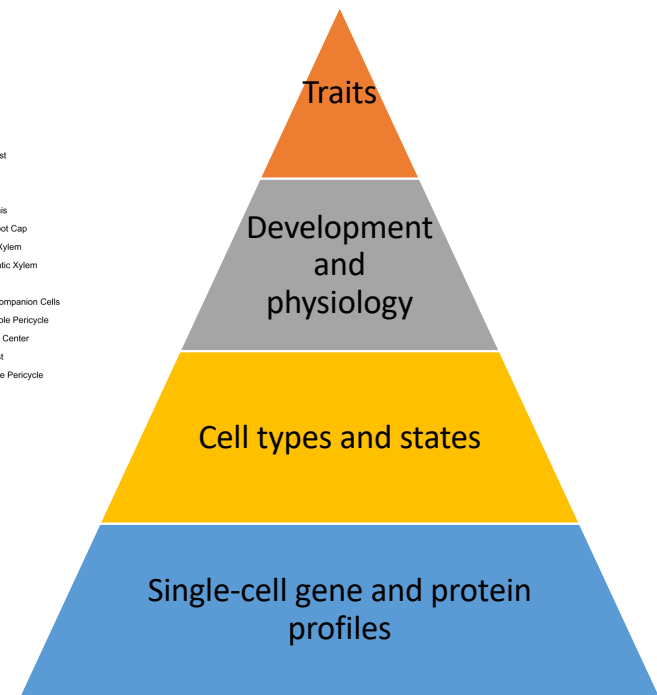
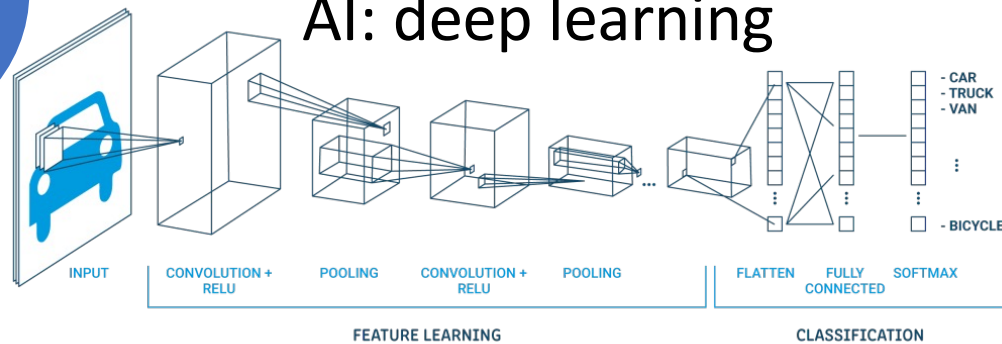
Cole et al (2021) Communications Biology Zhu et al (2022) bioRxiv doi: <https://doi.org/10.1101/2022.10.07.511353>

A new framework and language for describing biological entities

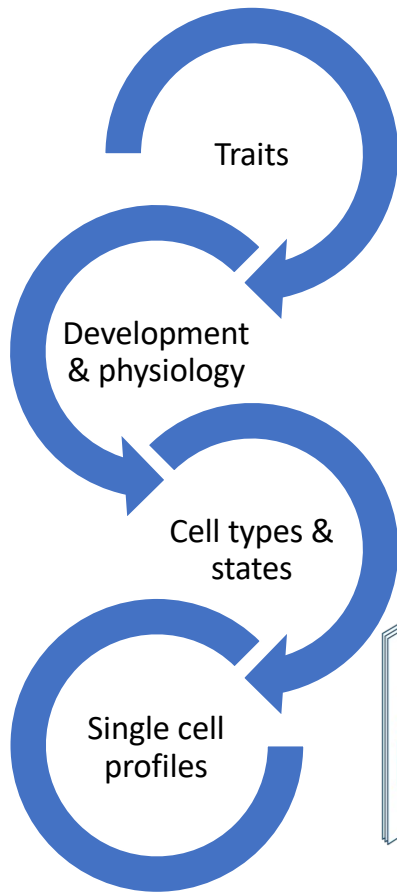
single cell and spatial omics



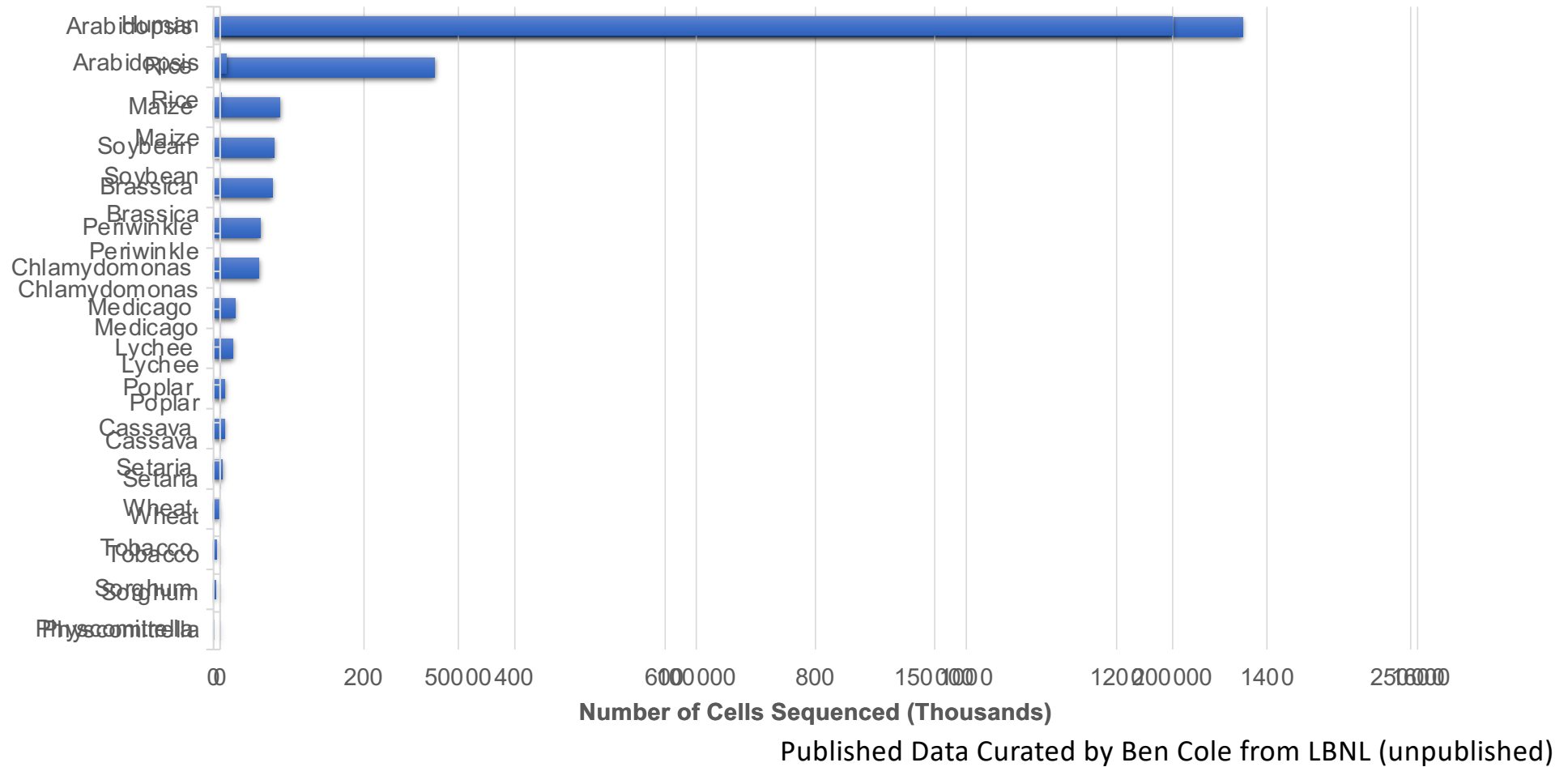
AI: deep learning



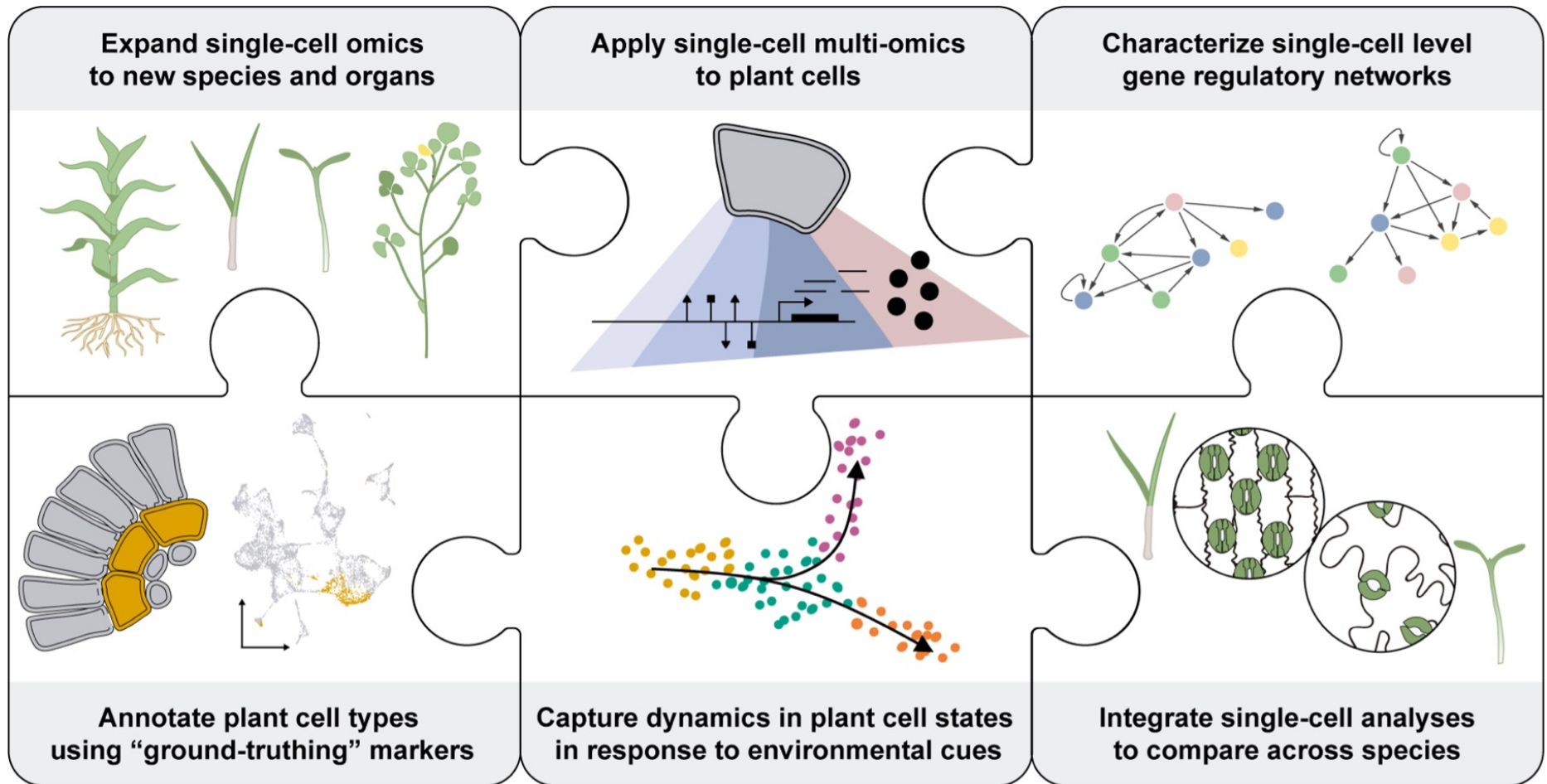
Conceptualization credit: Shin-Han Shiu at MSU



Current state of single cell transcriptomics in plants



Challenges & opportunities for plant single cell omics





A community effort to understand plants at single cell resolution,
build, and engineer plant cells



plantcellatlas.org

Rhee et al (2019) Trends in Plant Science
Plant Cell Consortium (2021) eLife



Goals

- Identify cell types, states and transitions
- Map proteins to cell types and subcellular structures
- Track the dynamic interactions among proteins
- Integrate these data to generate multi-scale models of cells and tissues

Plant Cell Atlas Core Member Institutions

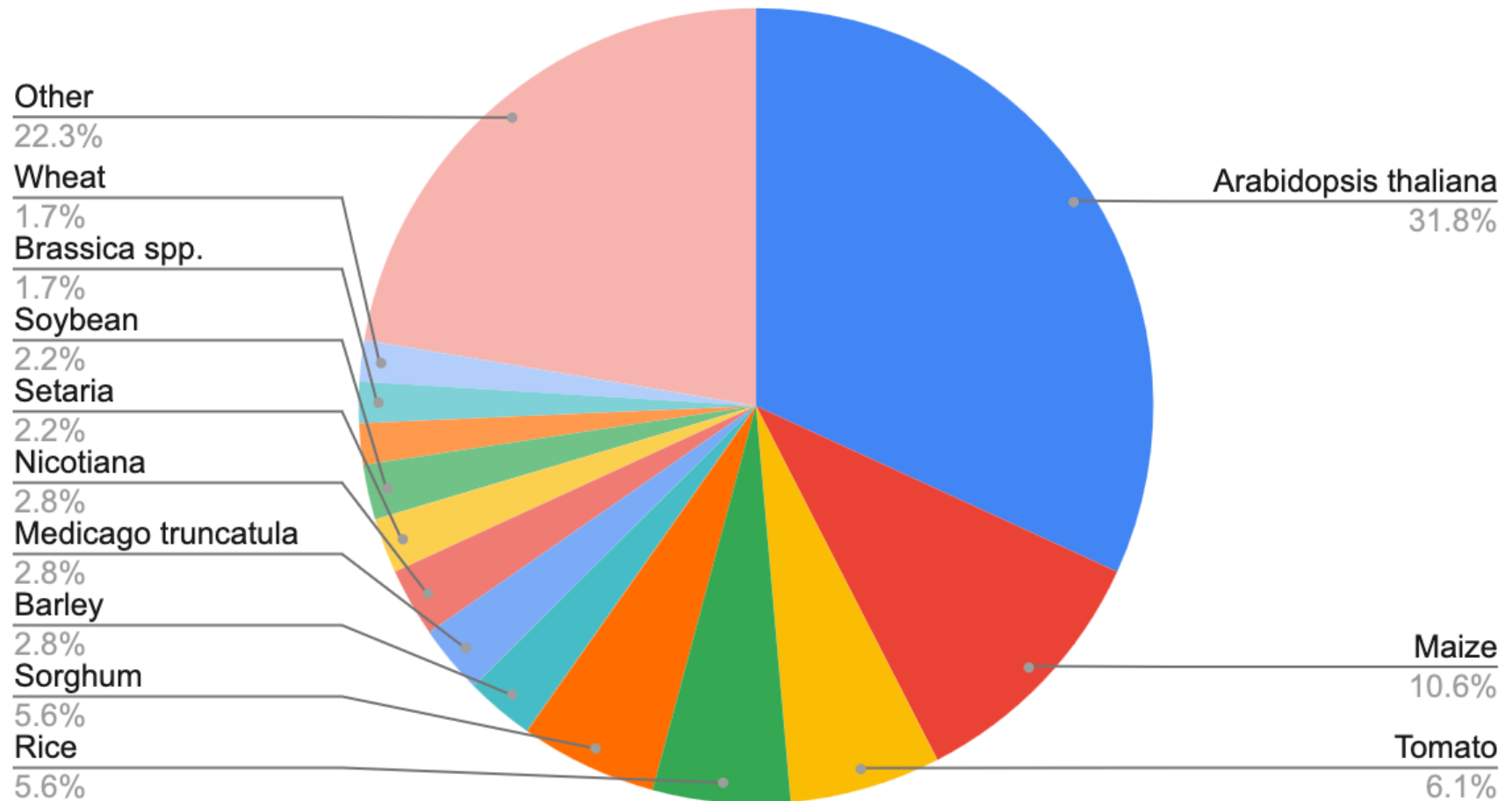


Updated Apr 25, 2023

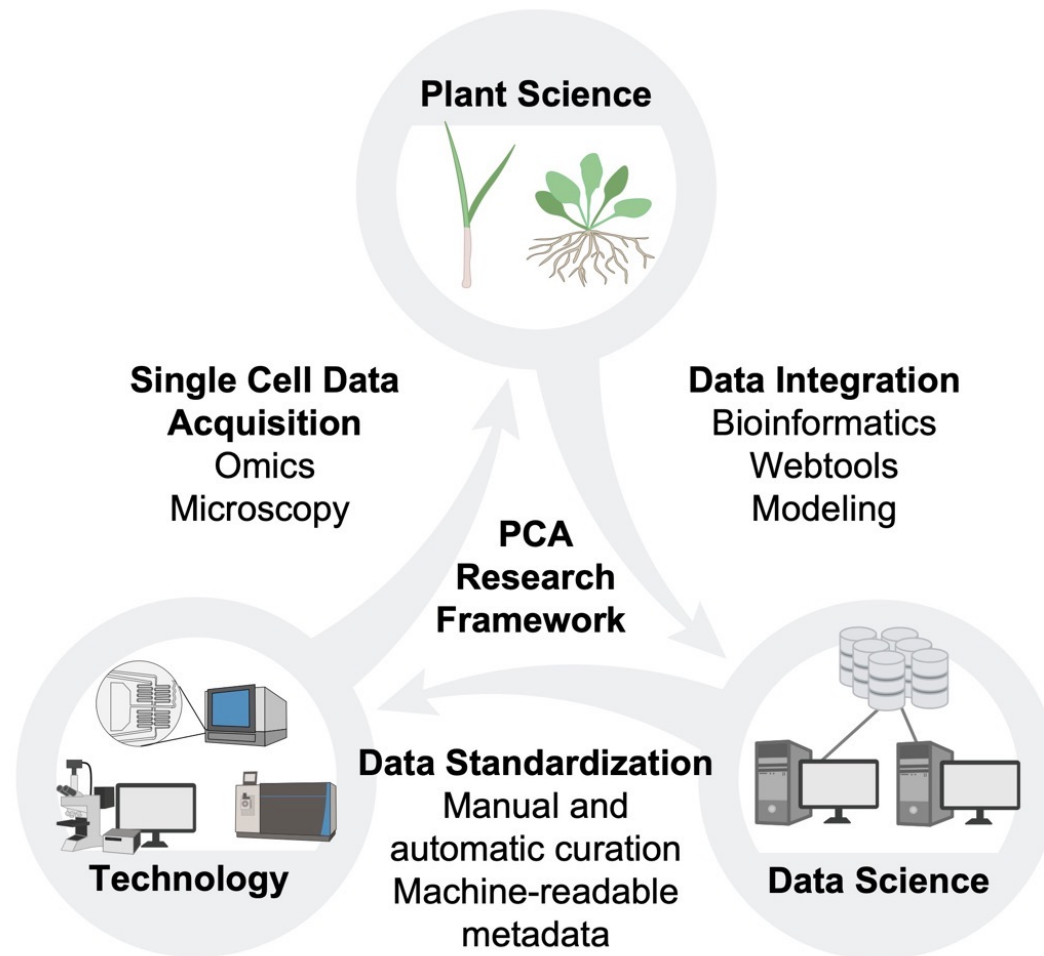




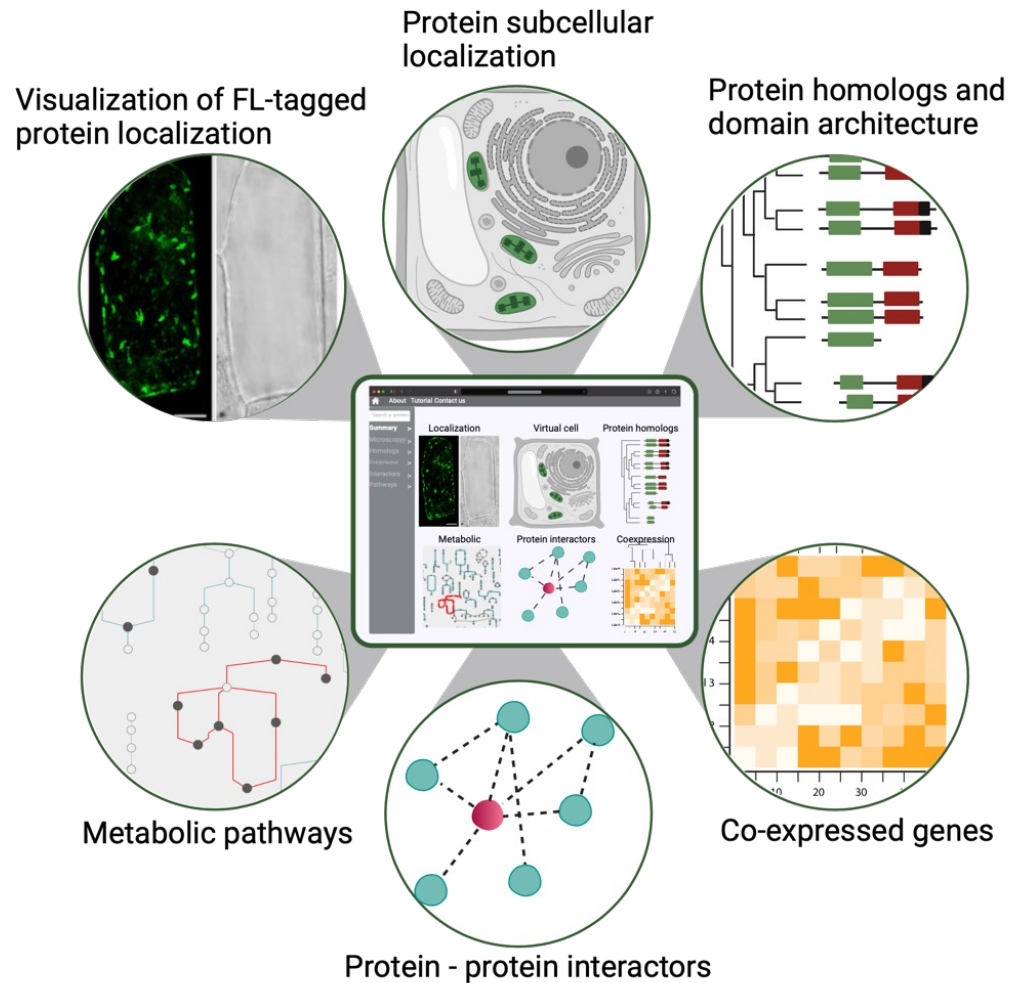
PCA Community works on a diverse array of plants



Plant Cell Atlas (PCA) research framework



One Stop Shop of PCA Data



Plant Cell Atlas Consortium
(2021) eLife

PCA Committee Leads



Dr. Chris Anderton
PNNL



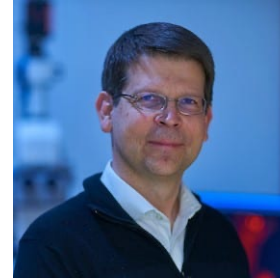
Dr. Jenn Brophy
Stanford



Dr. Marc Libault
U. Nebraska



Dr. Benjamin Cole
LBL



Dr. Kirk Czymmek
Danforth Center



Dr. Michelle Facette
U. Mass Amherst



Dr. Margaret Frank
Cornell



Dr. Noah Fahlgren
Danforth Center



Dr. R. Glen Uhrig
U. Alberta



Dr. Sam Leiboff
Oregon State



Dr. Selena Rice
Carnegie Institution



Dr. Shao-shan Carol
Huang
NYU

69% Early Career

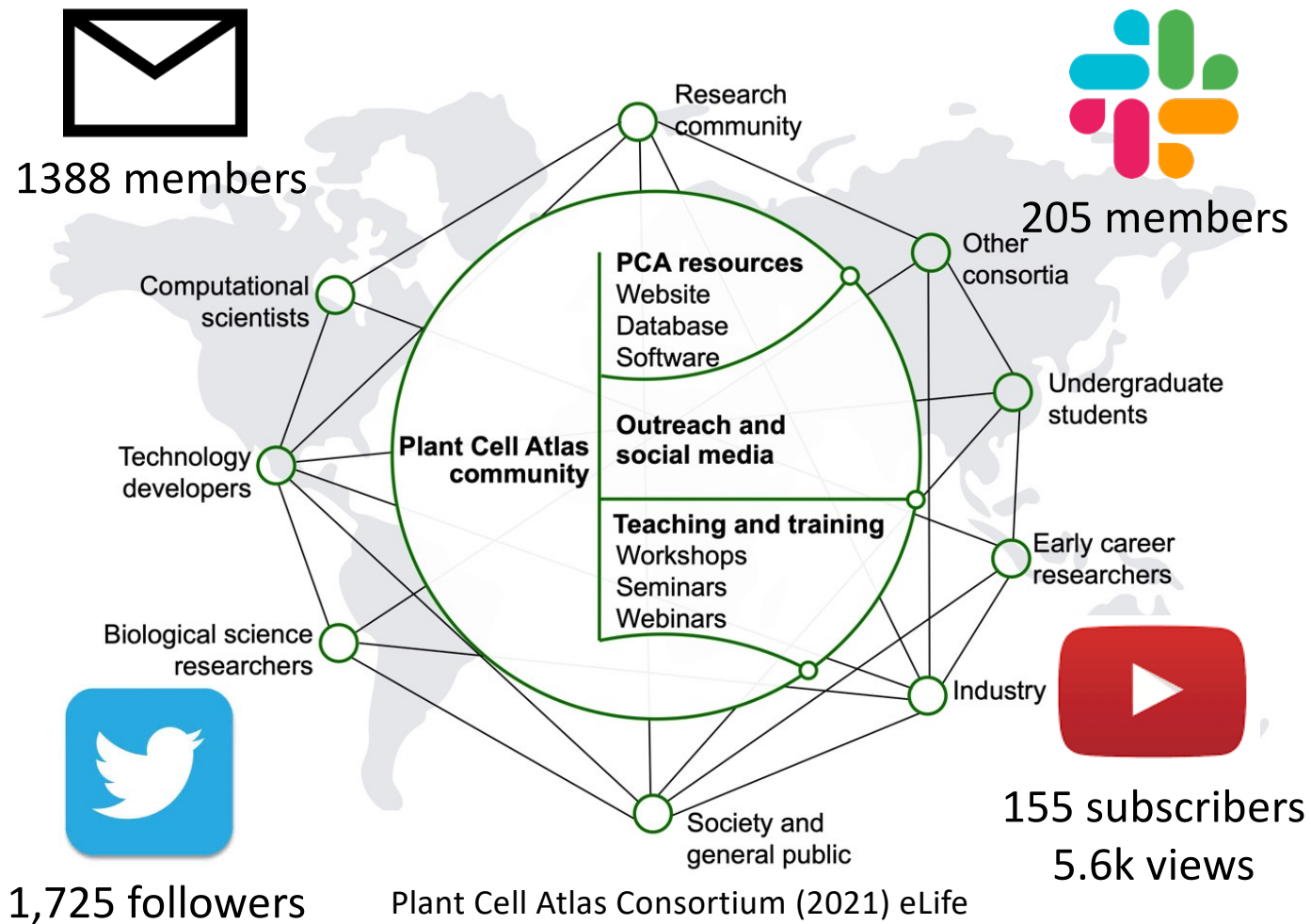
PCA Committees

1. Single Cell Sequencing
2. Proteomics
3. Imaging
4. Metabolomics
5. Phenomics
6. Training & Networking
7. Rubrics
8. Communications
9. Data Management
10. Data Infrastructure
11. Outreach
12. Computation, Modeling & AI
13. Systems & Synthetic Biology
14. Comparative Biology & Evolution
15. Spatial Omics – NEW!

Funding



PCA Stakeholders



- Find info on our website

- www.plantcellatlas.org

- Join the email group

- www.plantcellatlas.org/contact.html

- Join the SLACK workspace

- plantcellatlas.pca.slack.com

- Follow us on Twitter, LinkedIn, and Facebook

- @CellAtlas, Plant Cell Atlas

- Subscribe to our YouTube channel

- <https://www.youtube.com/c/PlantCellAtlas>

- Contact us by email

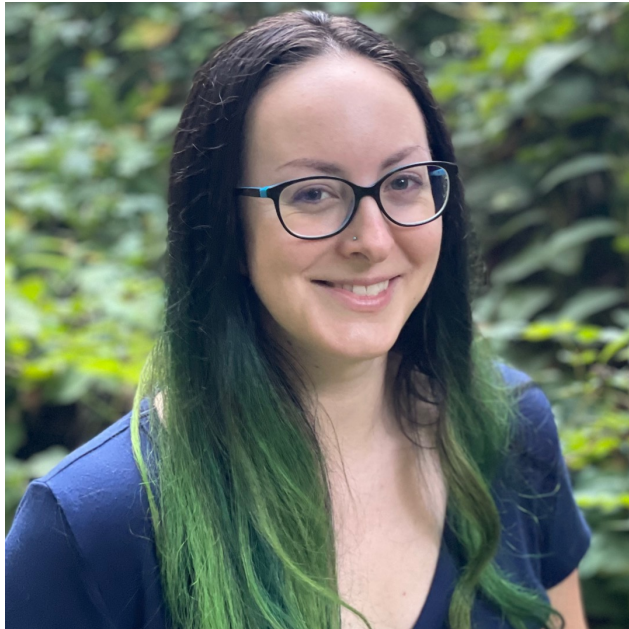
- plantcellatlas@gmail.com

How do I get
involved?



PLANT CELL ATLAS

PCA Coordinators



Dr. Selena Rice
Carnegie Institution for
Science



Elena Lazarus
Carnegie Institution for
Science

Single-Cell Approaches in Plant Biology

Gordon Research Conference

📅 July 30 - August 4, 2023

📍 Four Points Sheraton / Holiday Inn Express
1050 Schooner Drive
Ventura, CA, United States

Application Deadline: July 2, 2023

More Info: bit.ly/PCA-GRCInfo



Apply



Establishing a New Committee: Spatial Omics

- Spatial transcriptomics, proteomics metabolomics, etc.
- Topics addressed:
 - Applying techniques to plants & addressing challenges
 - Standardization – methods, data analysis
 - Data integration & visualization

Sign Up

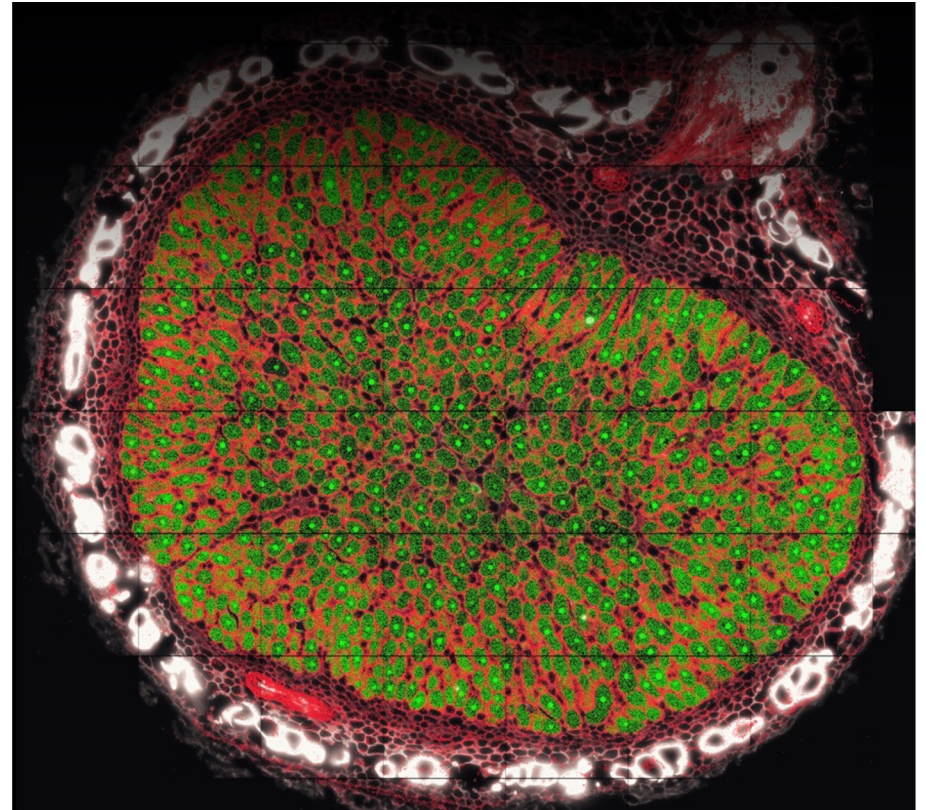
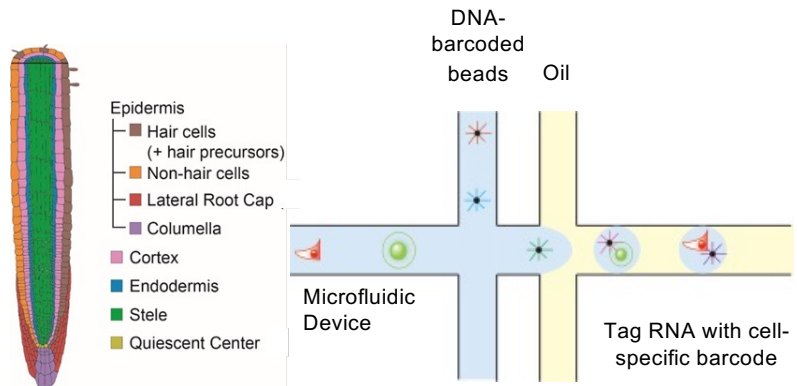


Image Credit: Sutton Tennant (Libault lab, UNL) and Resolve Biosciences (Germany)

Single-cell RNA-seq using microfluidics



| | <i>cell 1</i> | <i>cell 2</i> | <i>cell 3</i> | ... | <i>cell j</i> |
|---------------|---------------|---------------|---------------|-----|---------------|
| <i>gene 1</i> | 0 | 0 | 10 | | 2 |
| <i>gene 2</i> | 53 | 2 | 0 | | 80 |
| <i>gene 3</i> | 0 | 3 | 16 | | 0 |
| ... | | | | | |
| <i>gene i</i> | 25 | 30 | 24 | | 50 |

Normalize & Scale

Reduce Dimensions
(PCA, t-SNE, UMAP)

Classify cells into clusters
annotate cell types



~ 115k *Arabidopsis thaliana* root cells
Shannon et al (2022) *Developmental Cell*

<https://phytozome-next.jgi.doe.gov/tools/scrna/>

Slide from Ben Cole, JGI, LBNL

Sustainable, Plant-Based Future

ClimateTech

CleanTech

AgTech

PlantTech

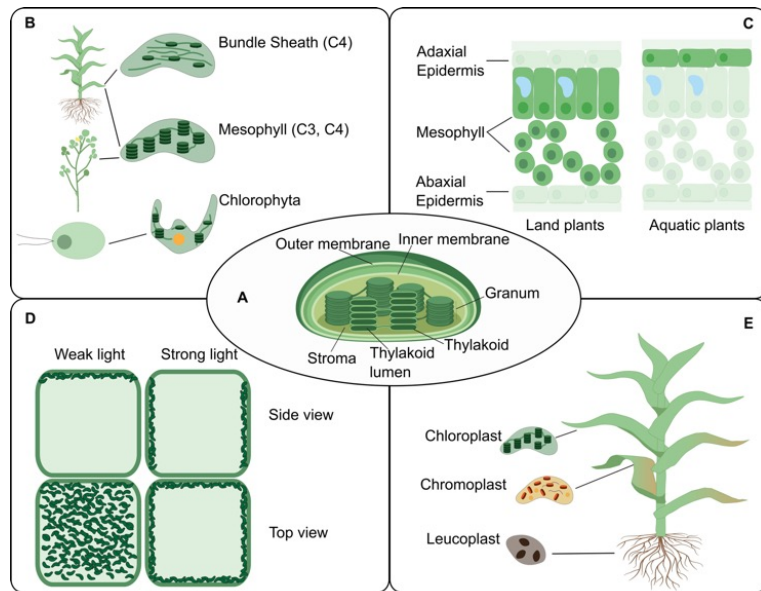
BioTech



A big challenge in plant sciences in the next few decades

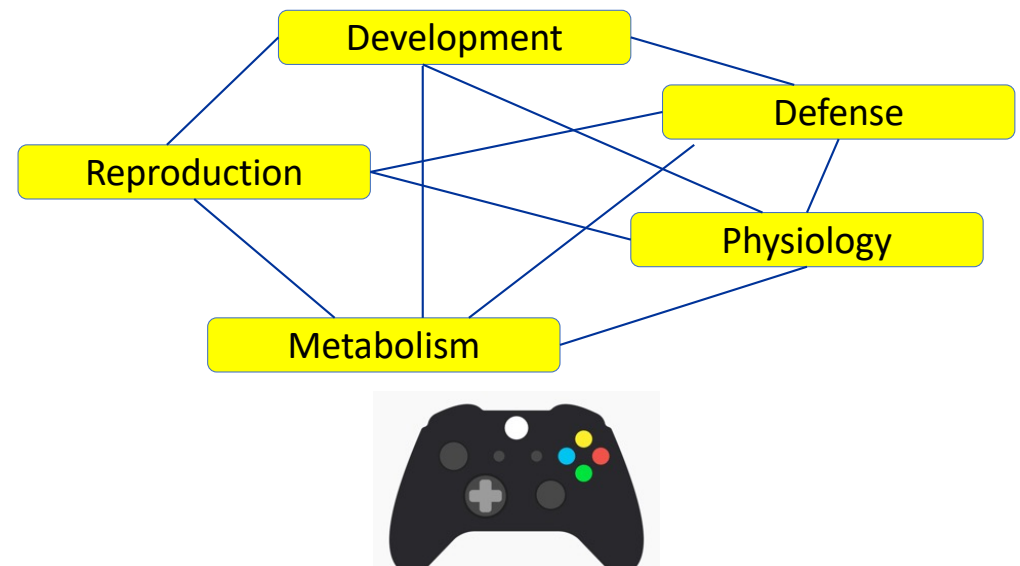
Understand and engineer plants to be resilient against climate extremes and uncertainties: stabilize productivity

Diverse mechanisms of adaptation

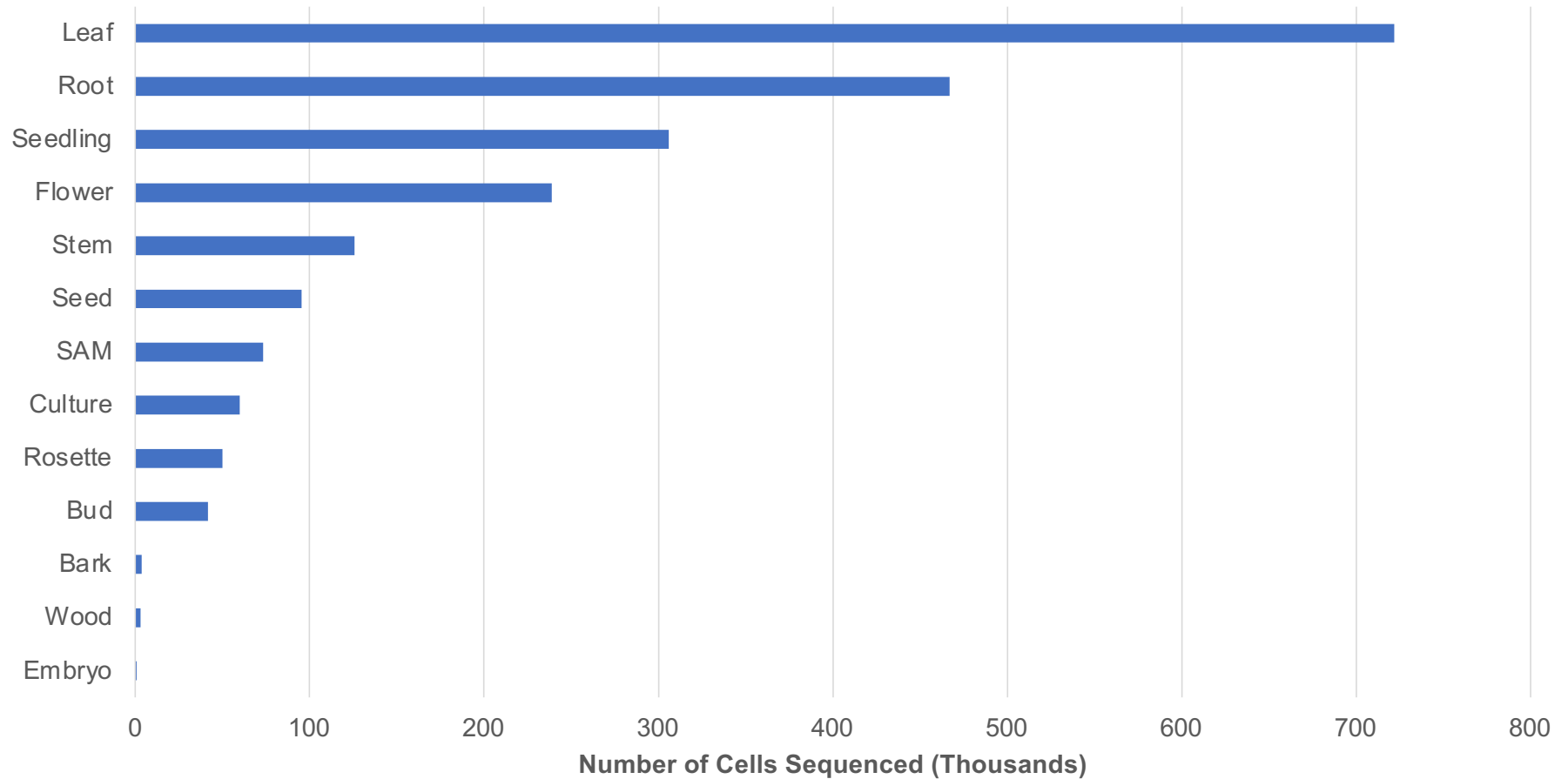


Plant Cell Consortium (2021) eLife

The Programmable Plant



Current state of single cell transcriptomics in plants



Published Data Curated by Ben Cole from LBNL (unpublished)

Milestones (2019-2023)

Workshops & Conferences

- 8 technical workshops
- 2 virtual symposia
- 2 organizational meetings
- 1 Gordon conference

Papers

- 4 roadmap papers
- 2 standards papers
- 2 meeting reports
- 18 focus issue papers

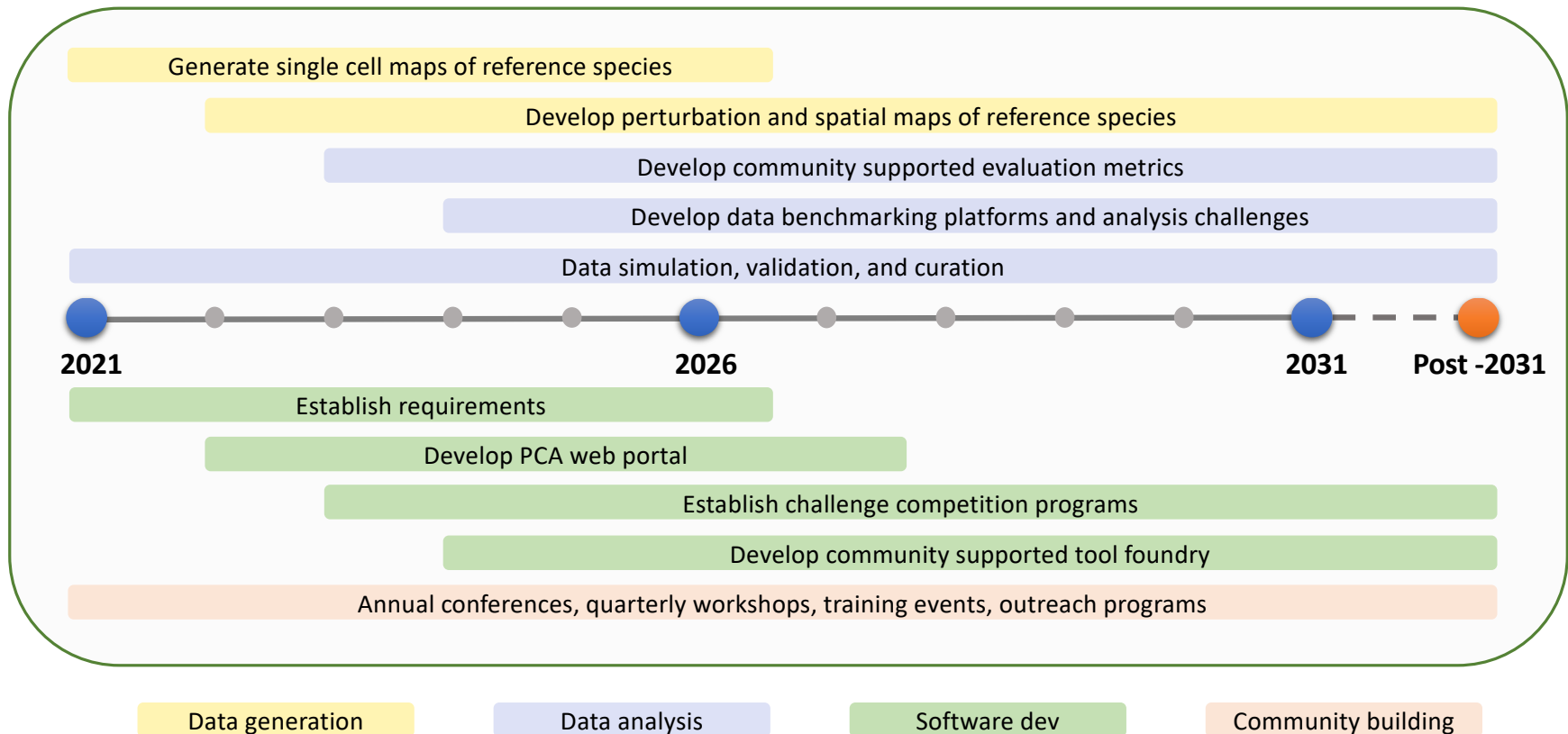
Training programs

- Academic career panel
- Writing accountability group
- International mentorship program

Outreach

- PCA website
- 7 art and science exhibits
- 6 booths at conferences
- 6 newsletters
- 2 annual reports

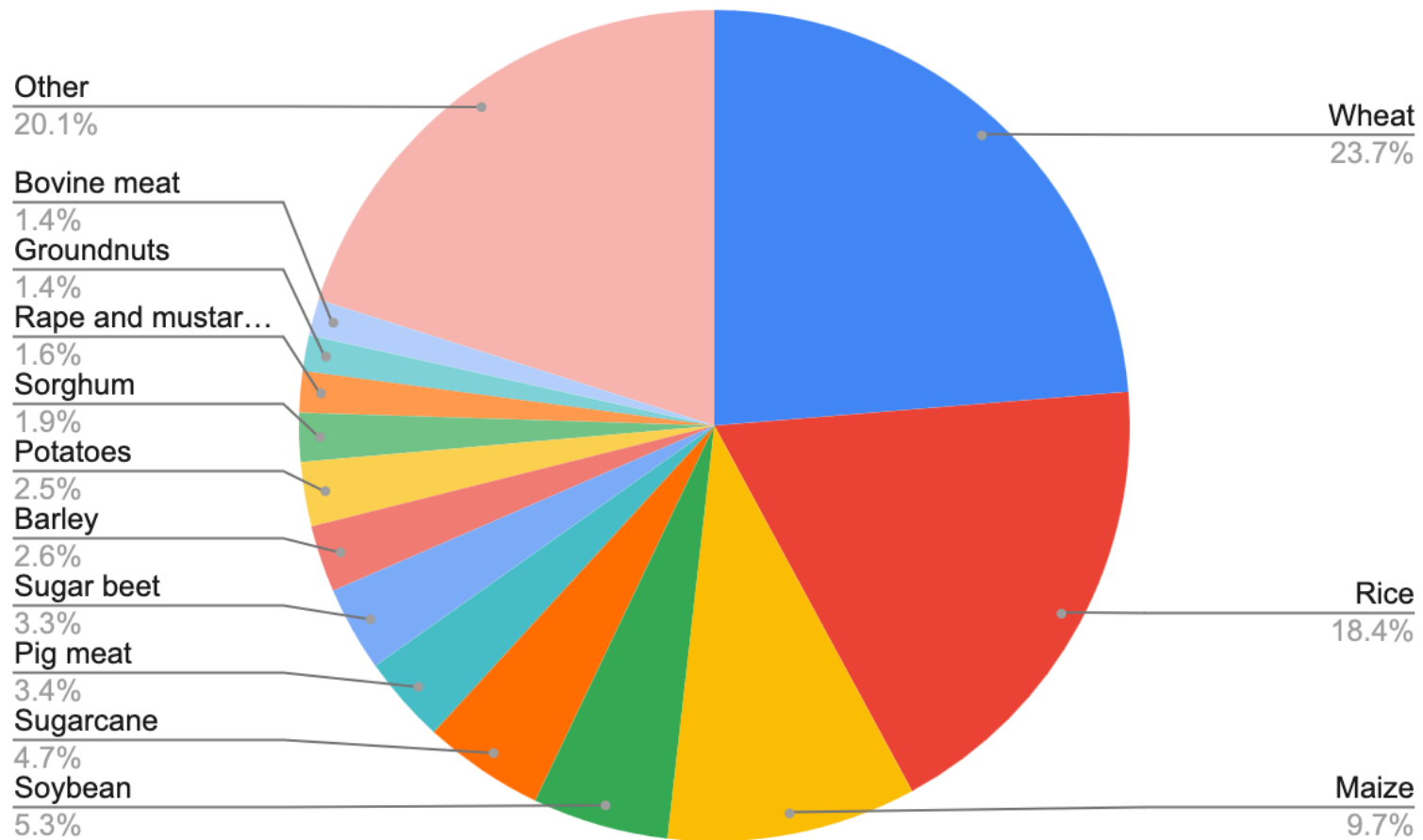
PCA Projected Milestones Timeline



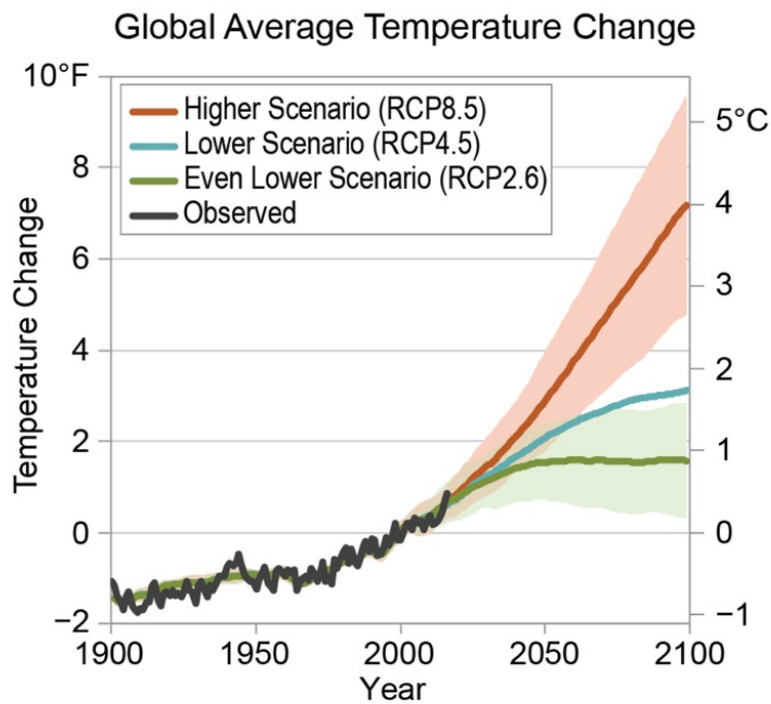
What technologies do we need?

- Single cell sequencing
- High content, high-throughput imaging
- Single cell proteomics
- Spatial omics
- Automated annotation
- High-performance computing
- Data visualization
- Integrative technologies

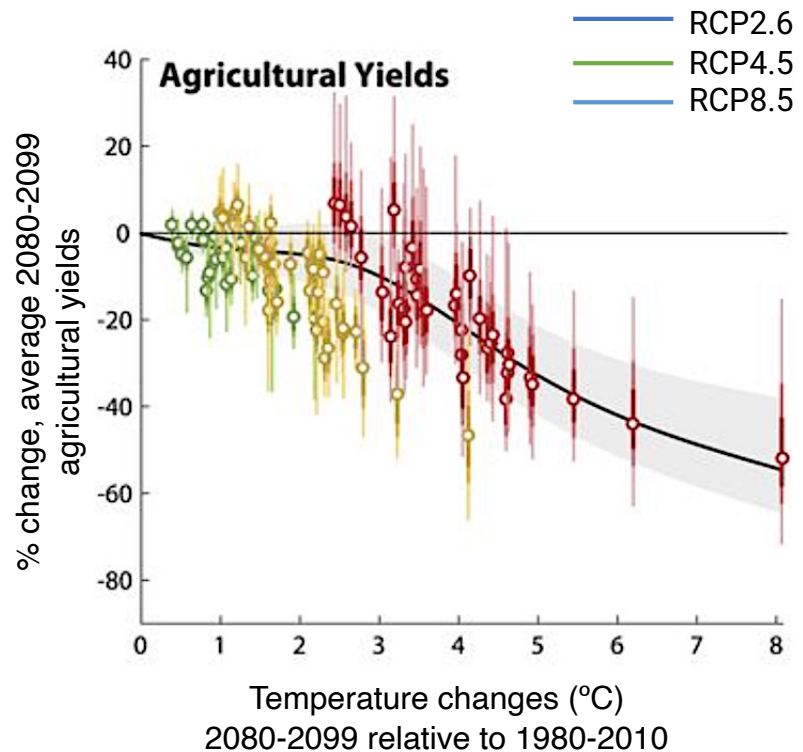
Half of our calorie intake comes from only 3 plants



Projected changes in global average temperature and its impacts on crop yield



<https://nca2018.globalchange.gov/>



DOI: 10.1126/science.aal4369