Information Visualization Meets Biology: Models and Methods for Collaboration

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www.cs.ubc.ca/~tmm/talks.html#clayton17

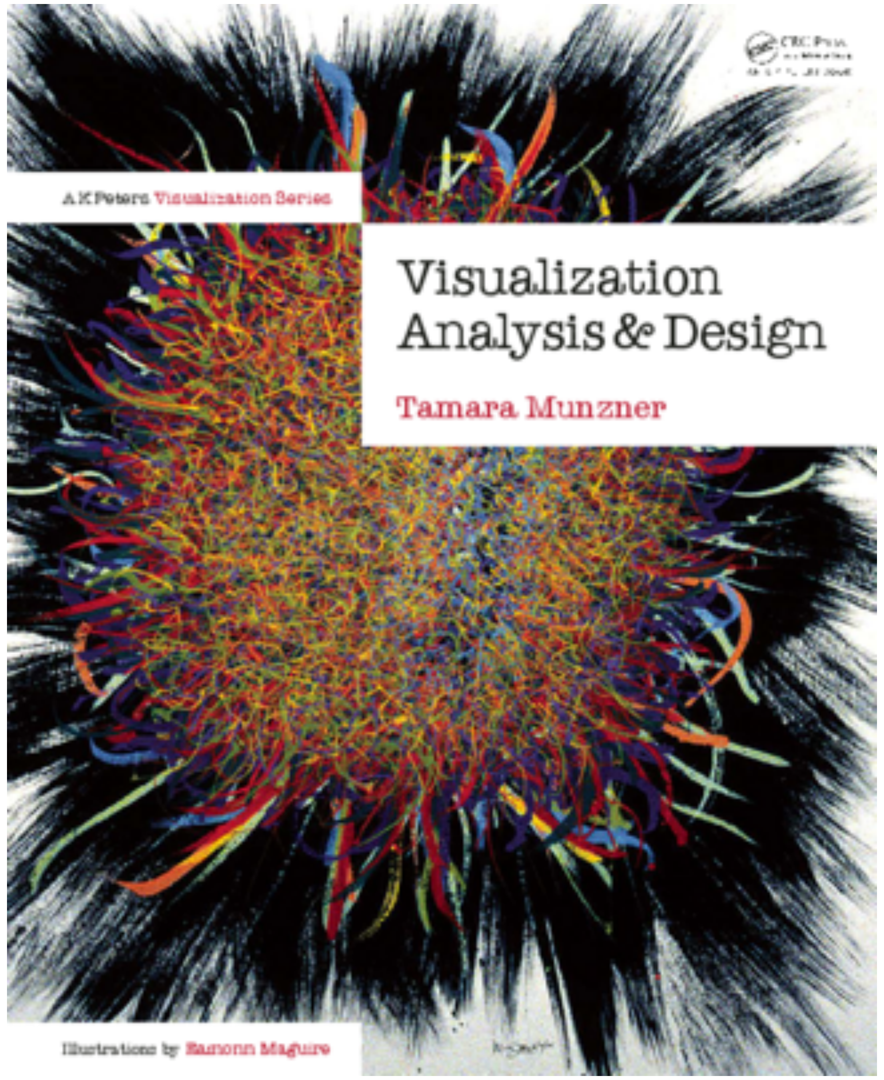
@tamaramunzner

Visualization (vis) defined & motivated

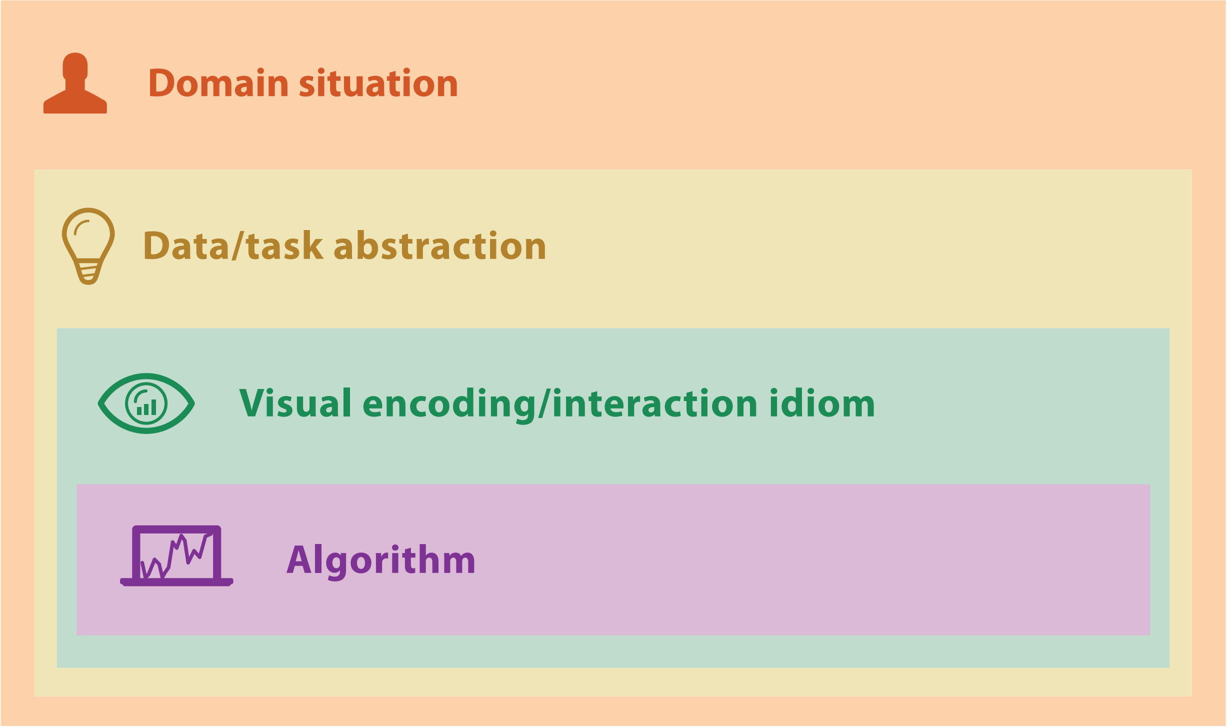
Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively.

Visualization is suitable when there is a need to augment human capabilities rather than replace people with computational decision-making methods.

- human in the loop needs the details
  - doesn't know exactly what questions to ask in advance
  - longterm exploratory analysis
  - presentation of known results
  - stepping stone towards automation: refining, trustbuilding
- external representation: perception vs cognition
- intended task, measurable definitions of effectiveness



more at:
Visualization Analysis and Design, Chapter 1.
Munzner. AK Peters Visualization Series, CRC Press, 2014.



A Nested Model

for Visualization Design and Validation

http://www.cs.ubc.ca/labs/imager/tr/2009/NestedModel

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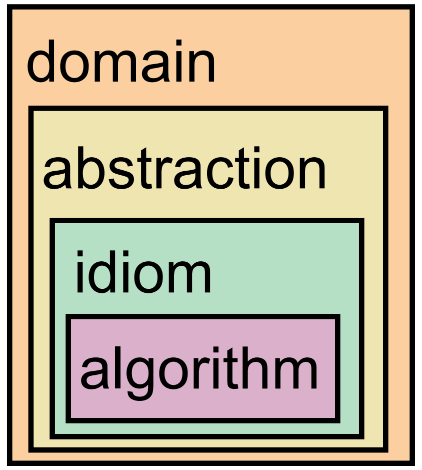
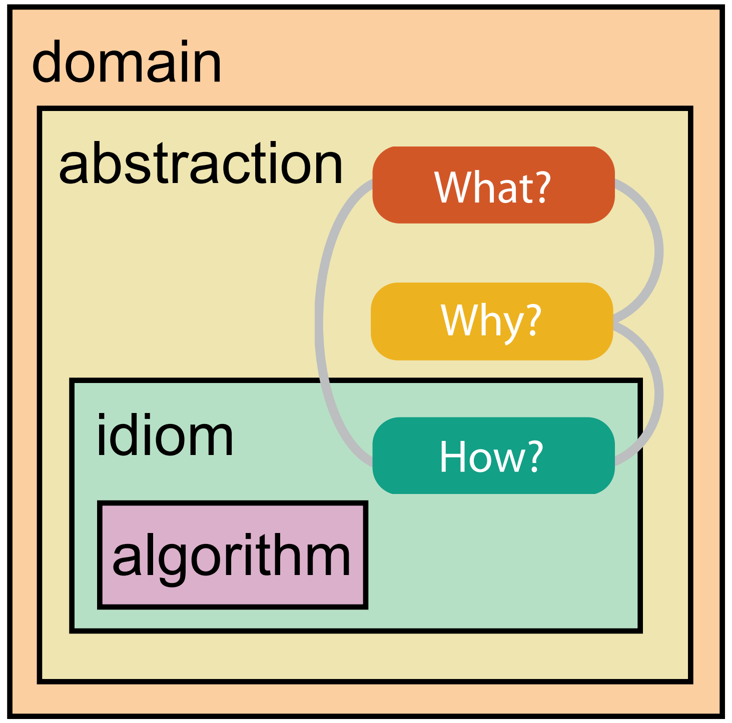
A Nested Model for Visualization Design and Validation.
Munzner. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 09), 15(6):921-928, 2009.

Vis analysis framework: Four levels, three questions

- *domain* situation
  - who are the target users? what are their needs & concerns?
- *abstraction*
  - translate from specifics of domain to vocabulary of vis
  - **what** is shown? **data abstraction**
    - often don't just draw what you're given: transform to new form
  - **why** is the user looking at it? **task abstraction**
- *idiom*
  - **how** is it shown?
    - **visual encoding idiom**: how to draw
    - **interaction idiom**: how to manipulate
- *algorithm*
  - efficient computation



[A Nested Model of Visualization Design and Validation.
Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]



[A Multi-Level Typology of Abstract Visualization Tasks
Brehmer and Munzner. IEEE TVCG 19(12):2376-2385, 2013 (Proc. InfoVis 2013).]

more at:
Visualization Analysis and Design, Ch 2/3/4. Munzner, CRC Press, 2014.

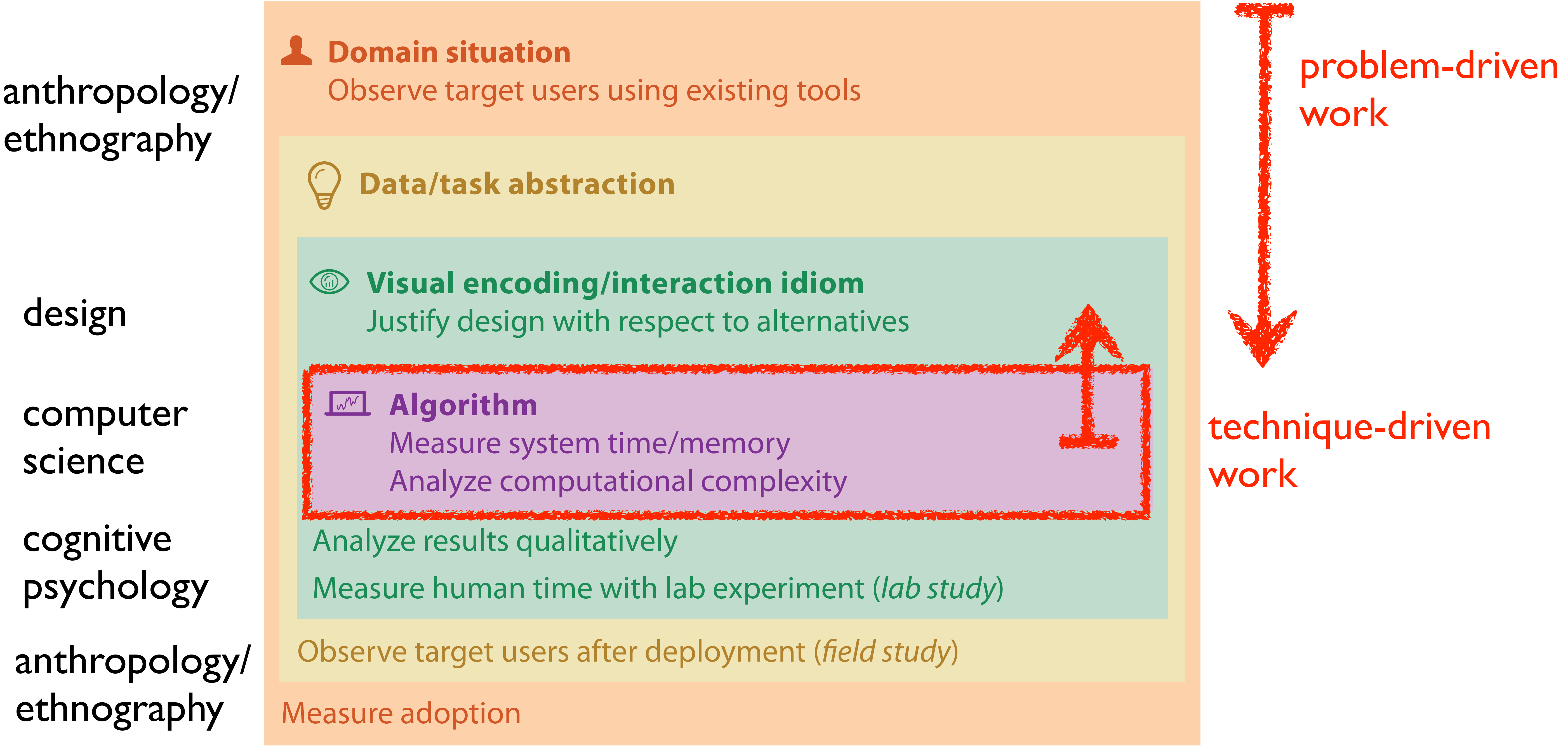
Why is validation difficult?

- different ways to get it wrong at each level

[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

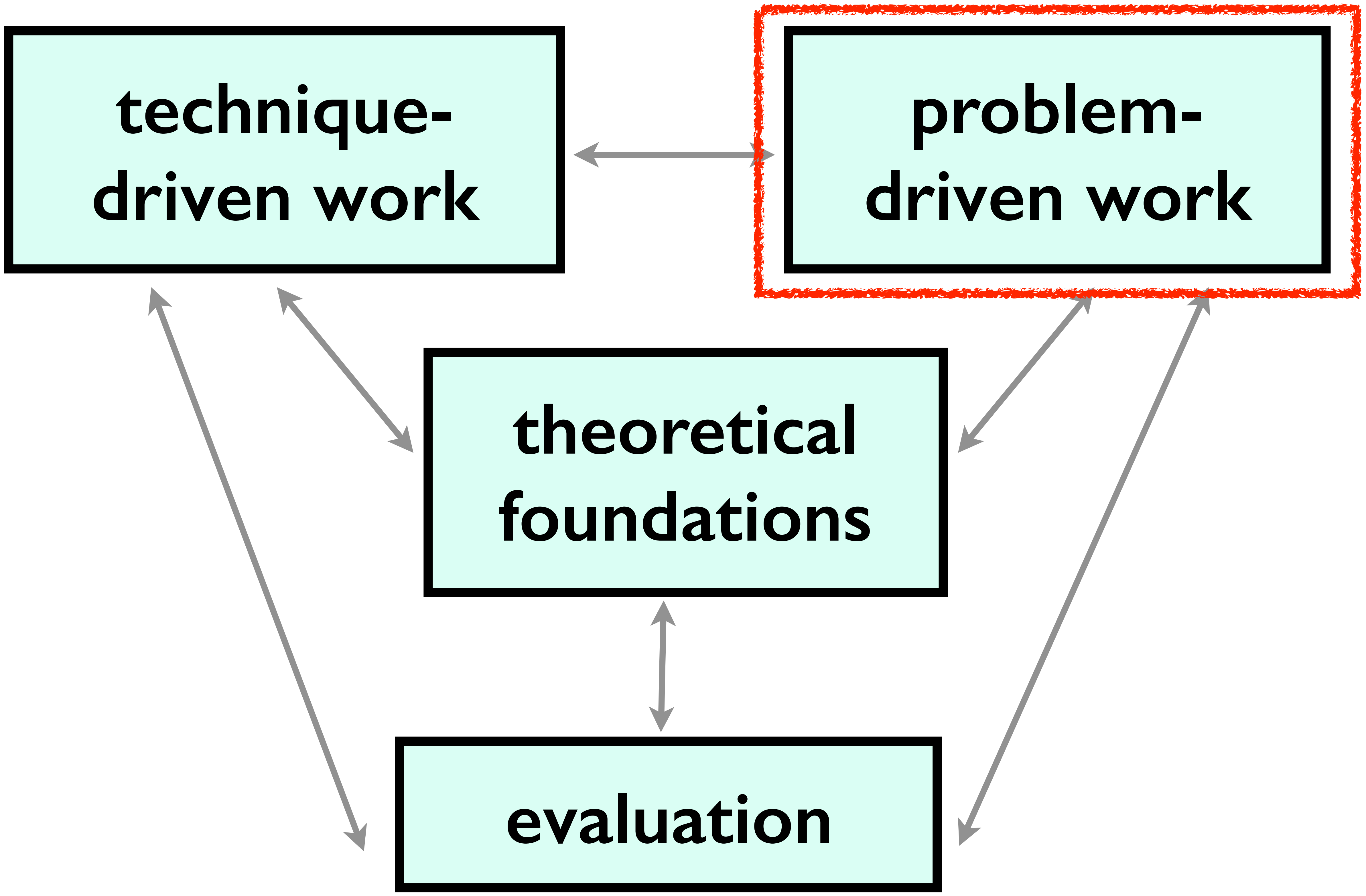
Validation solution: use methods from appropriate fields at each level

- avoid mismatches!



[A Nested Model of Visualization Design and Validation. Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Angles of attack: My own research agenda

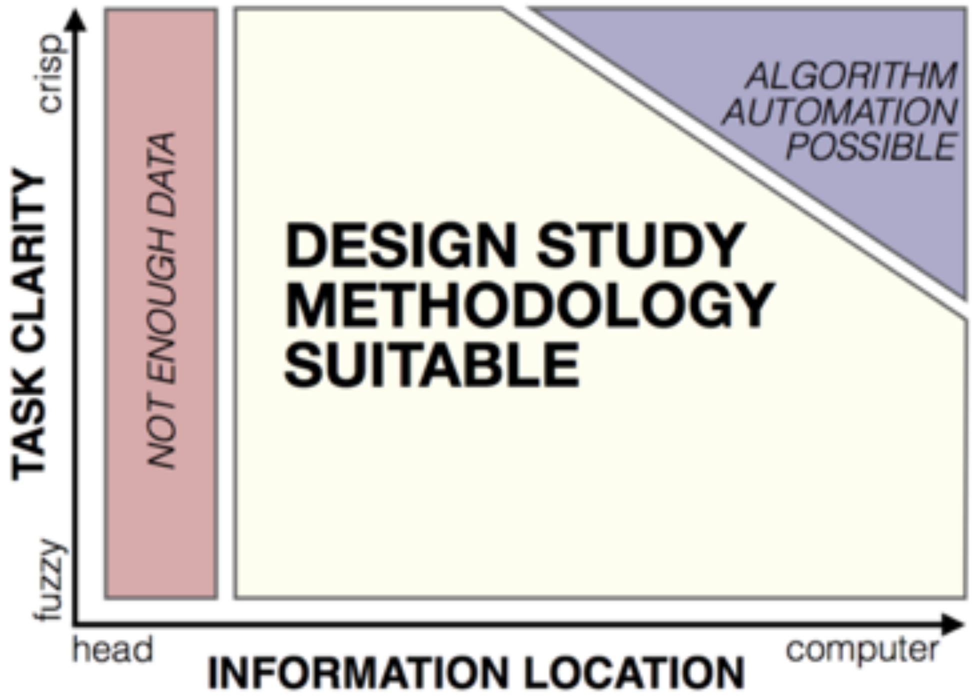


Vis meets bio

- biology encompasses many rich application domain for vis collaboration
  - challenging multi-level problems that won't be automated away any time soon
  - complex tasks, complex datasets
  - often existing infrastructure of computational workflows
    - many points where human-in-the-loop decision-making could bear fruit
- landscape of possible tools
  - axis from eureka to speedup
    - sexy use case: eureka moment
      - enable what was impossible before: vis tools for new insights & discoveries
    - workhorse use case: workflow speedup
      - vis tools to accelerate what you're already doing
      - sometimes enables the previously infeasible
  - axis from targeted to address specific pain points, to general purpose for broad use

Collaboration incentives: Bidirectional

- what's in it for bio?
  - bio win: access to more suitable tools, can do better/faster/cheaper science
  - time spent could pay off with earlier access and/or more customized tools
- what's in it for vis?
  - vis win: access to better understanding of your driving problems
    - crucial element in building effective tools to help
  - opportunities to observe how you use them
    - if they're good enough, vis win: research success stories
  - leads us to develop guidelines on how to build better tools in general
    - vis win: research progress in visualization
    - [The Computer Scientist as Toolsmith II, Fred Brooks, CACM 30(3):61-68 1996]



Michael Sedlmair

Miriah Meyer

Design Study Methodology

Reflections from the Trenches and from the Stacks

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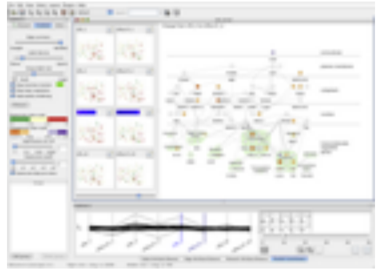
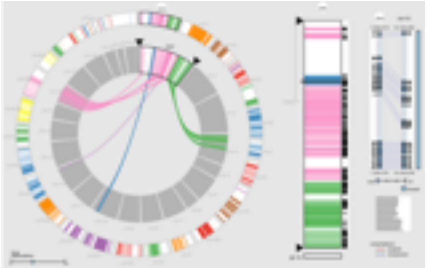
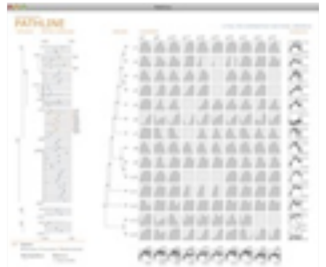
http://www.cs.ubc.ca/labs/imager/tr/2012/dsm/

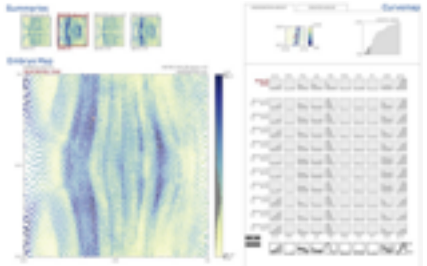
Design Study Methodology: Reflections from the Trenches and from the Stacks.
Sedlmair, Meyer, Munzner. IEEE Trans. Visualization and Computer Graphics 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).

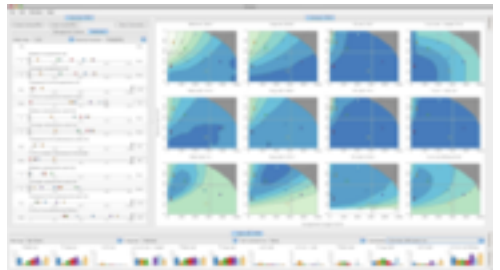
Design Studies: Lessons learned after 21 of them

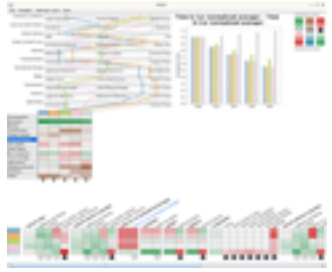

Cerebral
genomics


MizBee
genomics


Pathline
genomics

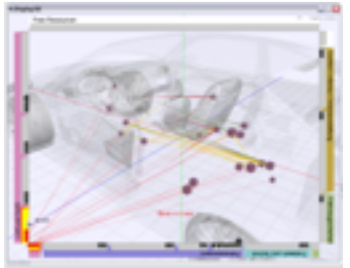

MulteeSum
genomics


Vismon
fisheries management


QuestVis
sustainability


WiKeVis
in-car networks


MostVis
in-car networks


Car-X-Ray
in-car networks


ProgSpy2010
in-car networks

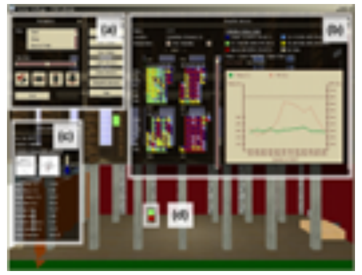

RelEx
in-car networks

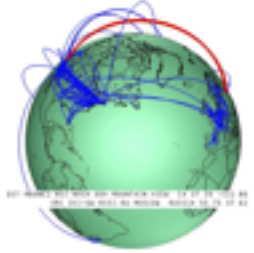

Cardiogram
in-car networks

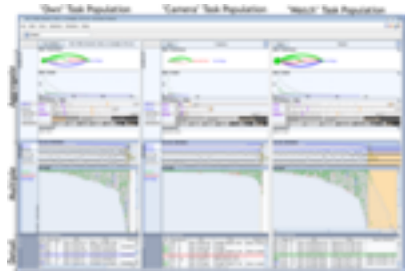

AutobahnVis
in-car networks

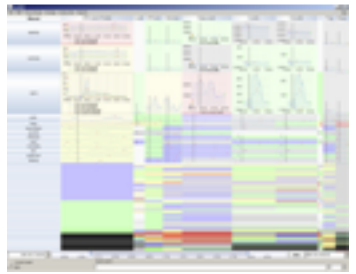

VisTra
in-car networks

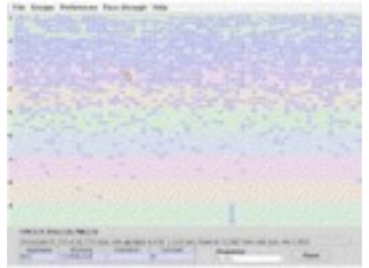

Constellation
linguistics

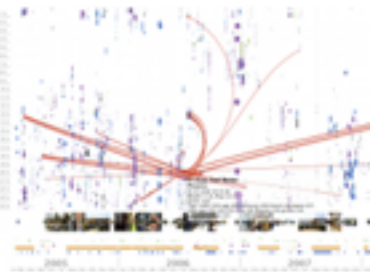

LibVis
cultural heritage


Caidants
multicast


SessionViewer
web log analysis


LiveRAC
server hosting

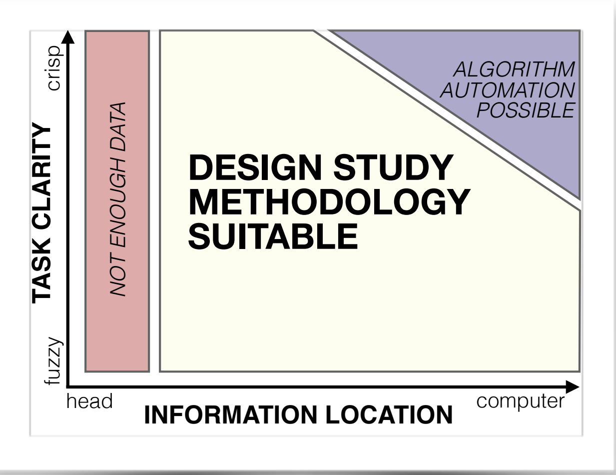

PowerSetViewer
data mining


LastHistory
music listening

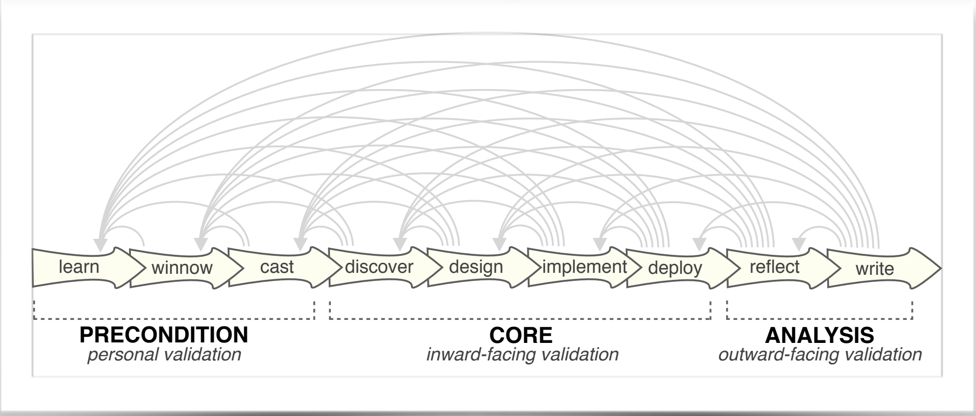
- commonality of representations cross-cuts domains!

Methodology for problem-driven work

- definitions



- 9-stage framework



- 32 pitfalls & how to avoid them

PF-1	premature advance: jumping forward over stages	general
PF-2	premature start: insufficient knowledge of vis literature	learn
PF-3	premature commitment: collaboration with wrong people	winnow
PF-4	no real data available (yet)	winnow
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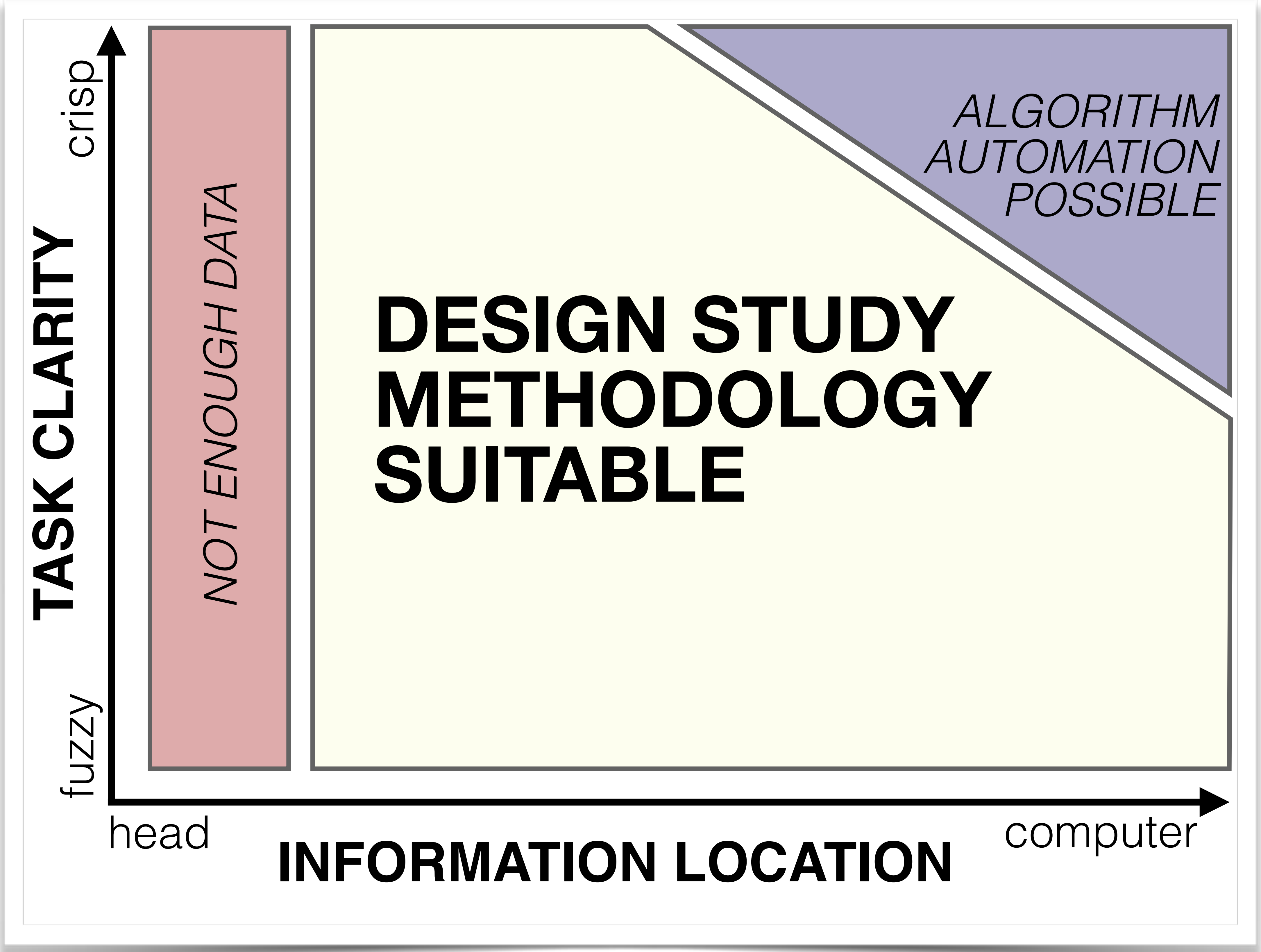
PF-9	no need for change: existing tools are good enough	winnow

- comparison to related methodologies

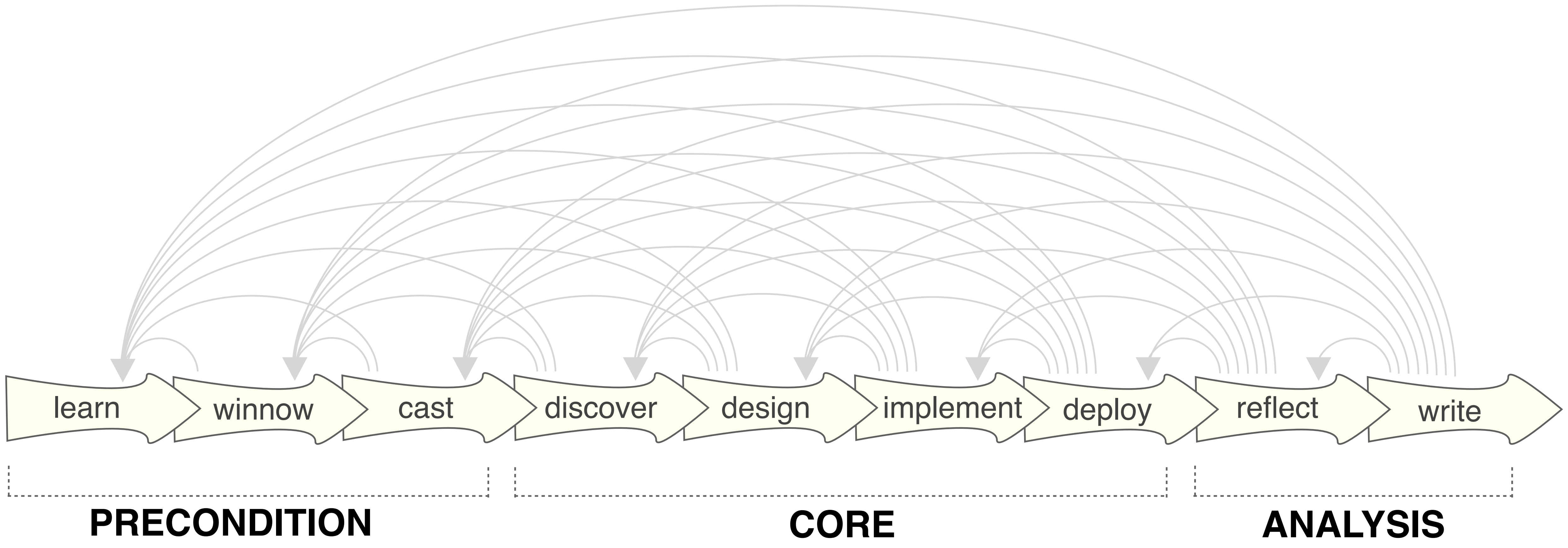
Design study methodology: definitions

- design studies: problem-driven work
  - in collaboration with target users
    - real data, real tasks
    - intensive requirements analysis
  - iterative refinement
    - rapid prototyping
    - deploy tools/systems to target users
  - typical evaluation: field studies
    - case studies provide evidence of utility for target users
      - replicate known results quickly/easily: show workflow speedup
      - examples of new results found using tool

Design study methodology: definitions



9 stage framework

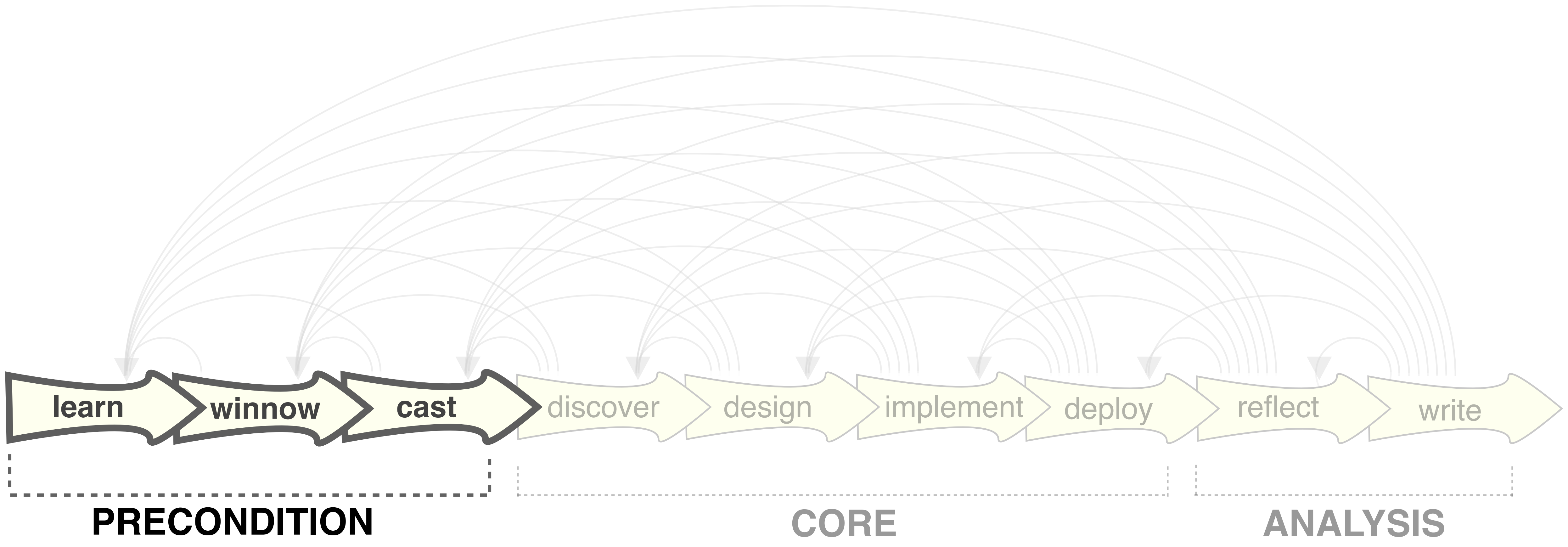


9-stage framework

learn

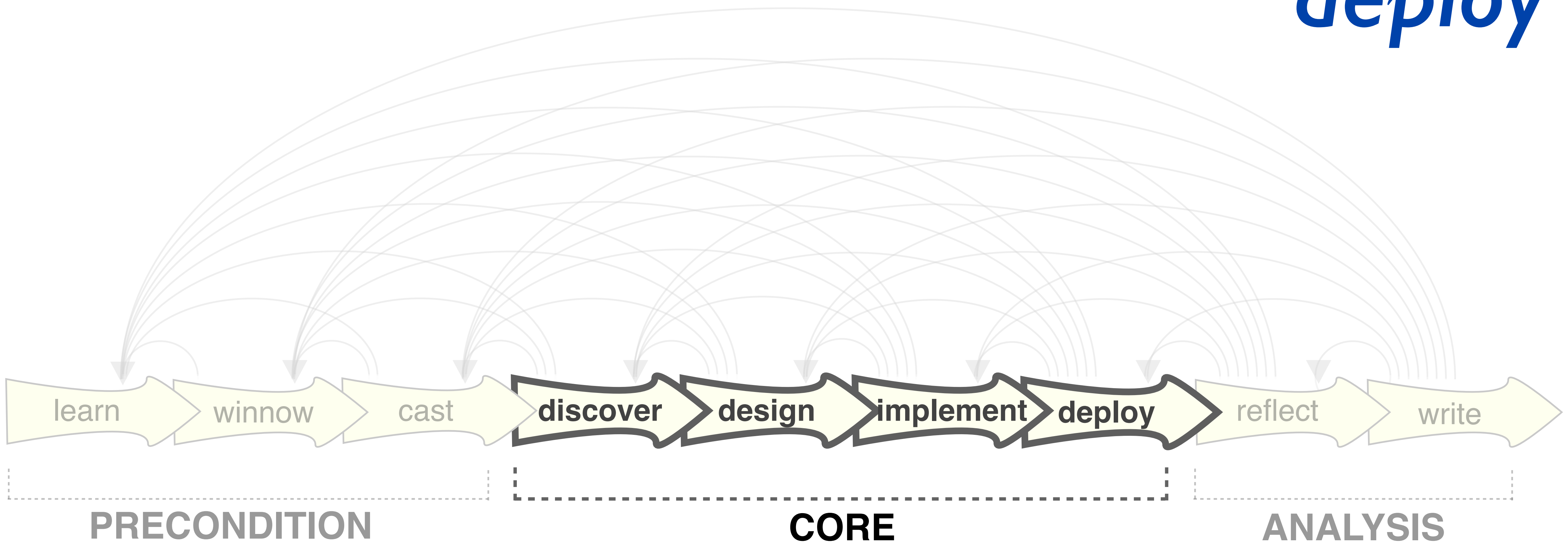
winnow

cast



9-stage framework

discover
design
implement
deploy

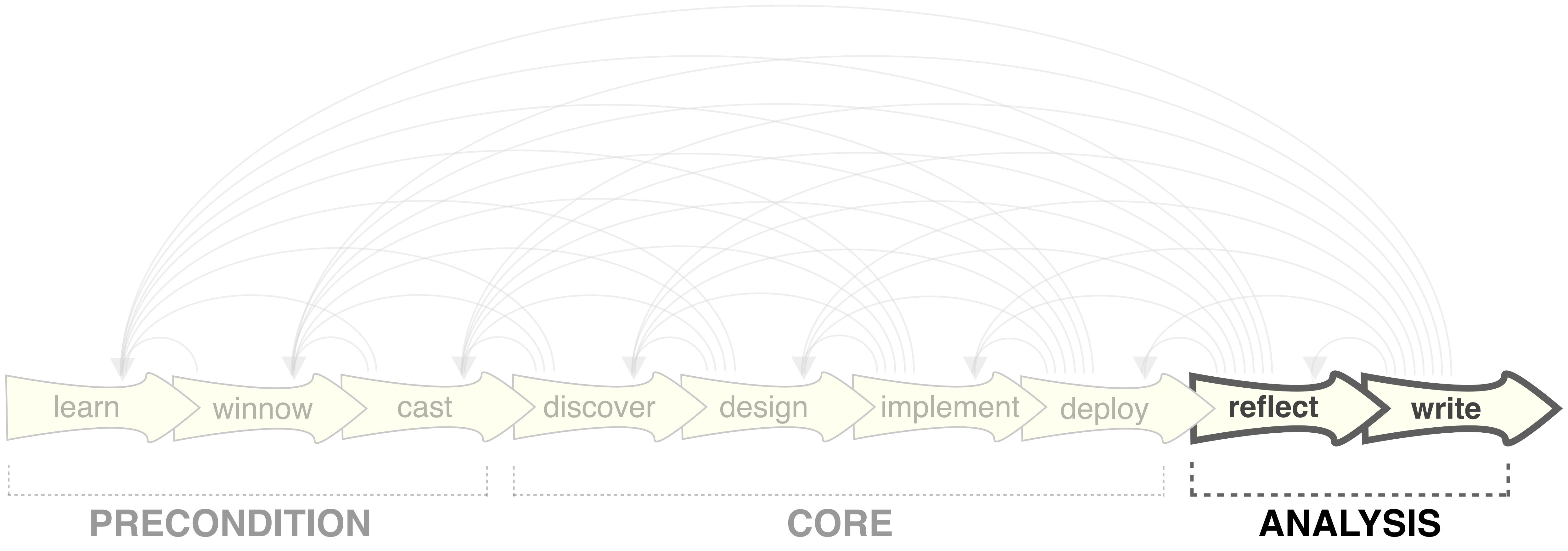


9-stage framework

reflect

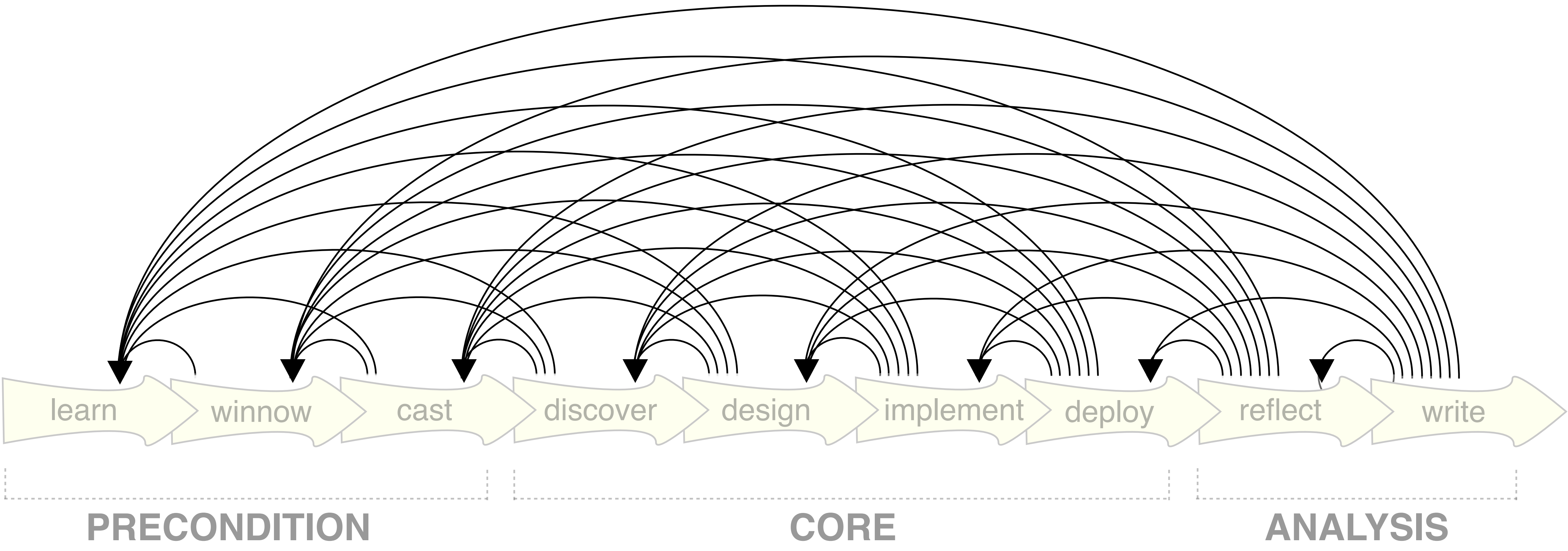
write

- guidelines: confirm, refine, reject, propose



9-stage framework

iterative



Design study methodology: 32 pitfalls

- and how to avoid them

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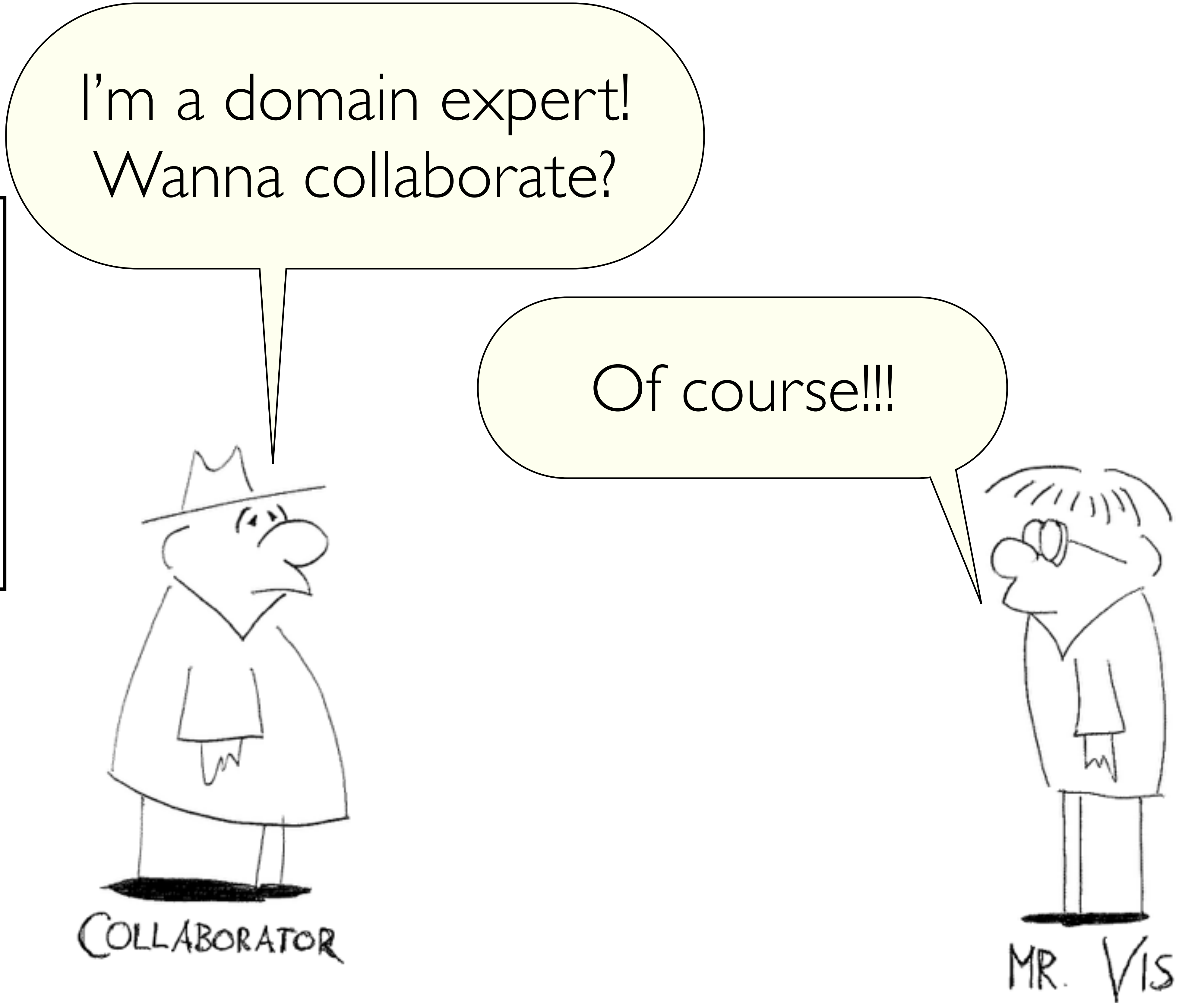
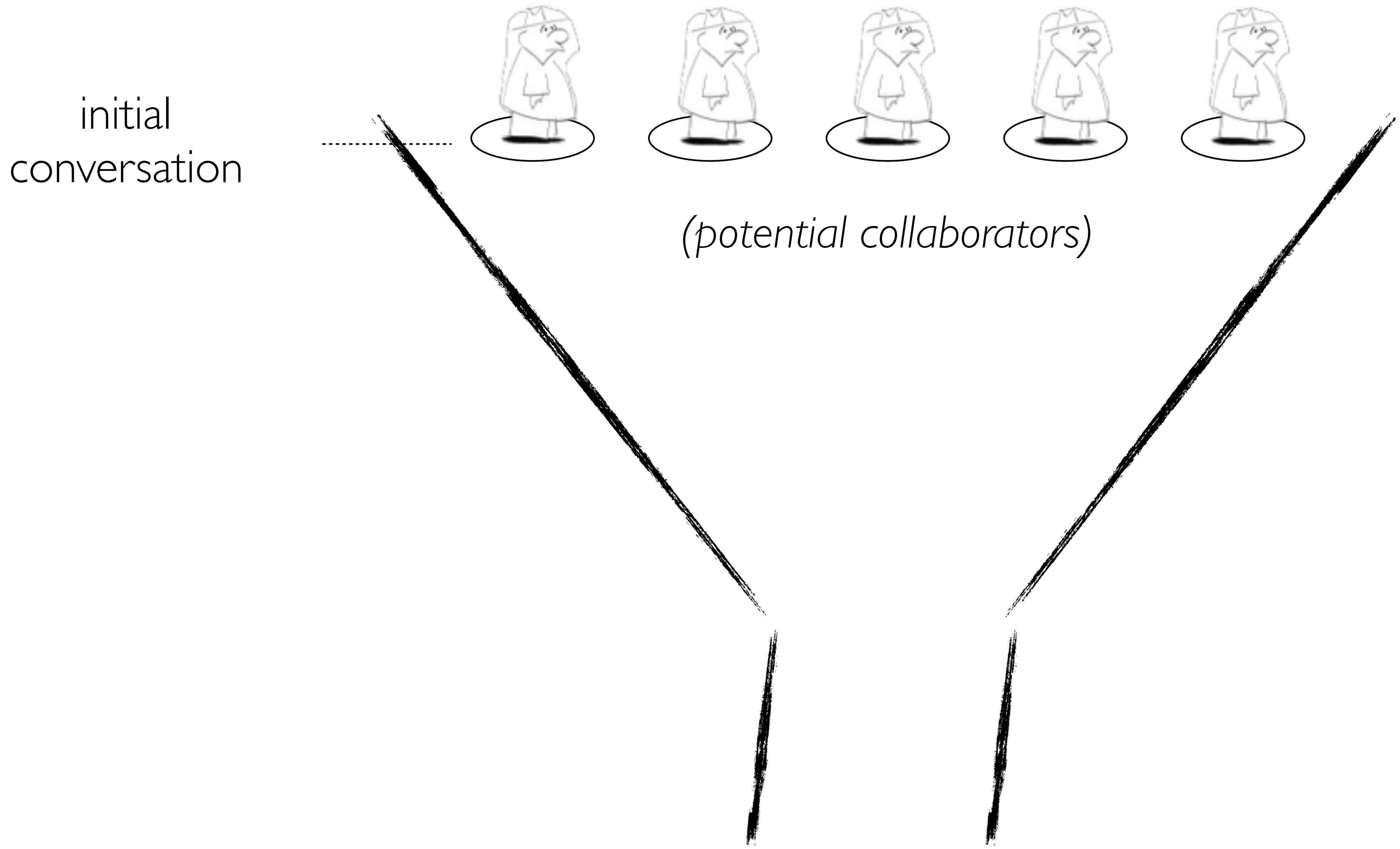
Pitfall

Premature Collaboration Commitment

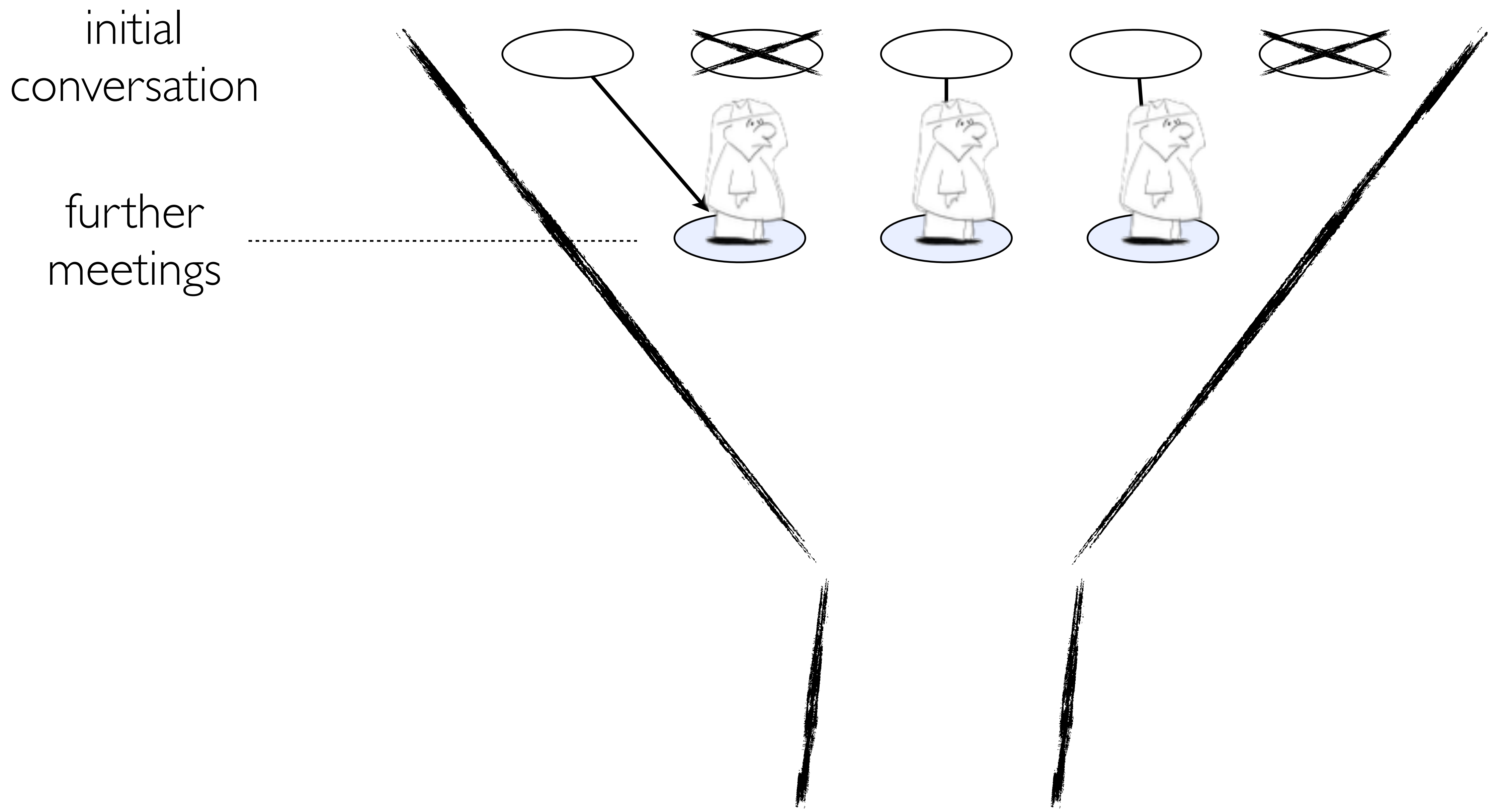


METAPHOR
Winnowing

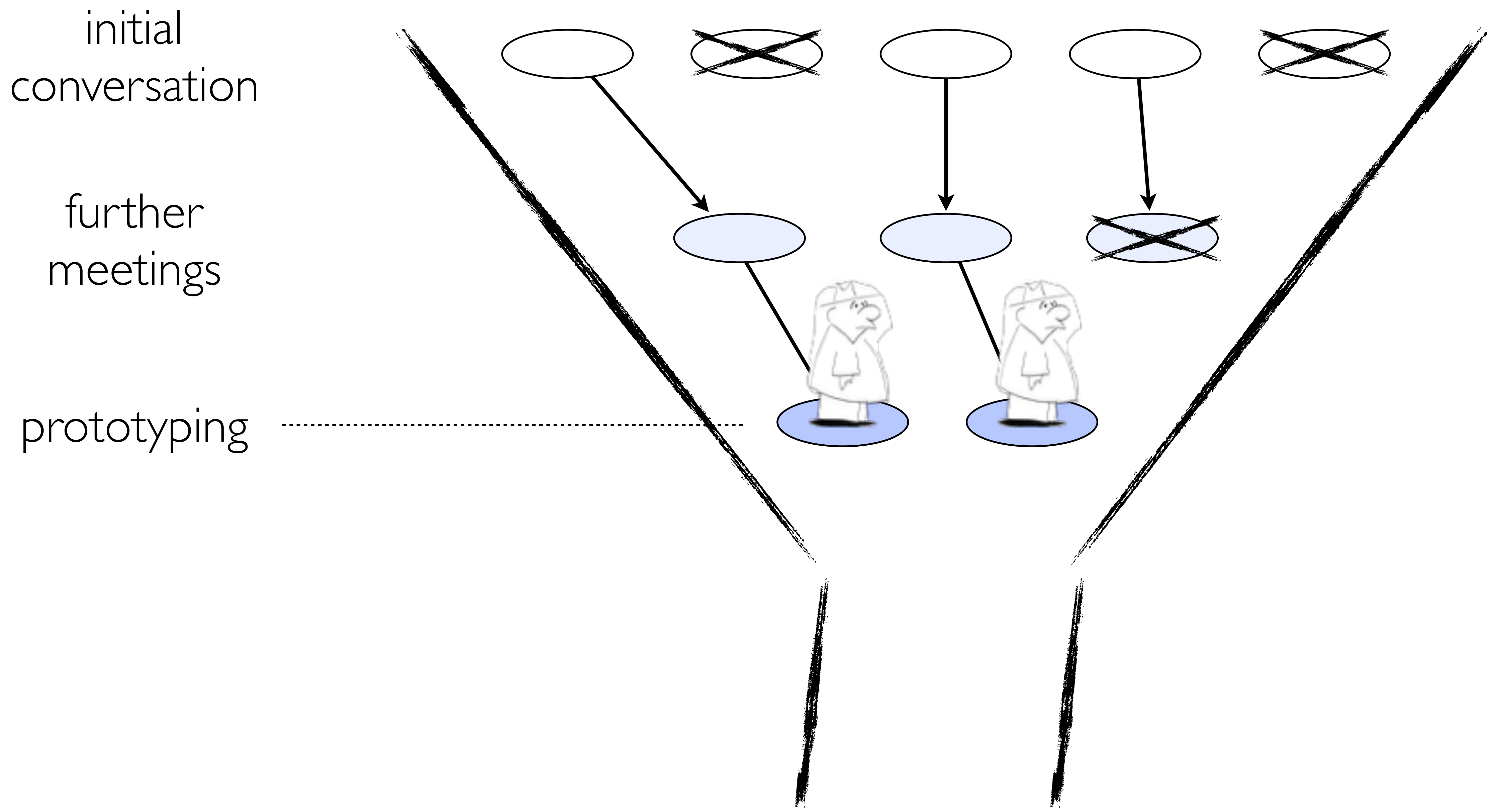
Collaborator winnowing



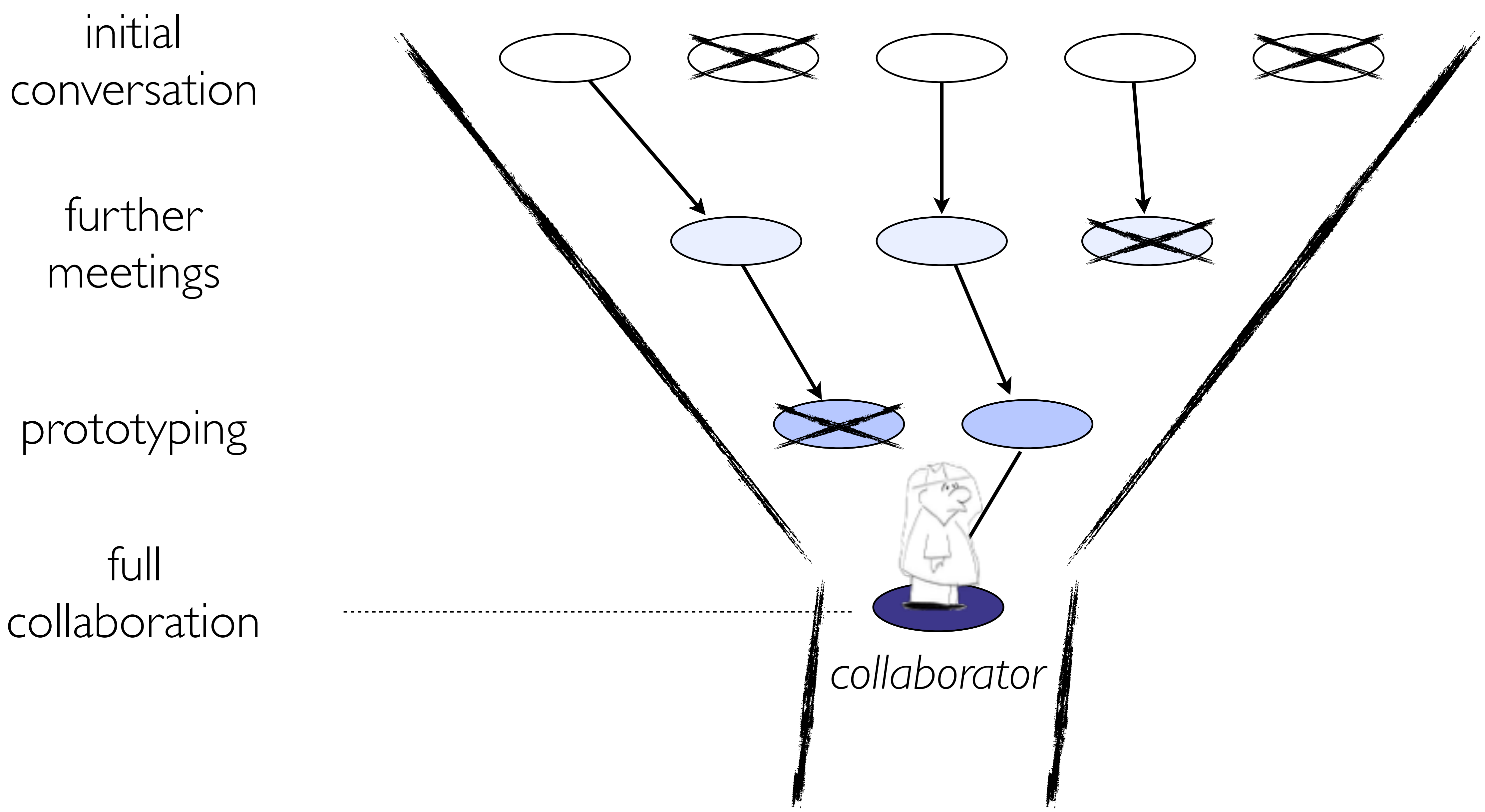
Collaborator winnowing



Collaborator winnowing



Collaborator winnowing



Collaborator winnowing

**Talk with many,
stay with few!**

Design study methodology: 32 pitfalls

- and how to avoid them

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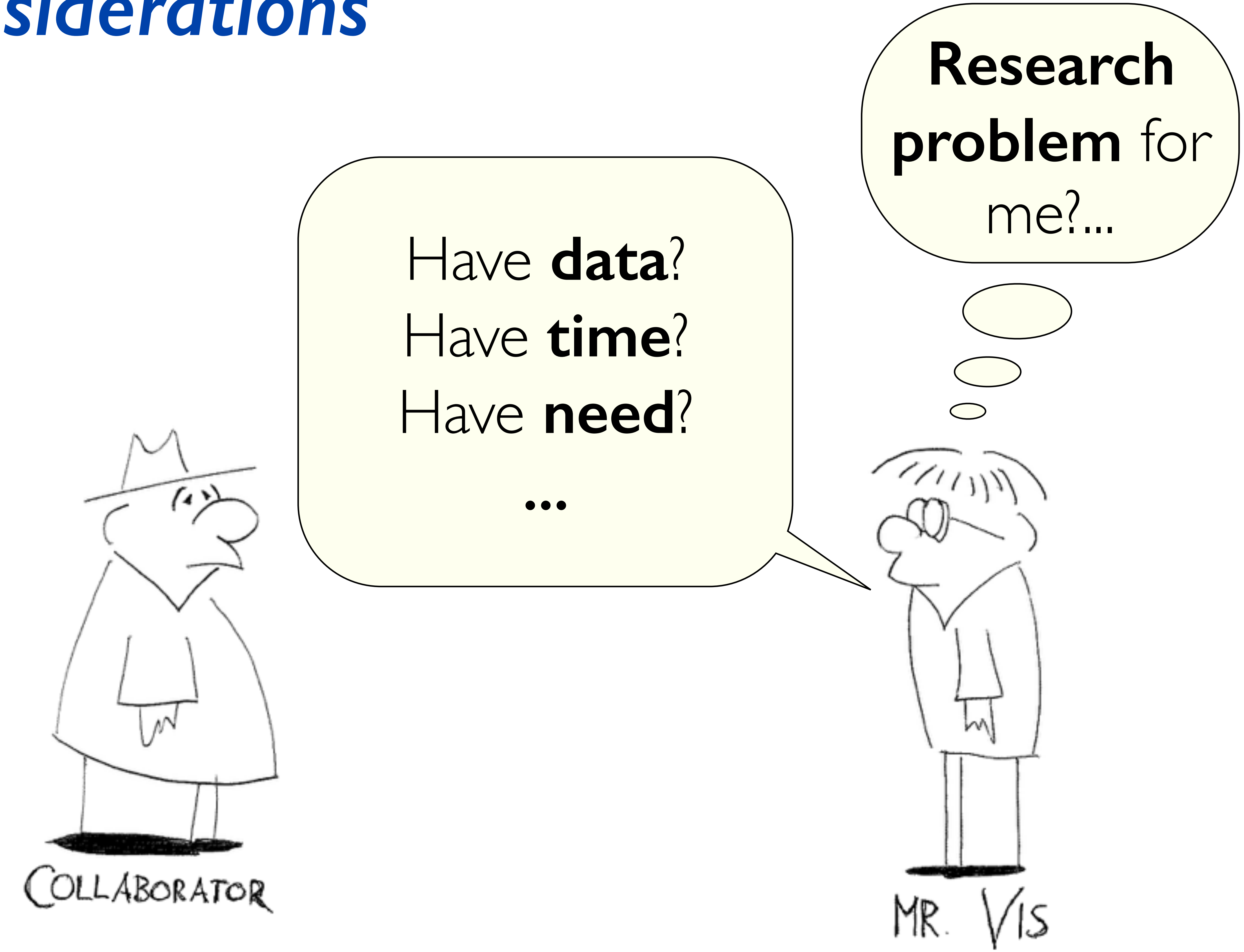
considerations



Design study methodology: 32 pitfalls

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PF-11	no rapport with collaborators	winnow
PF-12	not identifying front line analyst and gatekeeper before start	cast
PF-13	assuming every project will have the same role distribution	cast
PF-14	mistaking fellow tool builders for real end users	cast
PF-15	ignoring practices that currently work well	discover
PF-16	expecting *just talking* or *fly on wall* to work	discover
PF-17	experts focusing on visualization design vs. domain problem	discover
PF-18	learning their problems/language: too little / too much	discover
PF-19	abstraction: too little	design
PF-20	premature design commitment: consideration space too small	design

roles

biologist

Are you a **user**???

bioinformatician

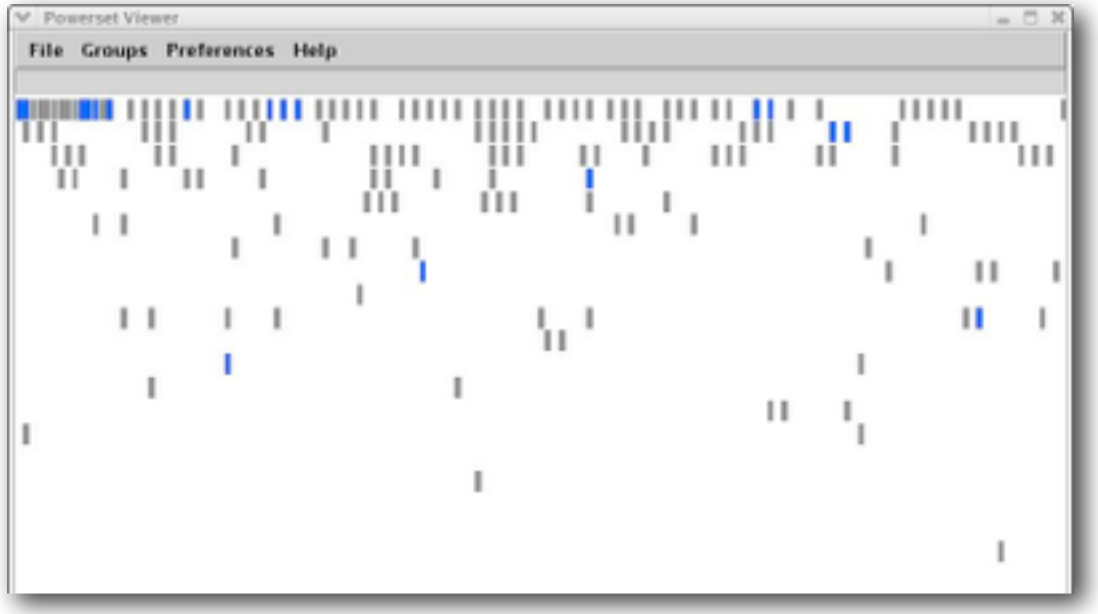
... or maybe a **fellow tool builder**?

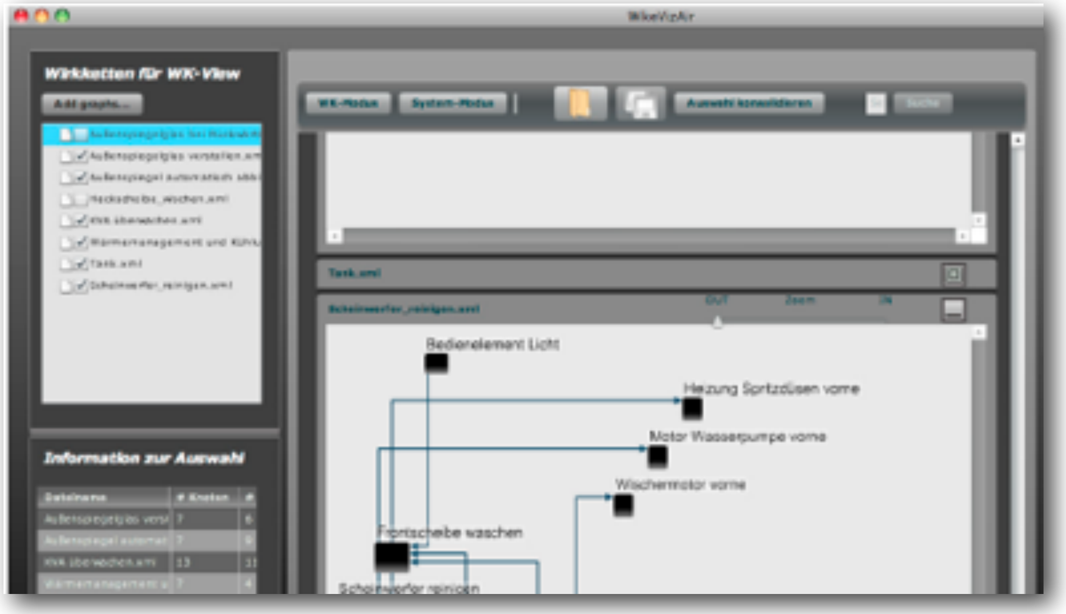
Examples from the trenches

- premature collaboration
- fellow tool builders with inaccurate assumptions about user needs
- data unavailable early so didn’t diagnose problems

PowerSet Viewer
2 years / 4 researchers

WikeVis
0.5 years / 2 researchers





Design study methodology: 32 pitfalls

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PITFALL

PREMATURE DESIGN COMMITMENT

I want a tool with that **cool technique** I saw the other day!

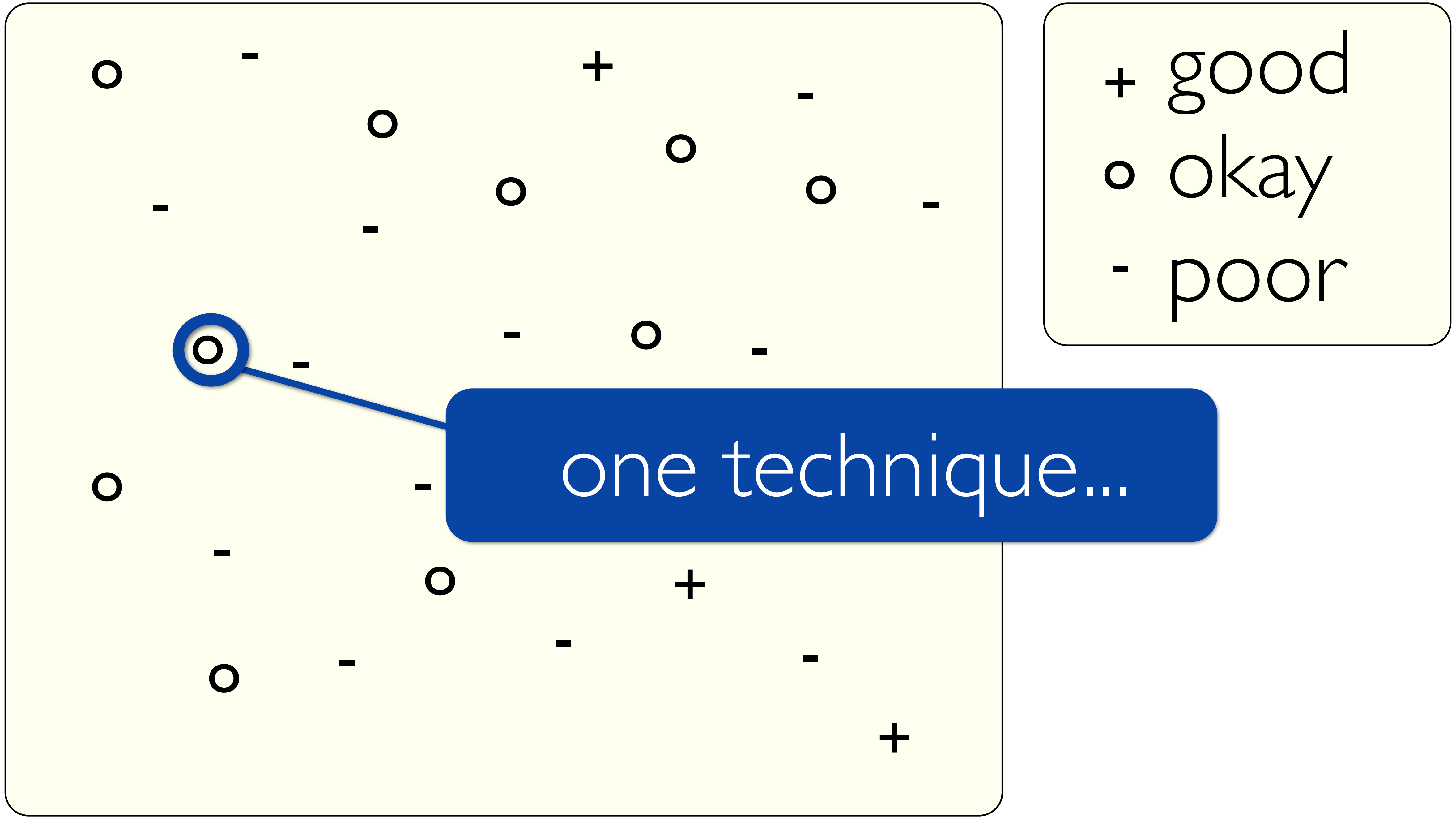
PITFALL

PREMATURE DESIGN COMMITMENT

Of course they need the **cool technique** I built last year!

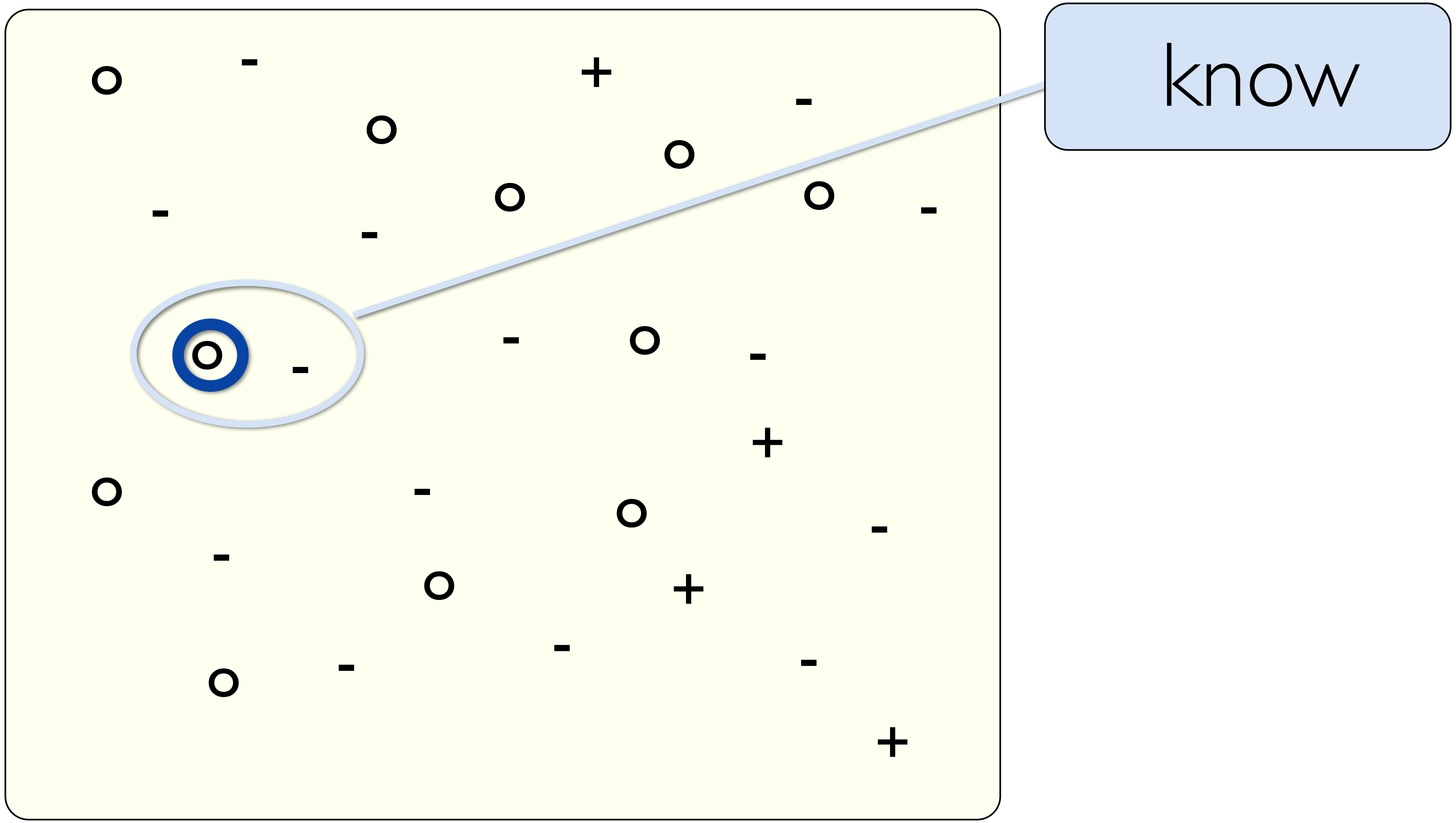
Metaphor

Design Space



METAPHOR

Design Space



small scope

Design study methodology: 32 pitfalls

- and how to avoid them

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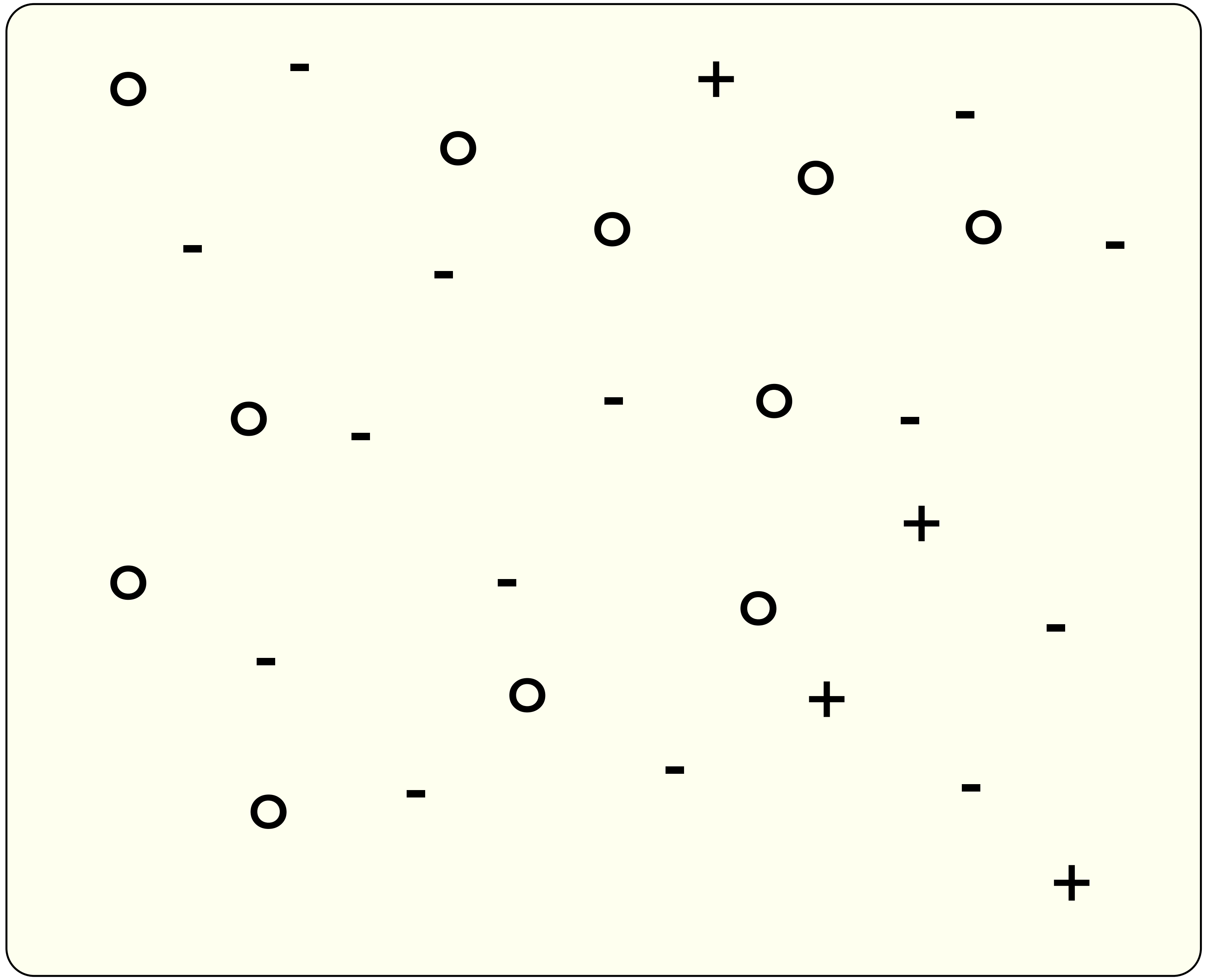
Metaphor

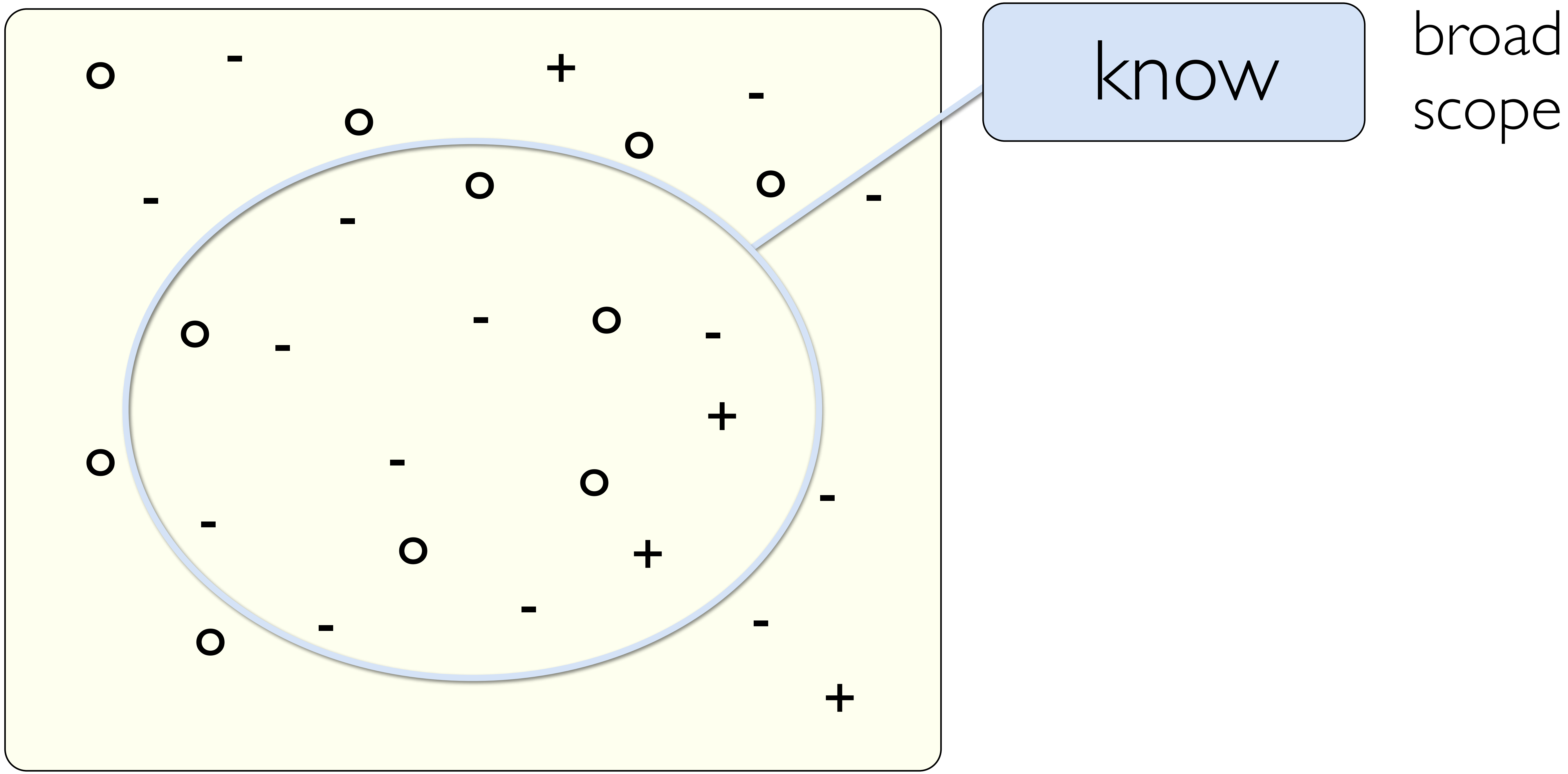
Design Space



+ good
o okay
- poor

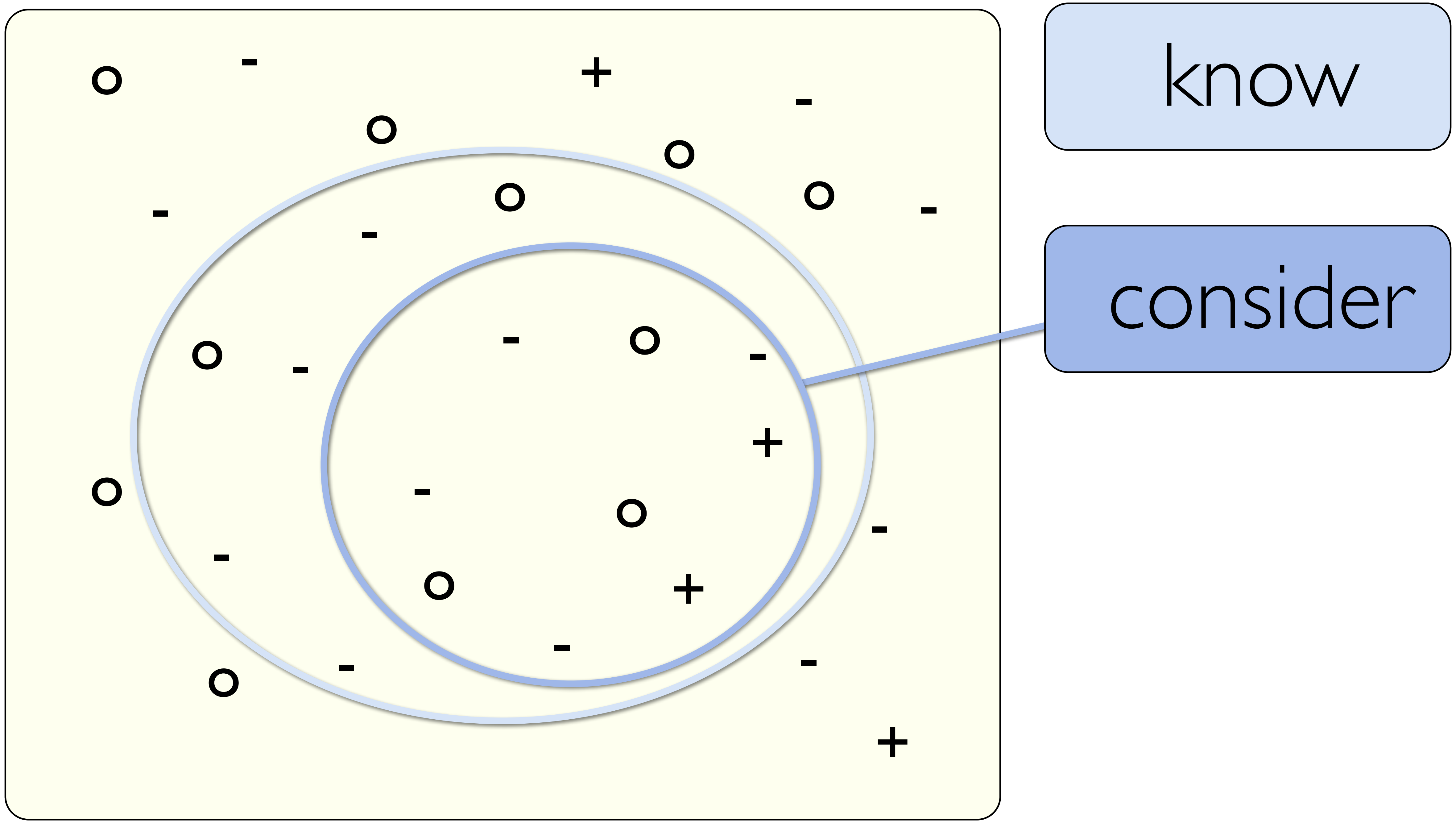
METAPHOR

Design Space



METAPHOR

Design Space



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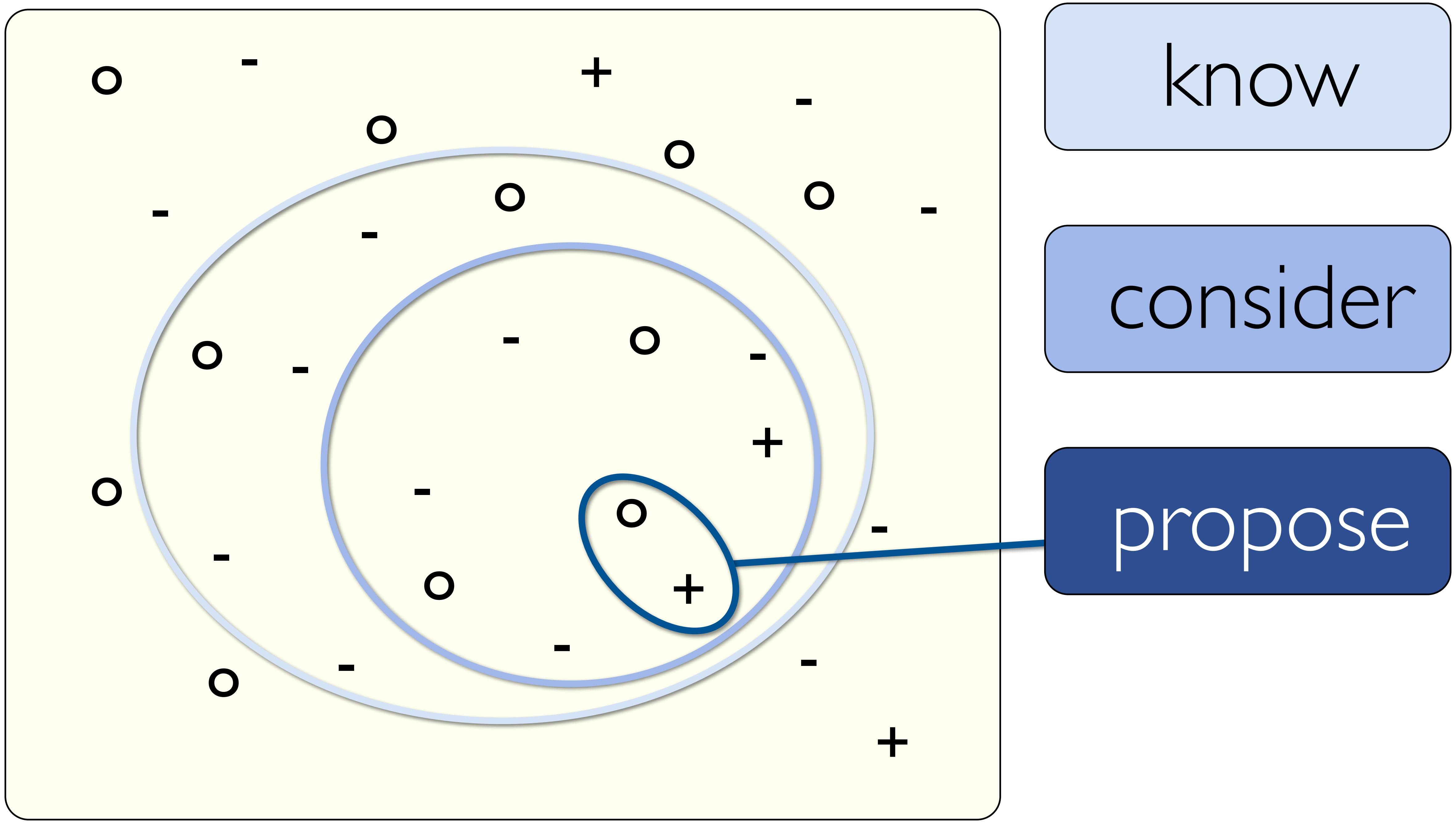
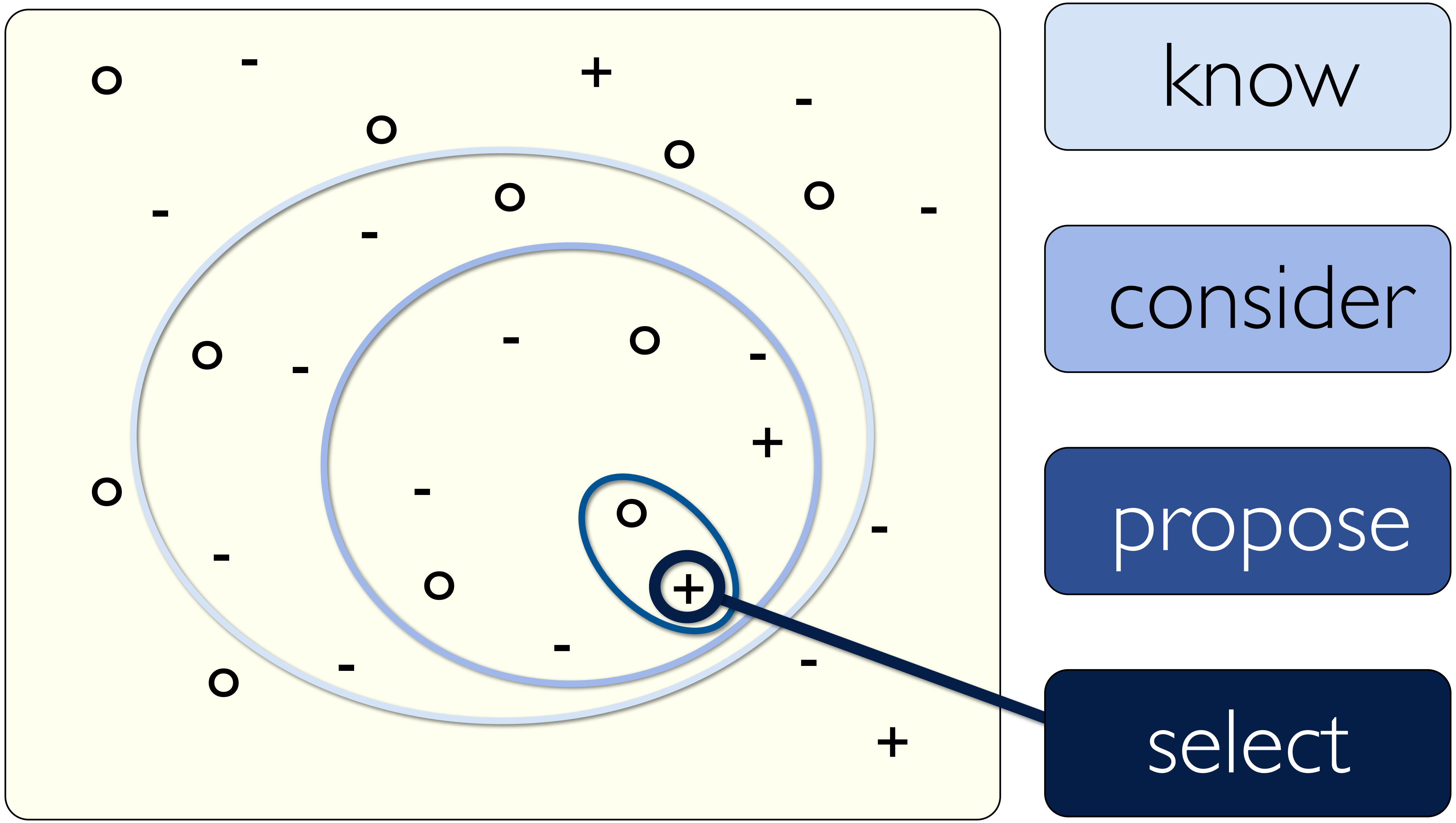
Design Space



METAPHOR

Design Space



Metaphor

Design Space

Think broad!

Design study methodology: 32 pitfalls

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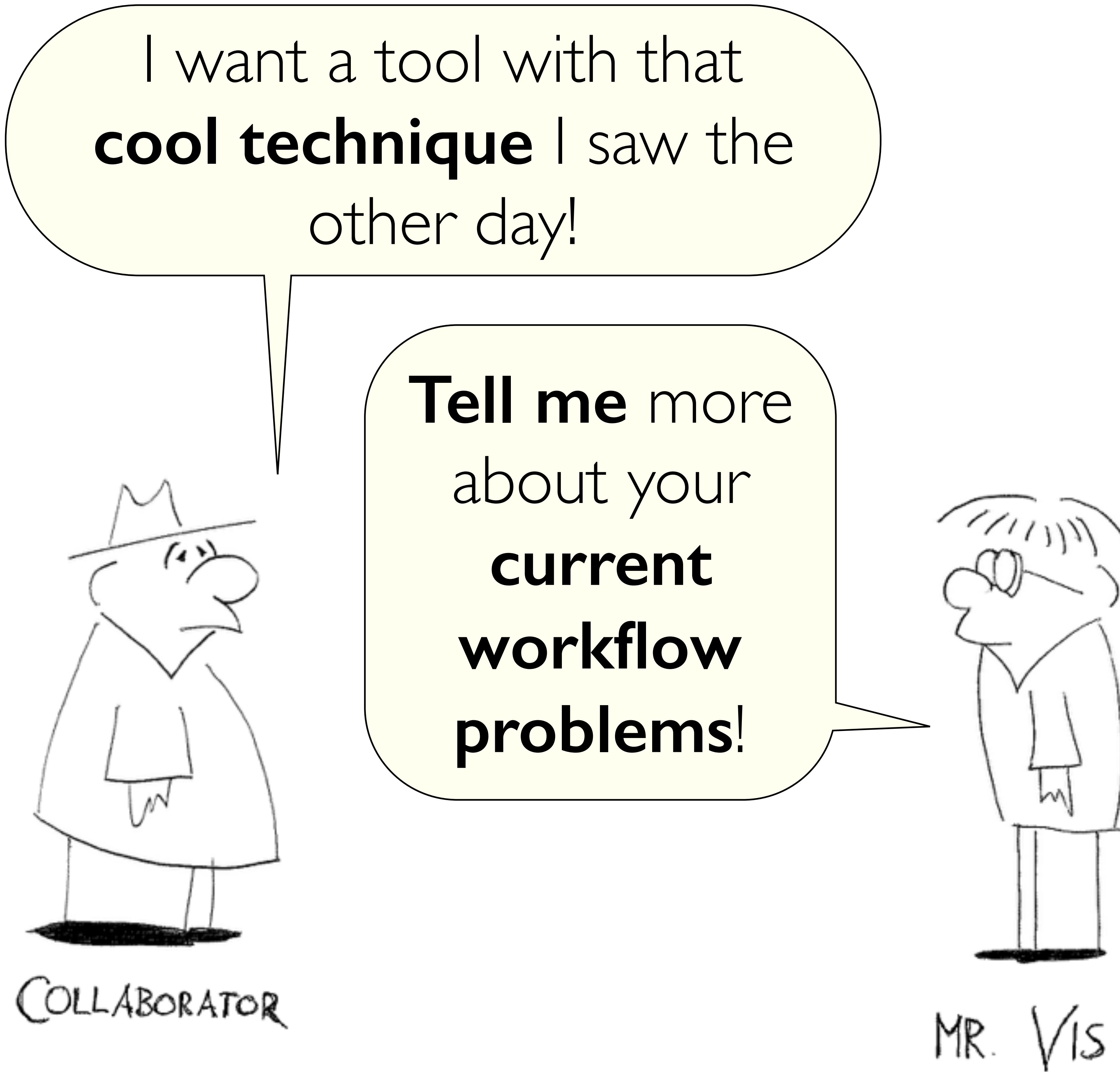
Pitfall

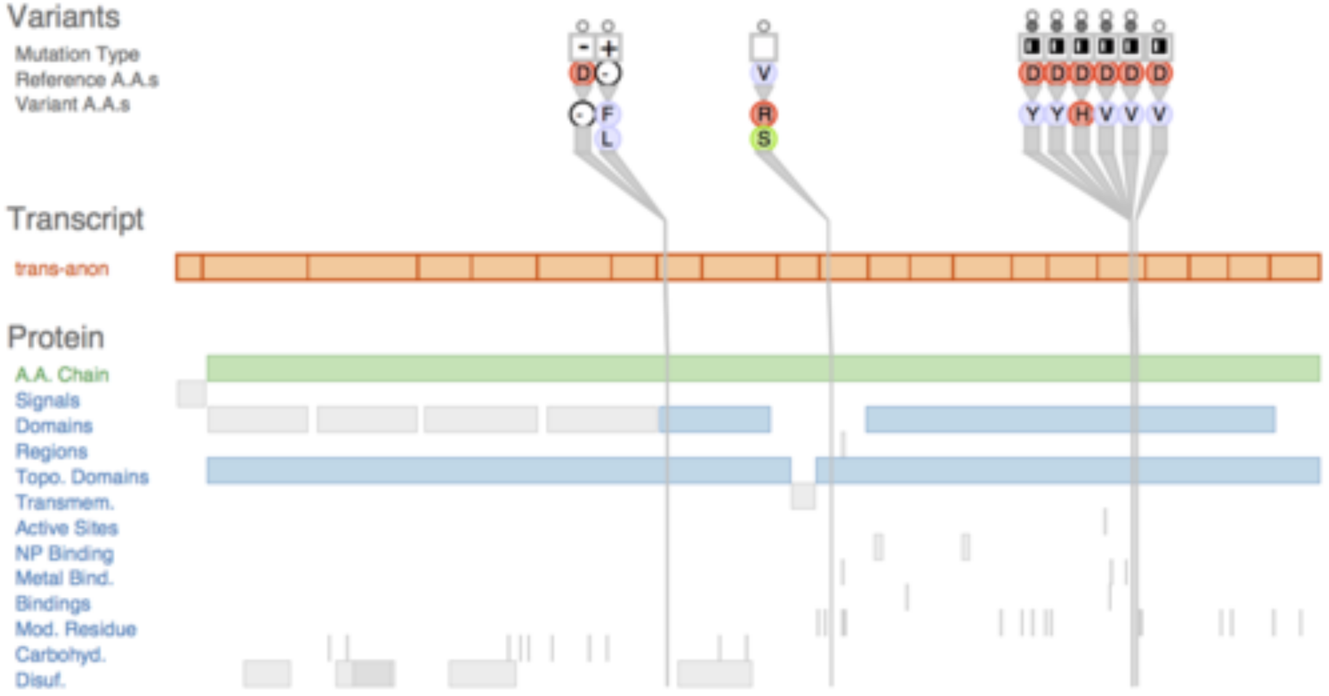
Premature Design Commitment

Domain Experts Focused on Vis Design vs Domain Problem



Design study methodology: 32 pitfalls

PF-21	mistaking technique-driven for problem-driven work	design
PF-22	nonrapid prototyping	implement
PF-23	usability: too little / too much	implement
PF-24	premature end: insufficient deploy time built into schedule	deploy
PF-25	usage study not case study: non-real task/data/user	deploy
PF-26	*liking* necessary but not sufficient for validation	deploy
PF-27	failing to improve guidelines: confirm, refine, reject, propose	reflect
PF-28	insufficient writing time built into schedule	write
PF-29	no technique contribution $\neq$ good design study	write
PF-30	too much domain background in paper	write
PF-31	story told chronologically vs. focus on final results	write
PF-32	premature end: win race vs. practice music for debut	write



Joel Ferstay

Cydney Nielsen
@cydneybn

Variant View

Visualizing Sequence Variants in their Gene Context

Tamara Munzner
@tamaramunzner

http://www.cs.ubc.ca/labs/imager/tr/2012/VariantView/

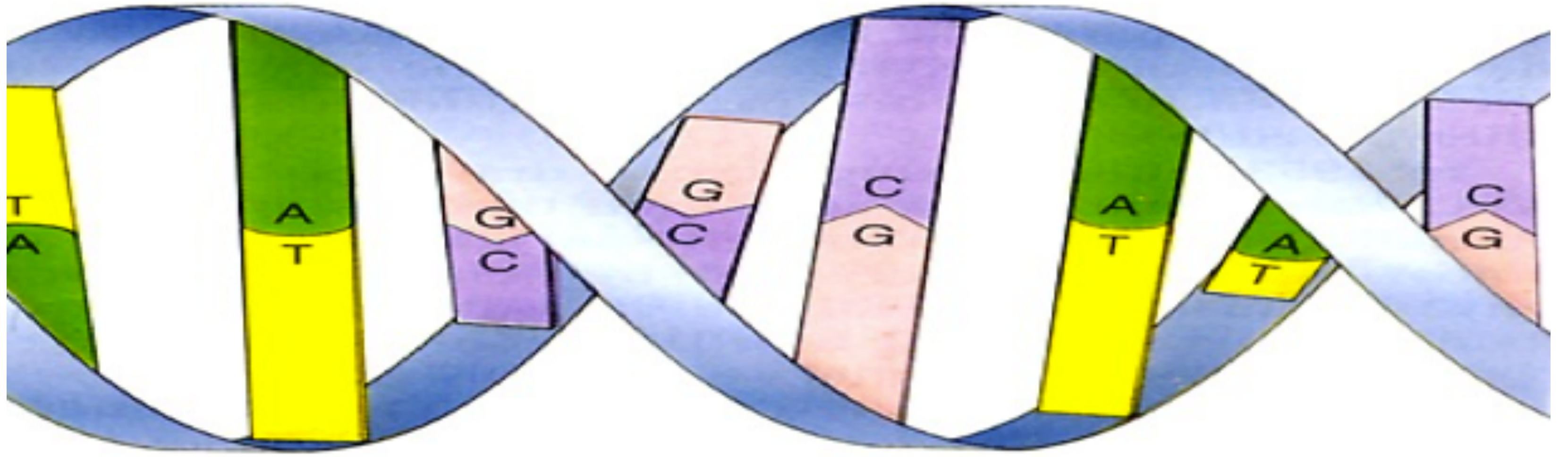
Variant View: Visualizing Sequence Variants in their Gene Context.
Ferstay, Nielsen, Munzner. IEEE TVCG 19(12): 2546-2555, 2013 (Proc. InfoVis 2013).

Variant View: Visualization *Design Study*

- first after DSM, tried following guidelines explicitly
- a specific real-world problem
  - real users and real data,
  - collaboration is (often) fundamental
- design a visualization system
  - implications: requirements, multiple ideas
- validate the design
  - at appropriate levels: case studies via deployment
- reflect about lessons learned
  - transferable research: improve design guidelines for vis in general
    - confirm, refine, reject, propose

Sequence Variant Definition

- Sequence variants
  - Difference between reference and given genome



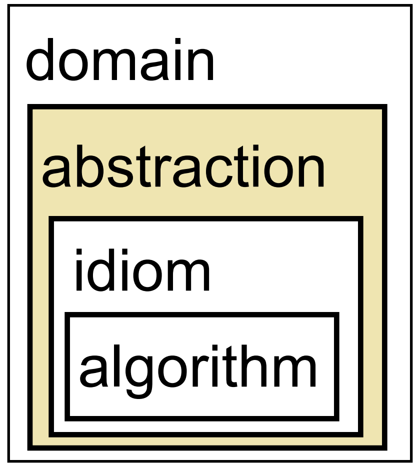
Reference Genome DNA:	ATA TGA TCA ACA CTT
Sample 1 Genome DNA:	ATA TGG TCA ATA CTT
Sample 2 Genome DNA:	ATA TGA TGA ACA CCT

Harmful?

Harmless?

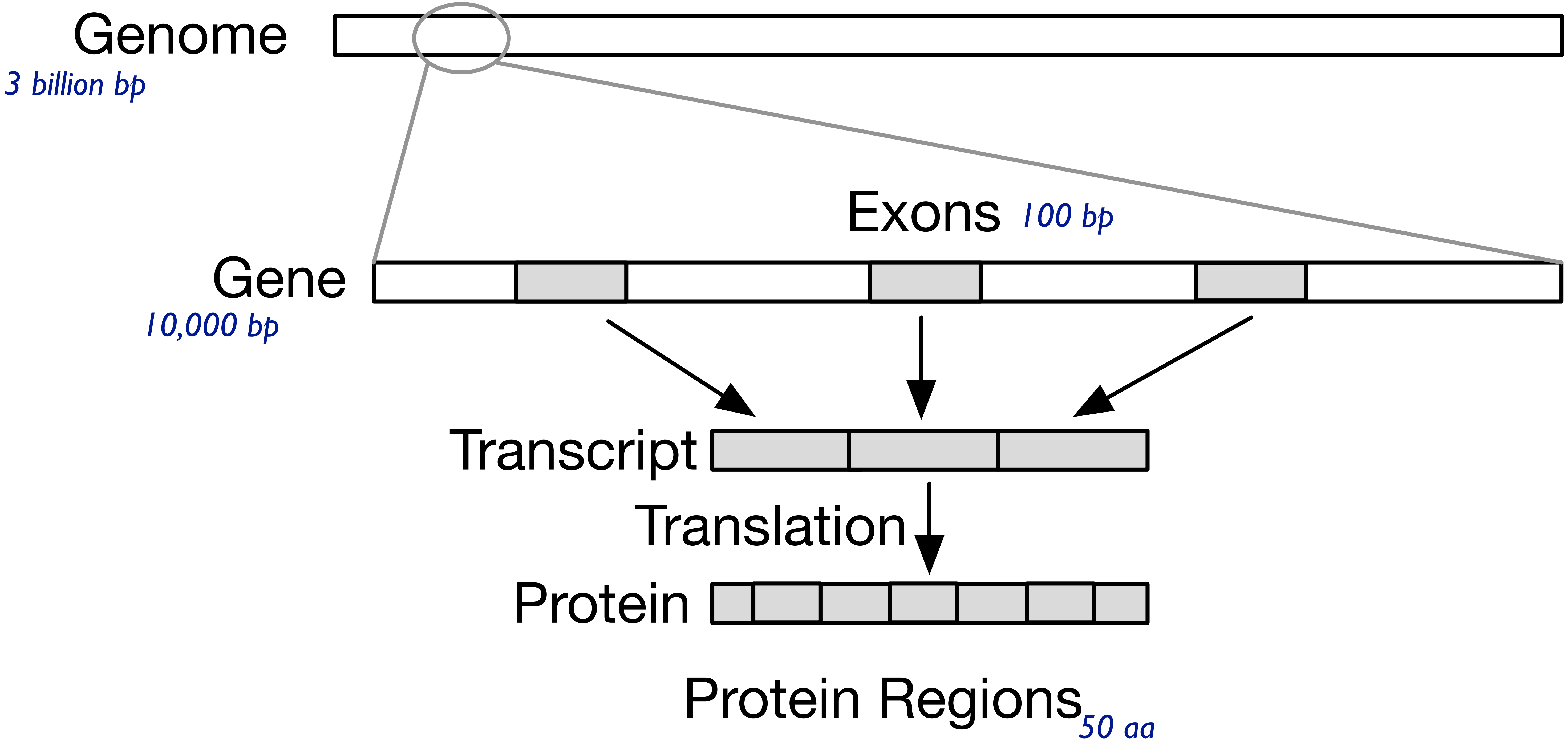
Cancer Research

- collaboration with analysts at BC Genome Sciences Center
  - studying genetic basis of leukemia
- driving task
  - discover new candidate genes with harmful variants
- two big questions
  - what to show
    - data abstraction
    - challenge: enormous range of scales in the data
  - how to show it
    - visual encoding idiom
    - challenge: information density and perceptual considerations

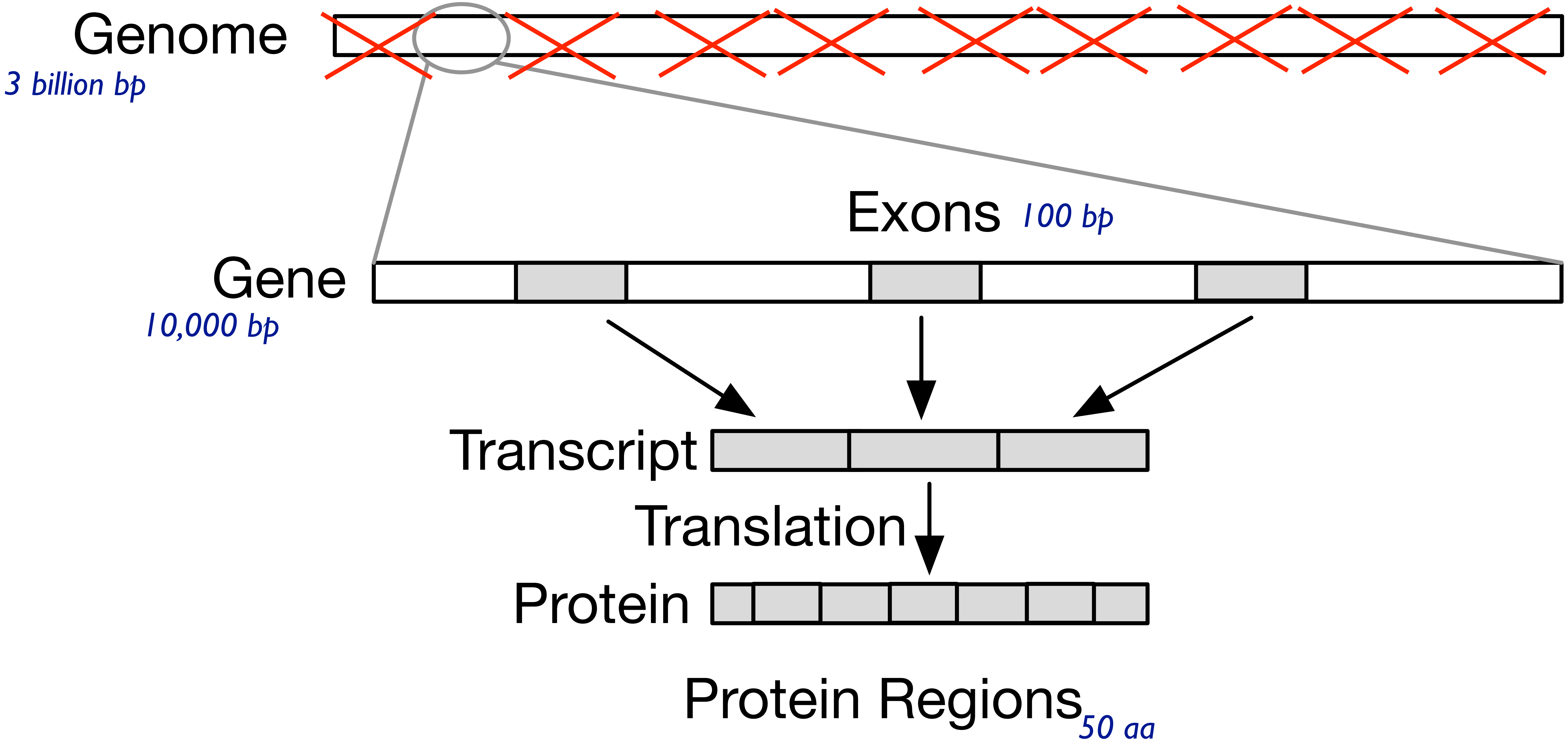


Abstractions

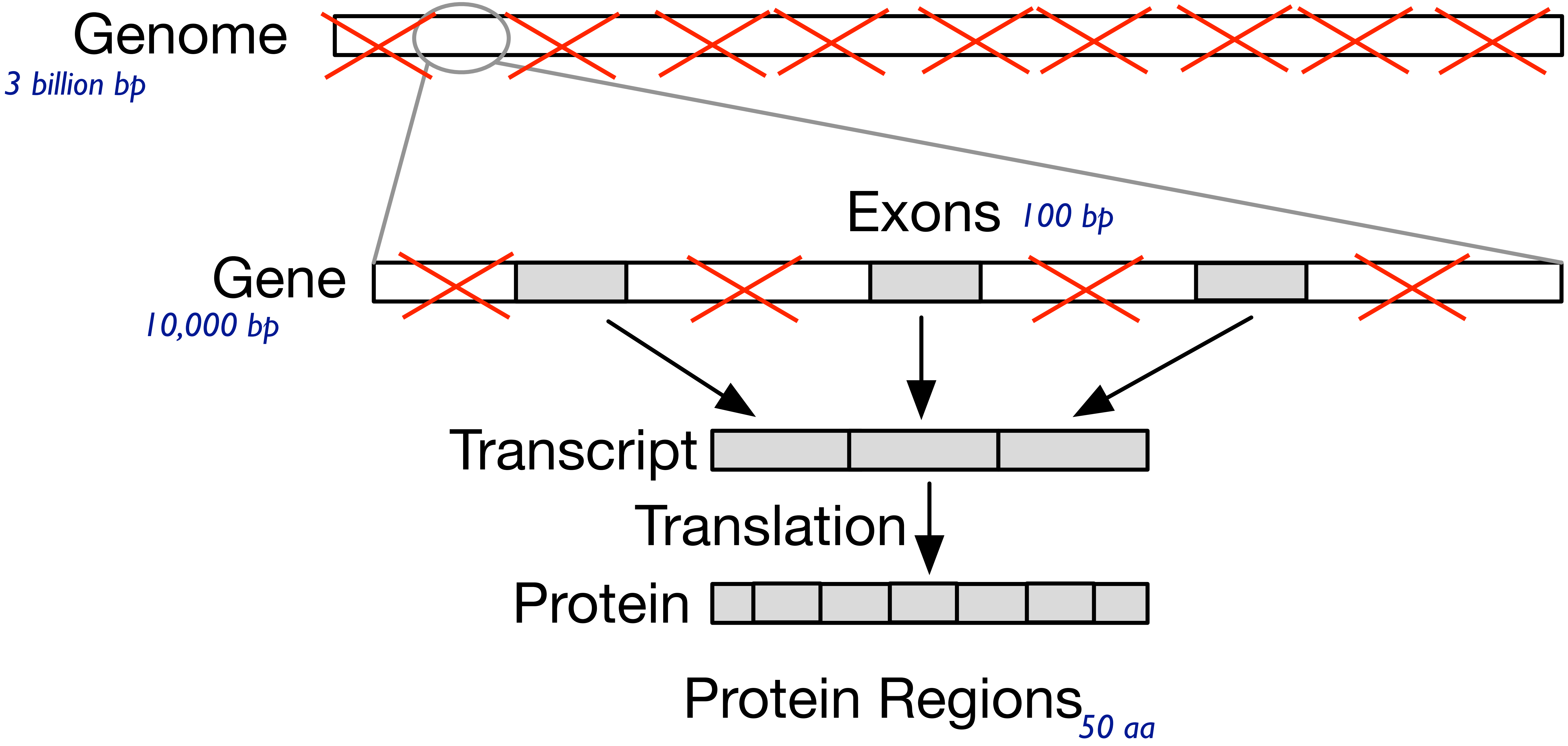
Data: Filtering to relevant biological levels and scales



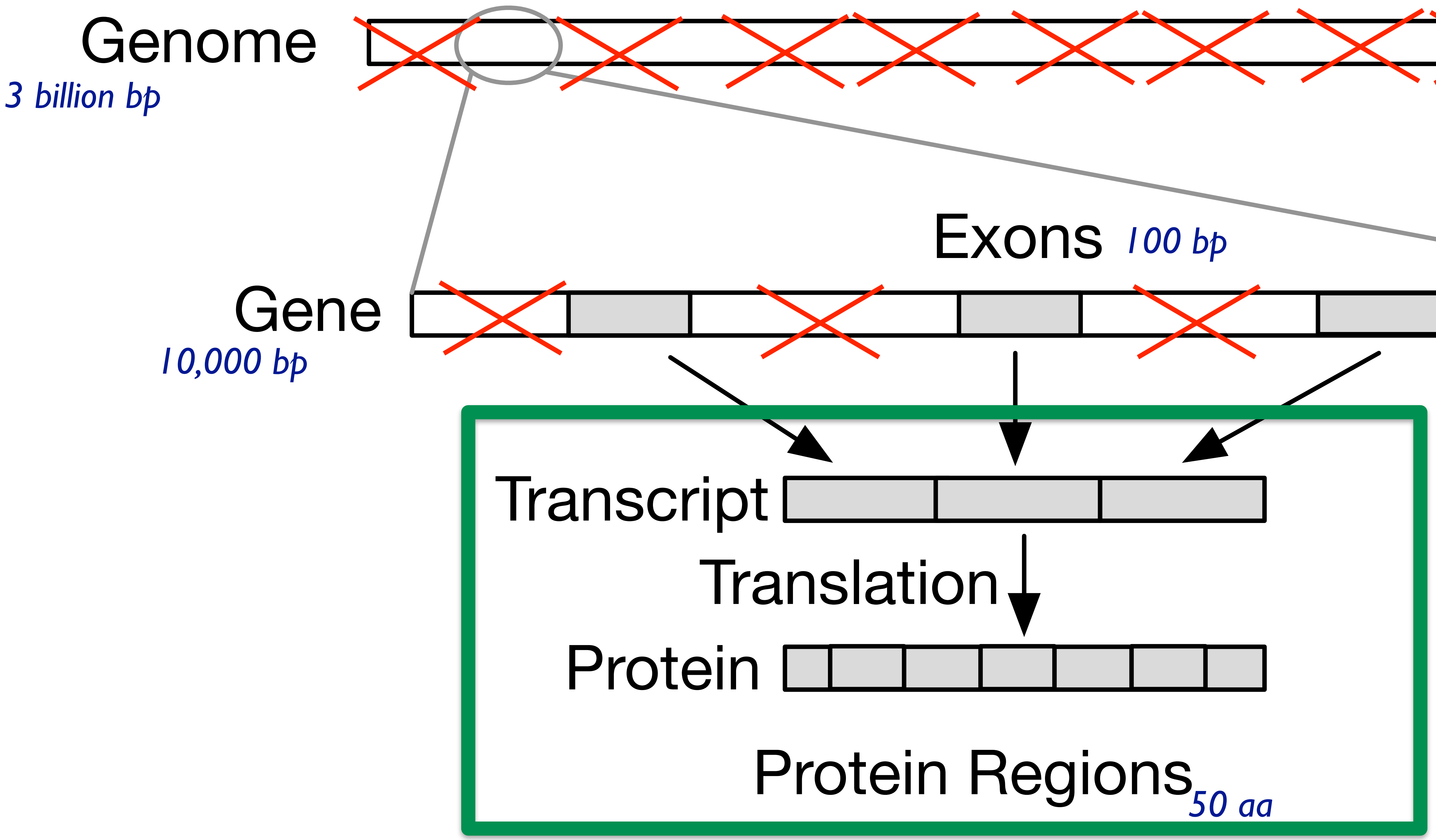
Filter out whole genome; keep genes



Filter out non-exon regions

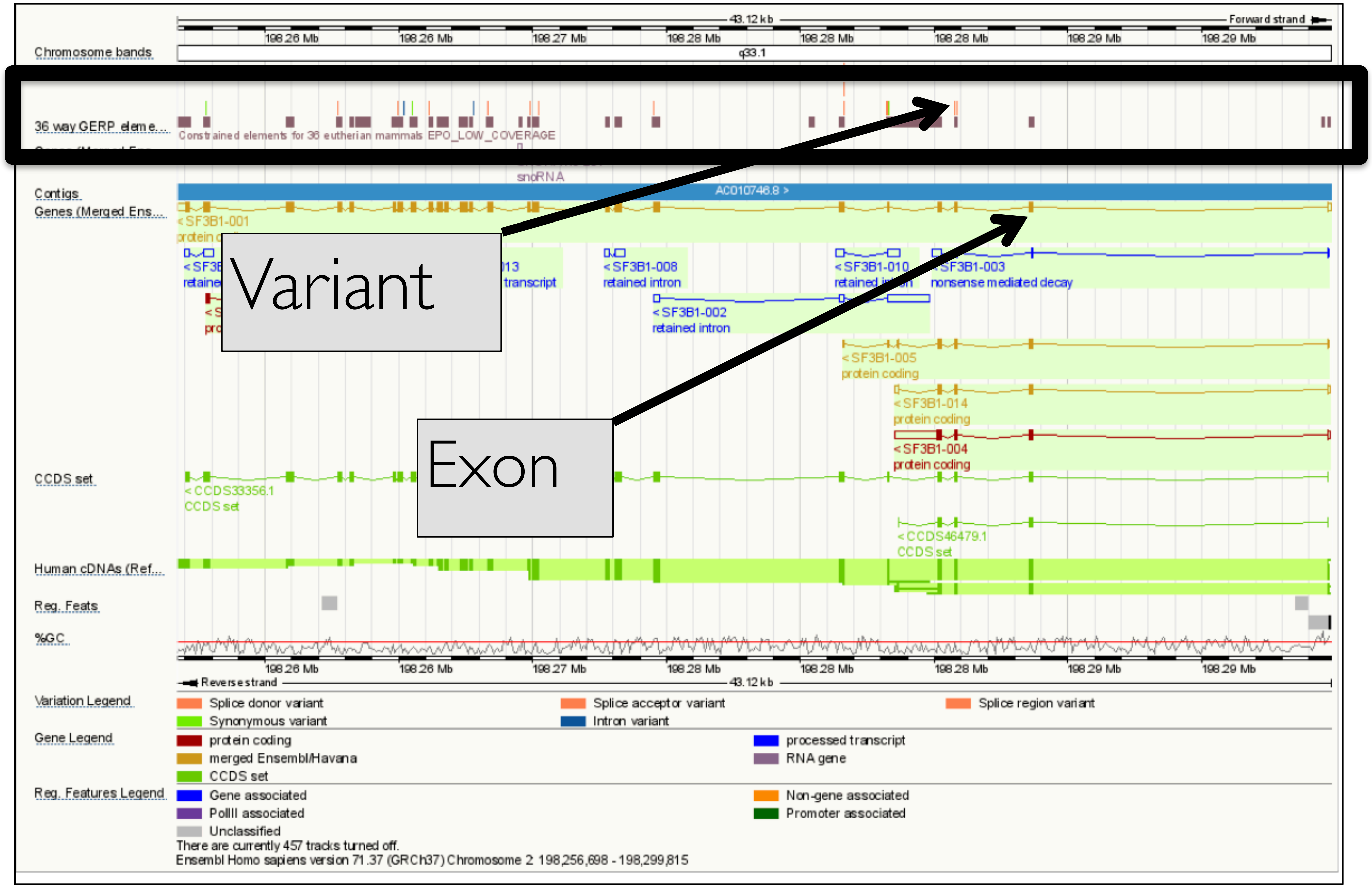


Data abstraction: highly filtered scope of *transcript coordinates*



Dominant paradigm: genome browsers

- strengths: flexible and powerful
  - horizontal tracks: user data
  - shared coordinate system: *genome coordinates* (bp)
- problems
  - tiny features of interest spread out across large extent
    - must zoom far in to inspect known feature, then zoom out and pan to locate next
    - high cognitive load for interaction
    - must already know where to look

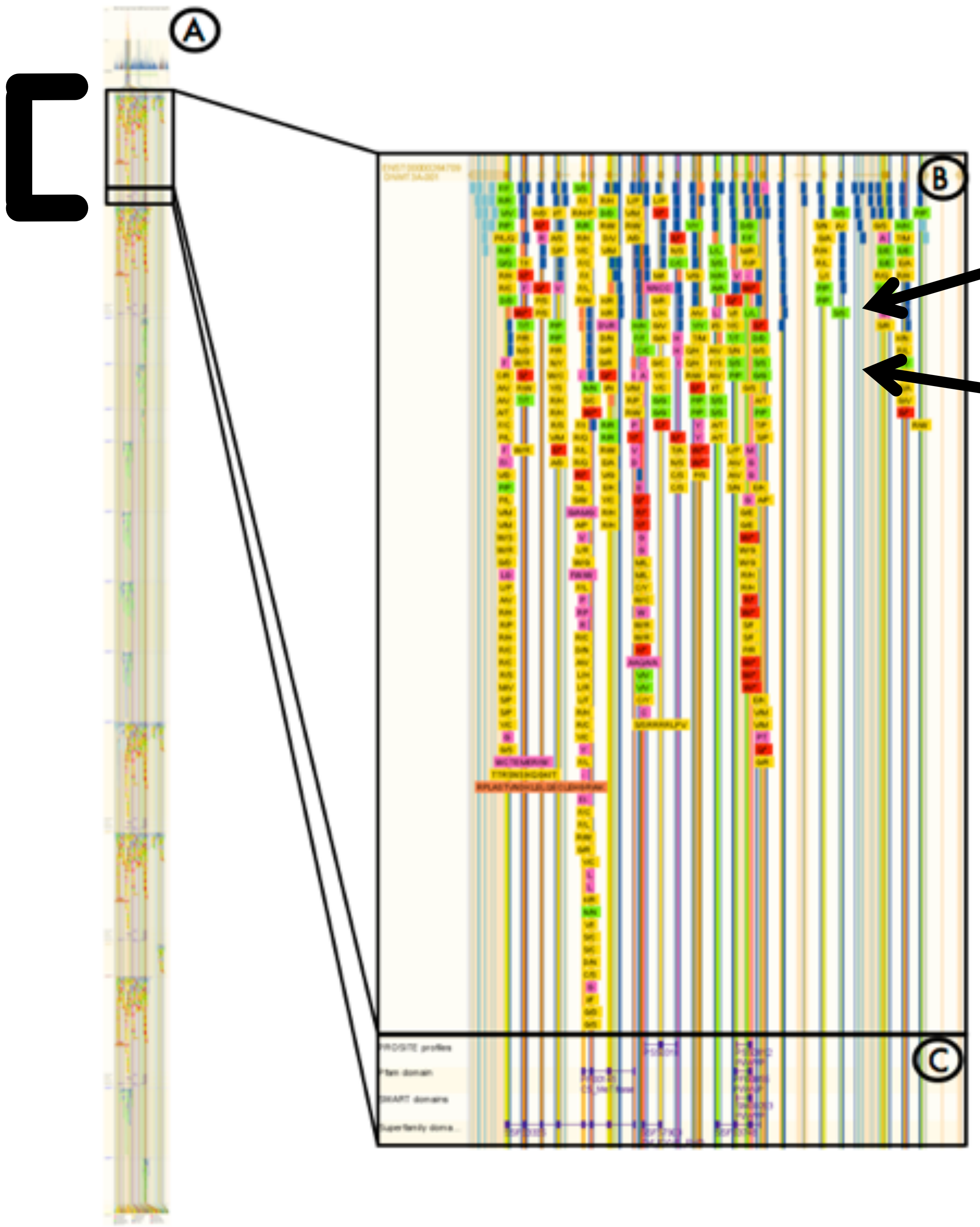


representative example: Ensembl

Chen et al, BMC Bioinforrmatics 2010.

Features of interest small even in variant-specific view

1st Screen

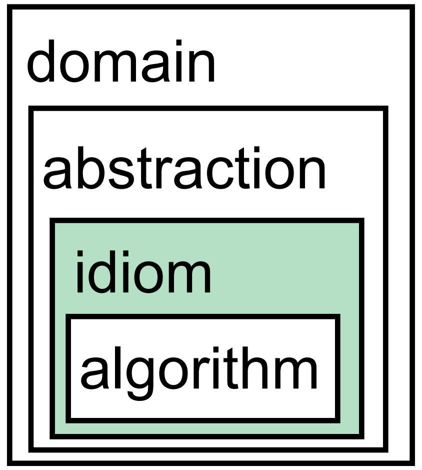


Exon regions small

Color coding difficult to see

Ensembl Variant Image

Chen et al, BMC Bioinforrmatics 2010.



Idioms

Variant View

Variant View

Information-dense single gene view

Variant View

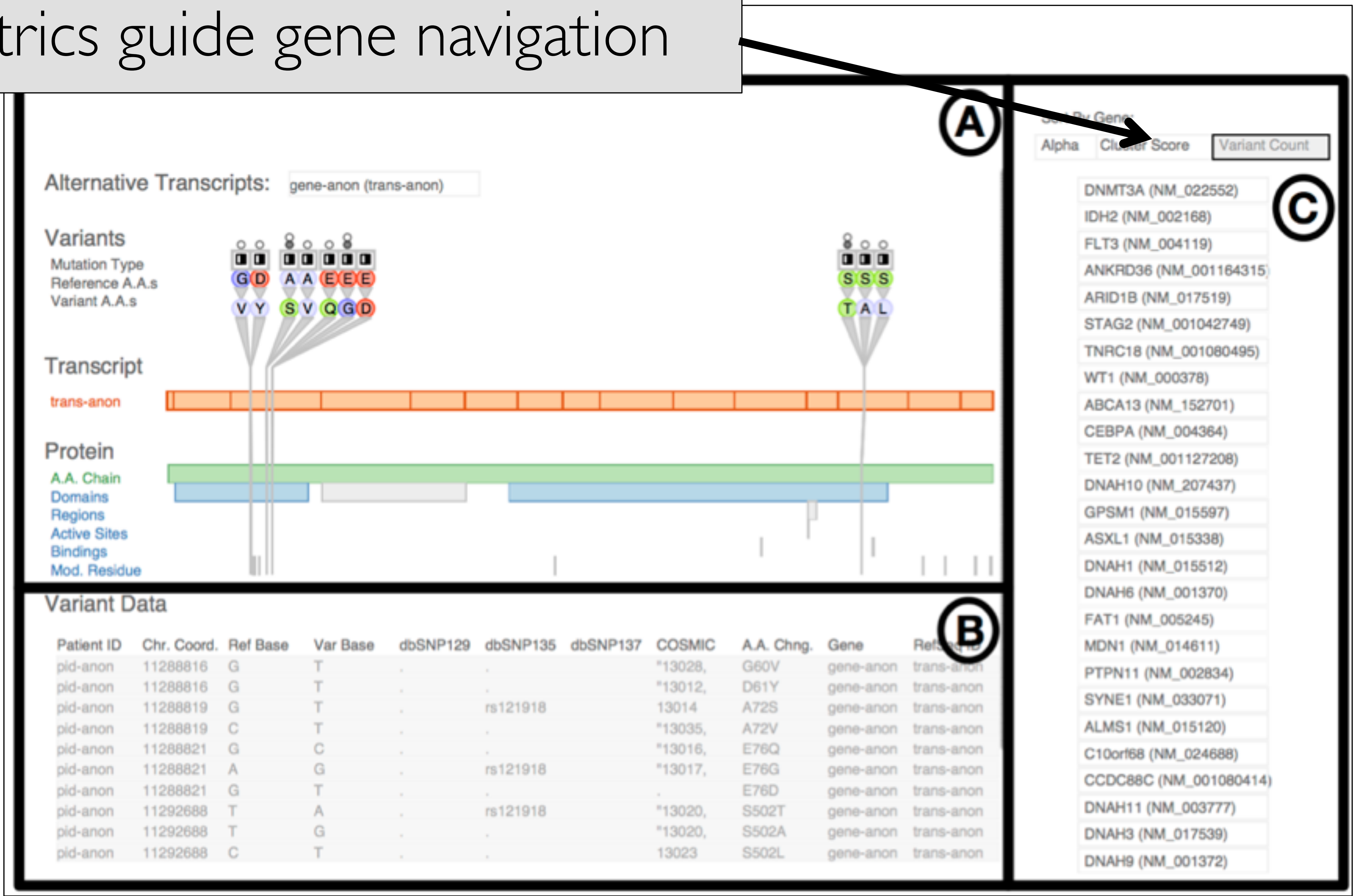
Information-dense single gene view

No need for pan and zoom

Variant View

derived data guides
human-in-the-loop analytics

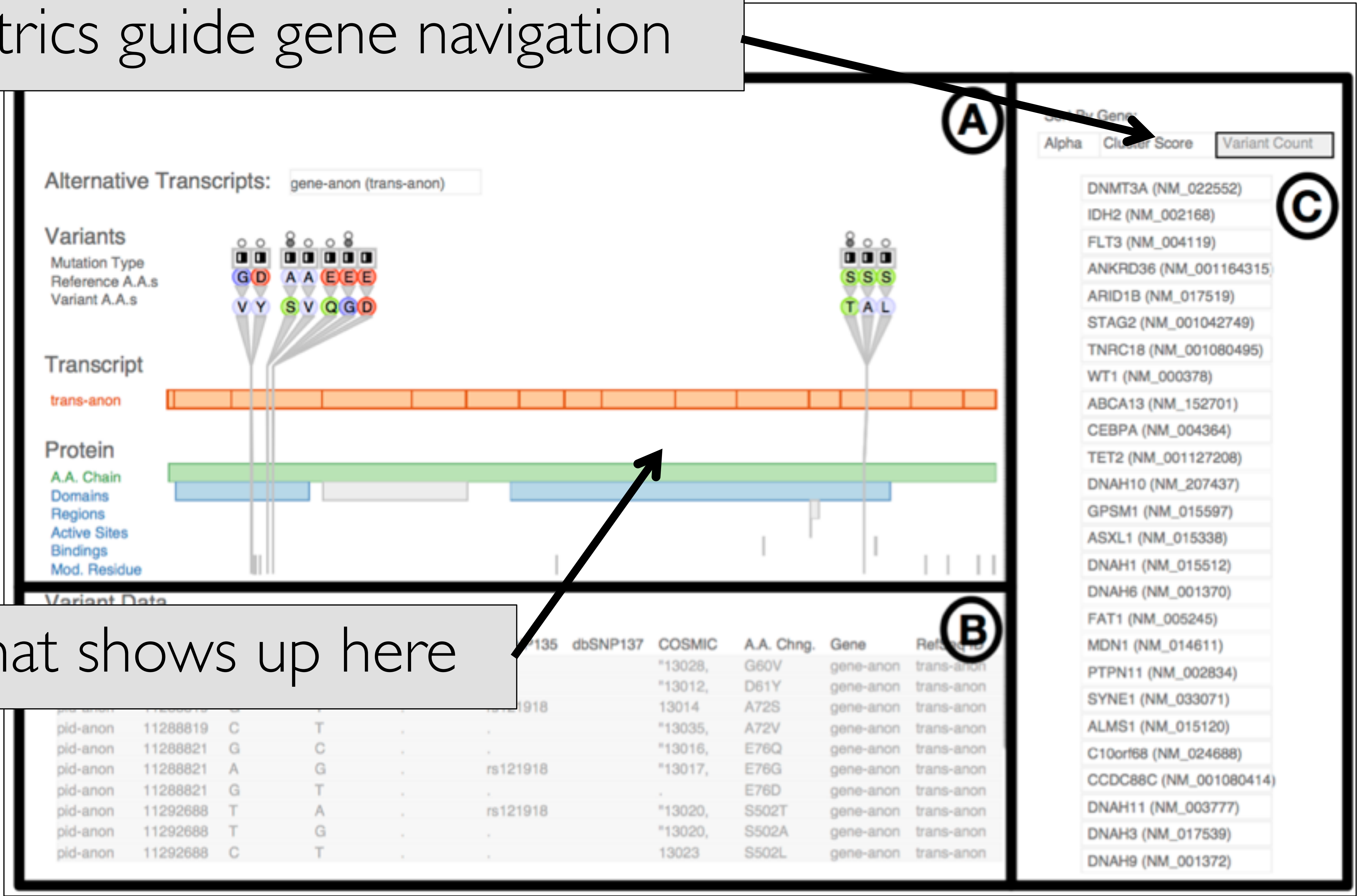
Sorting metrics guide gene navigation



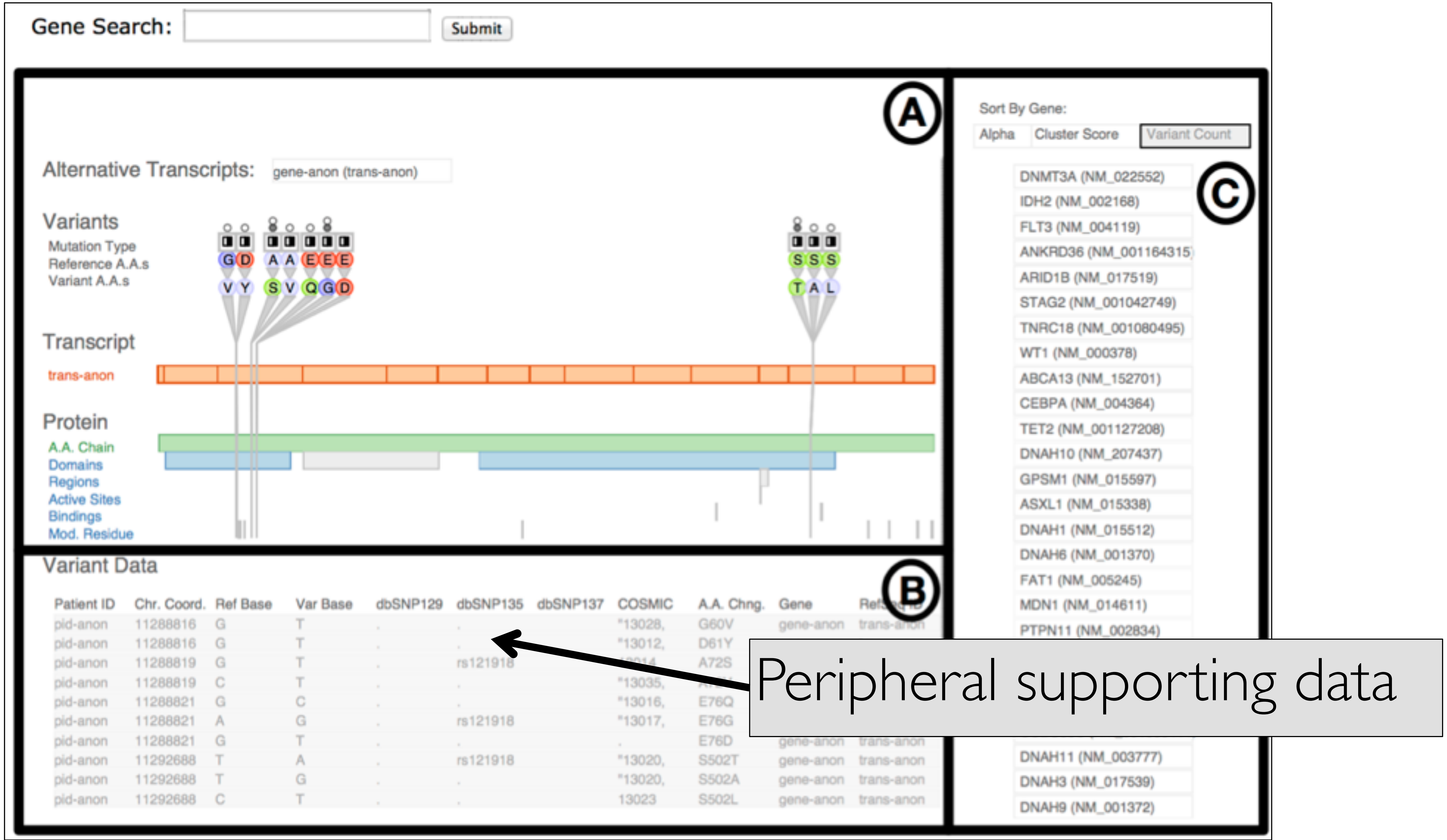
Variant View

Sorting metrics guide gene navigation

Control what shows up here

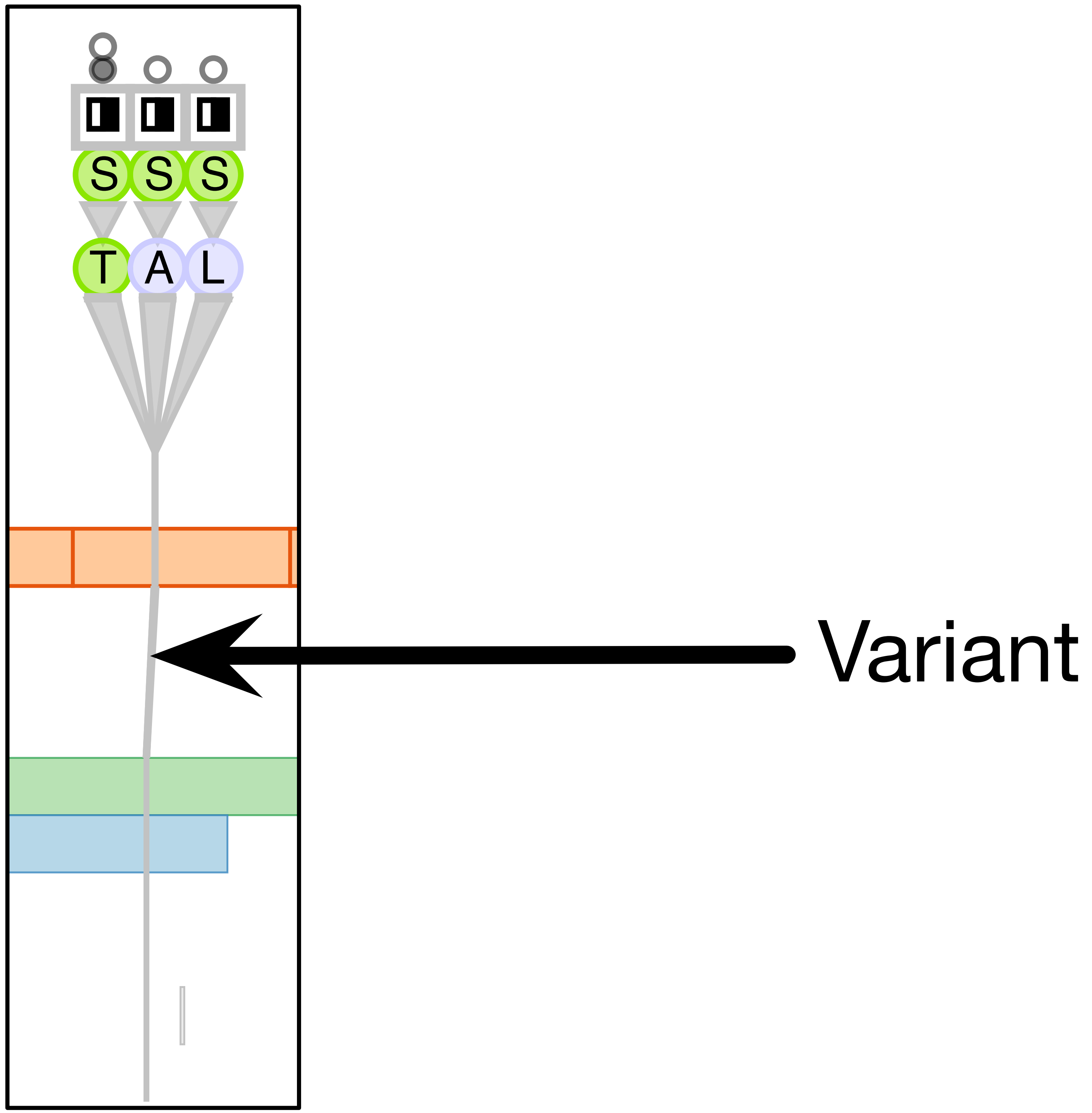


Variant View



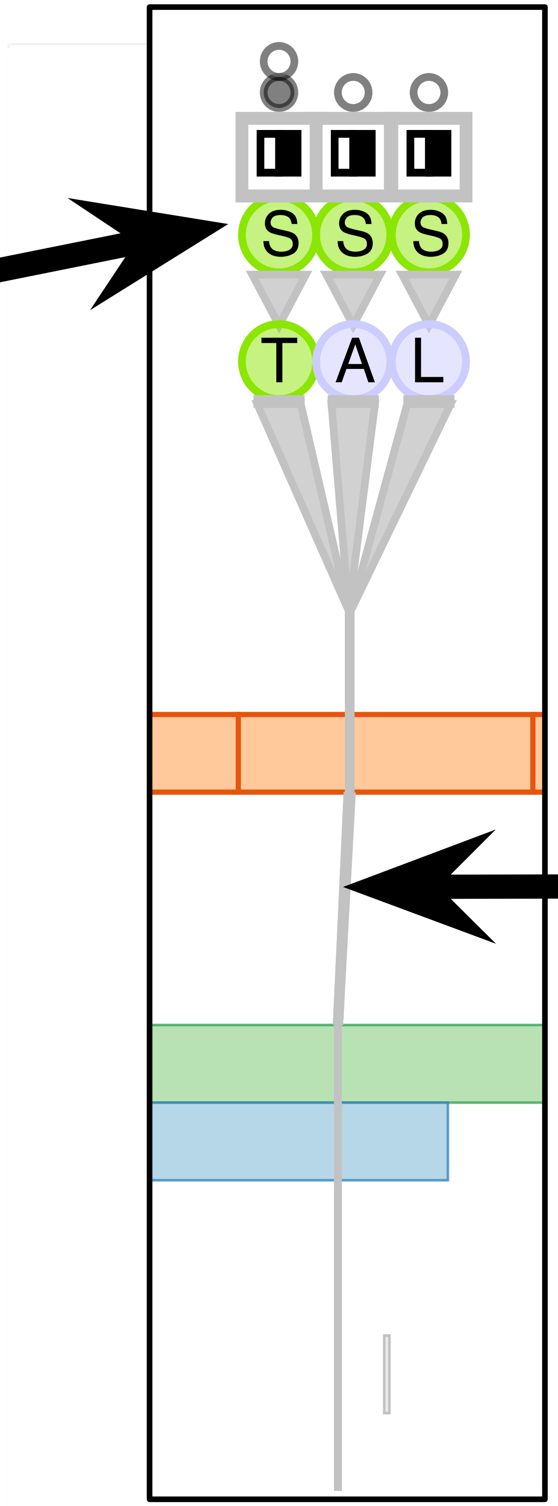
Design information-dense visual encoding

- show all attributes necessary for variant analysis
  - match salience with importance for analysis task
- variant not just a thin line!
- emphasize with high salience
  - collocated variants fan out at top
  - grey variant vertical stroke intersects horizontal colored protein regions



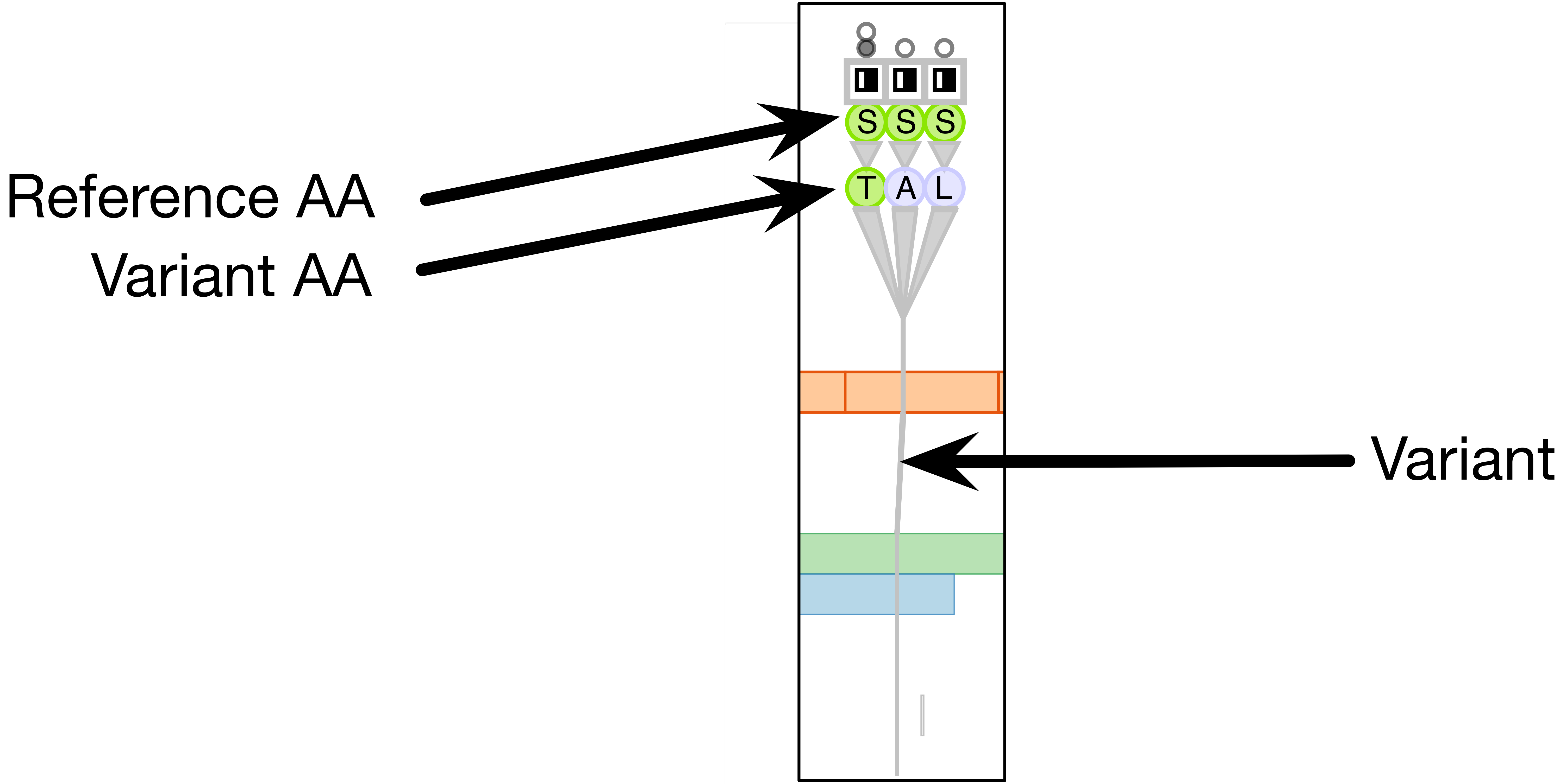
Design information-dense visual encoding

Reference AA

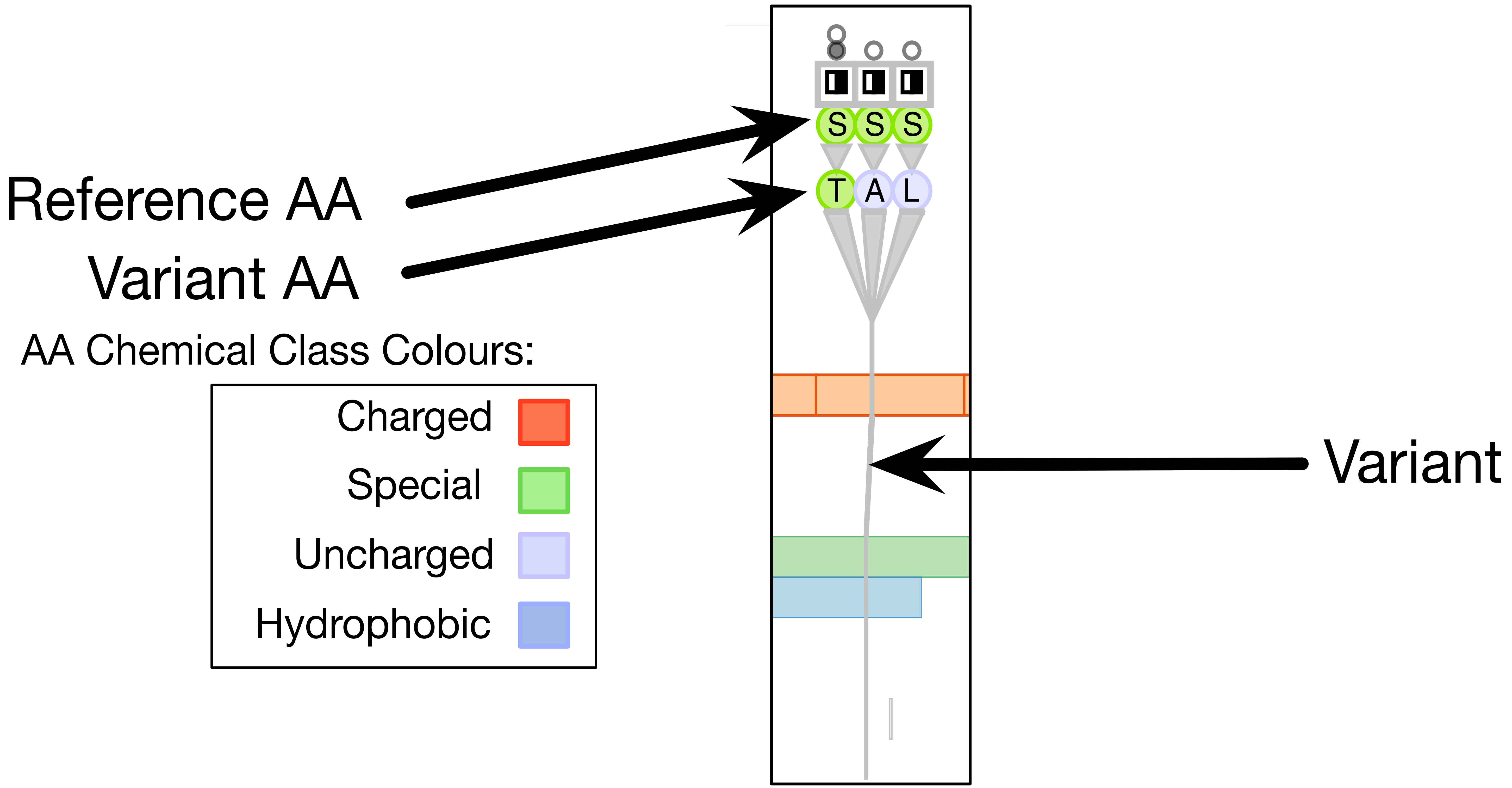


Variant

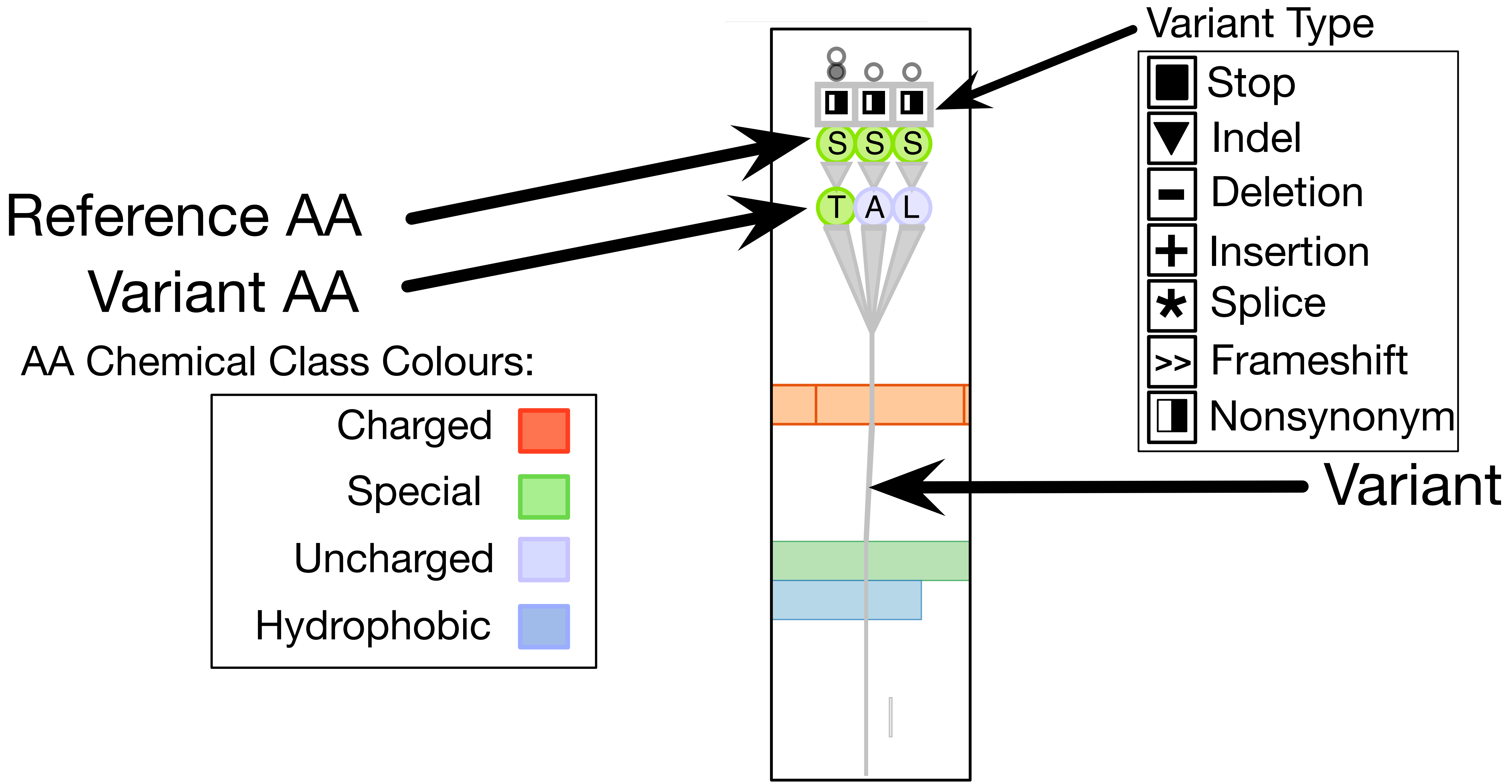
Design information-dense visual encoding



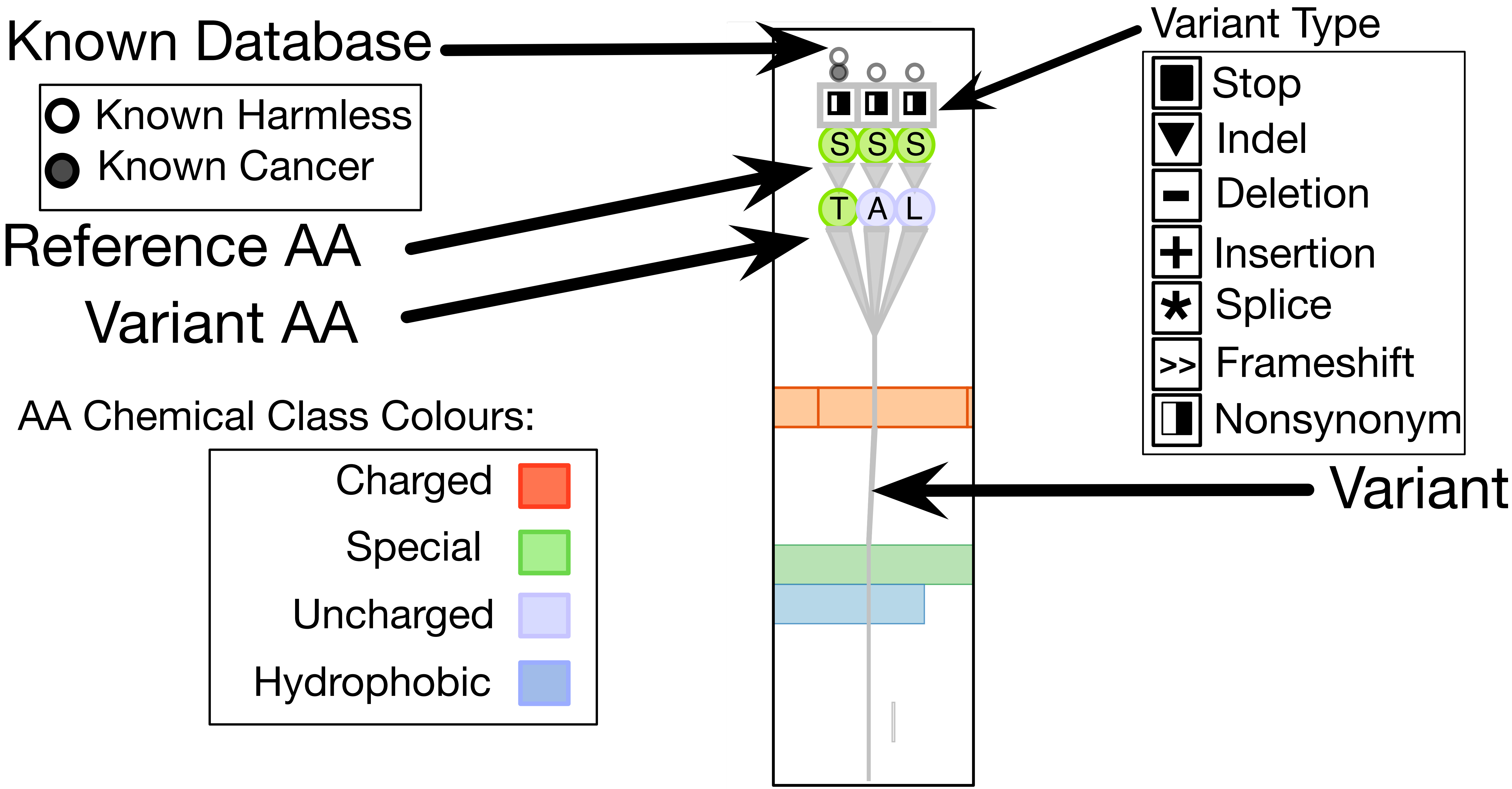
Design information-dense visual encoding



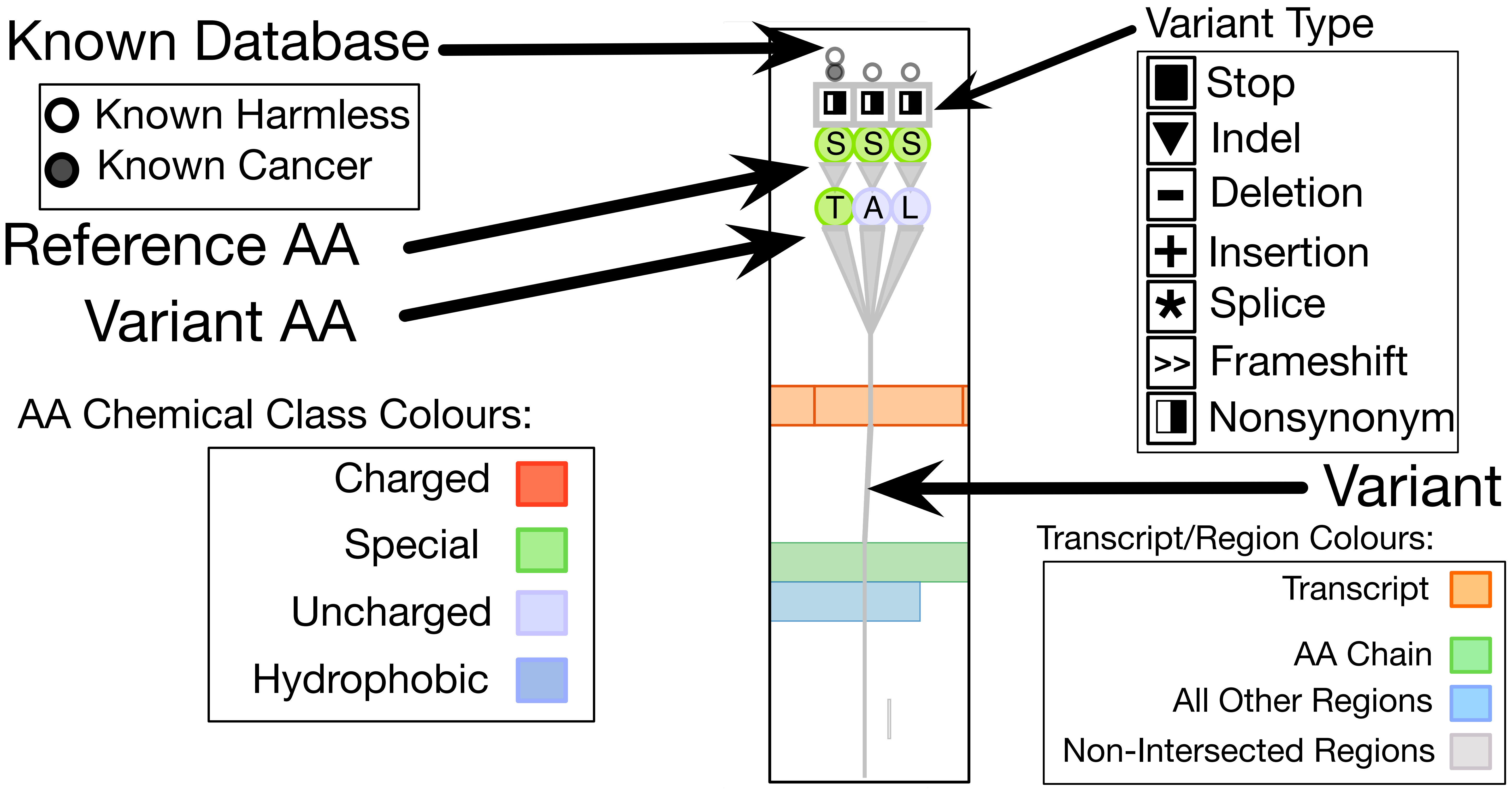
Design information-dense visual encoding



Design information-dense visual encoding

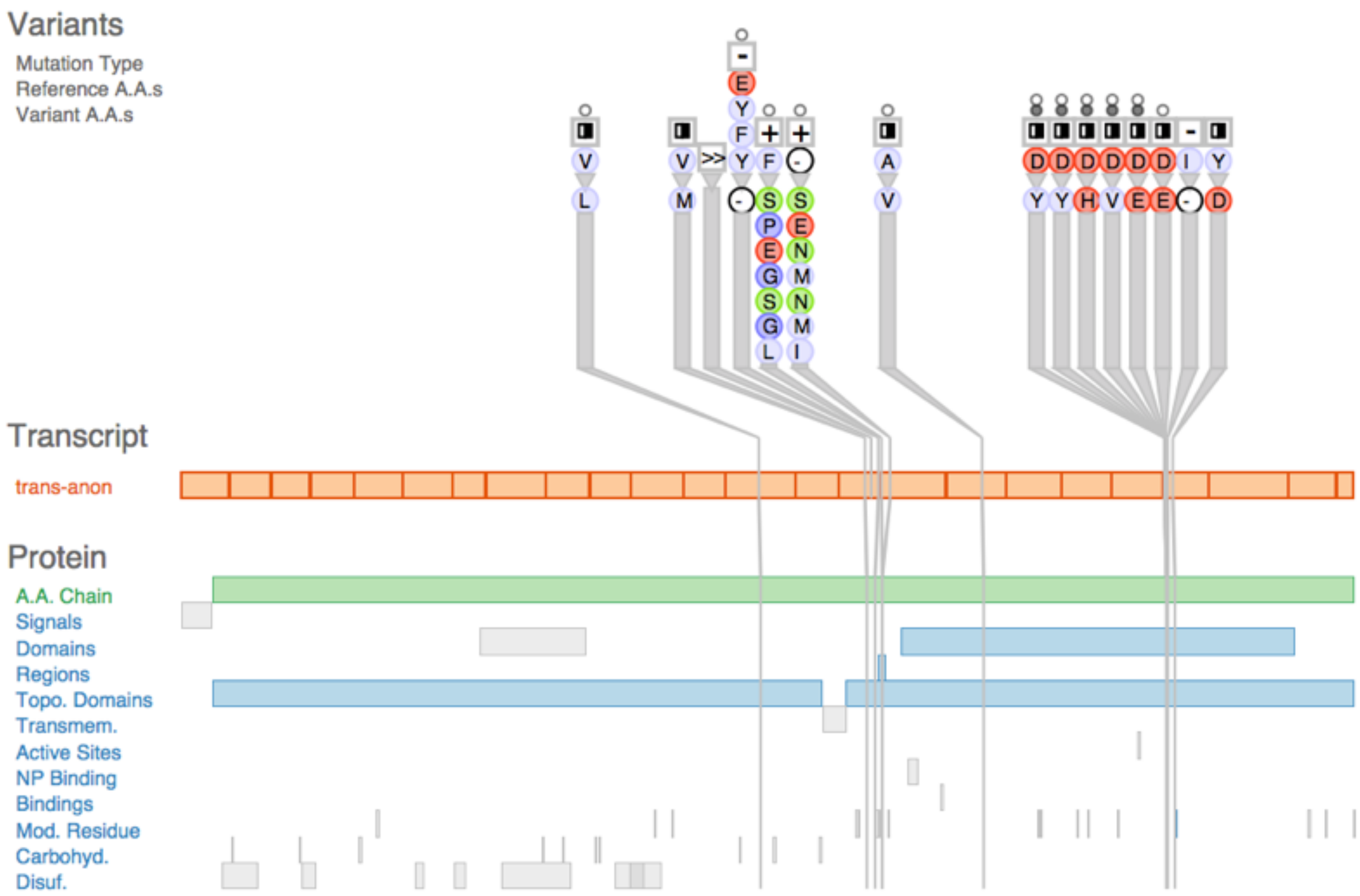


Design information-dense visual encoding

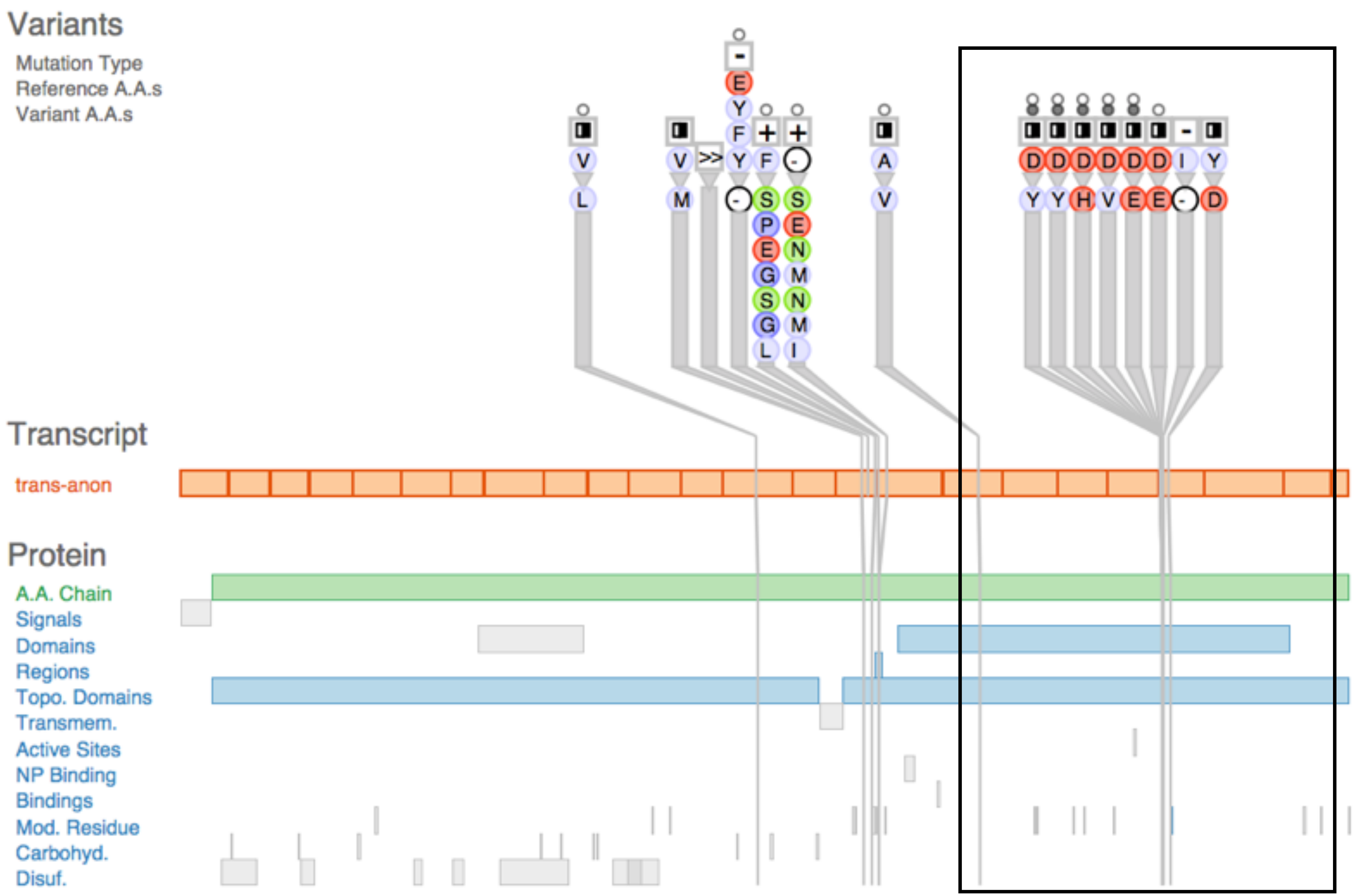


Results

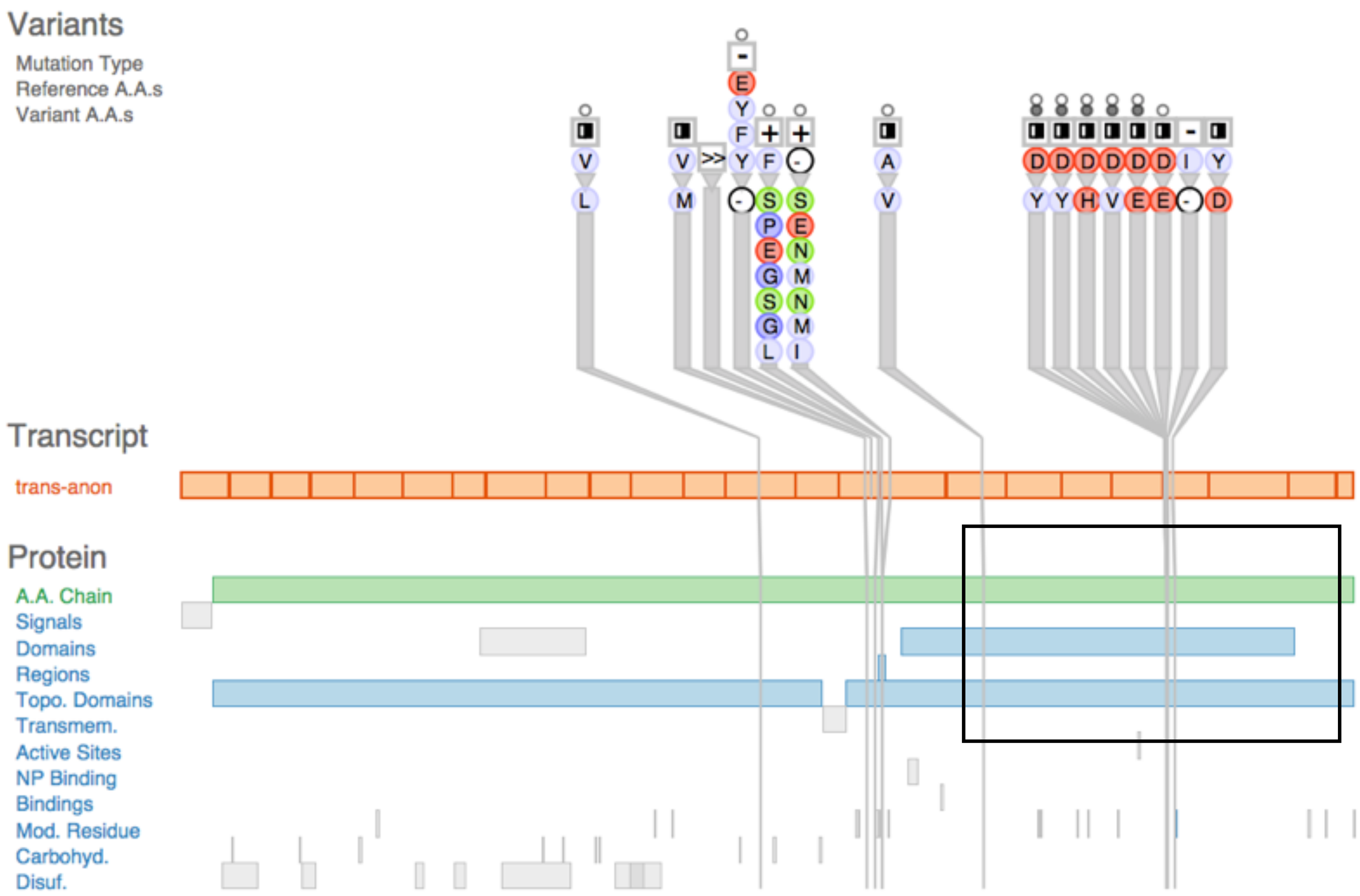
Known leukemia gene: Find fast with sorting metric high score



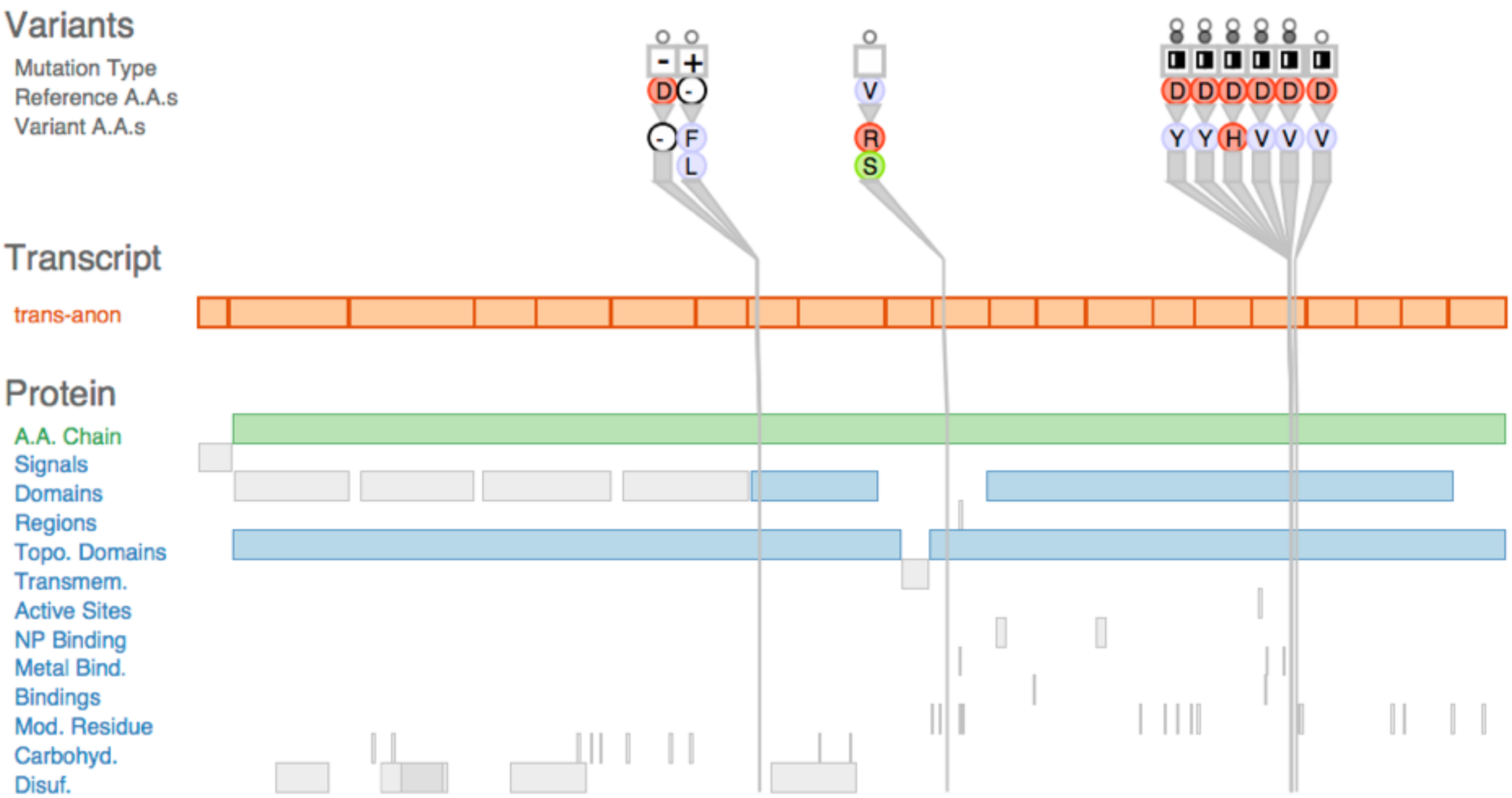
Known leukemia gene: Fanout shows collocation of variants



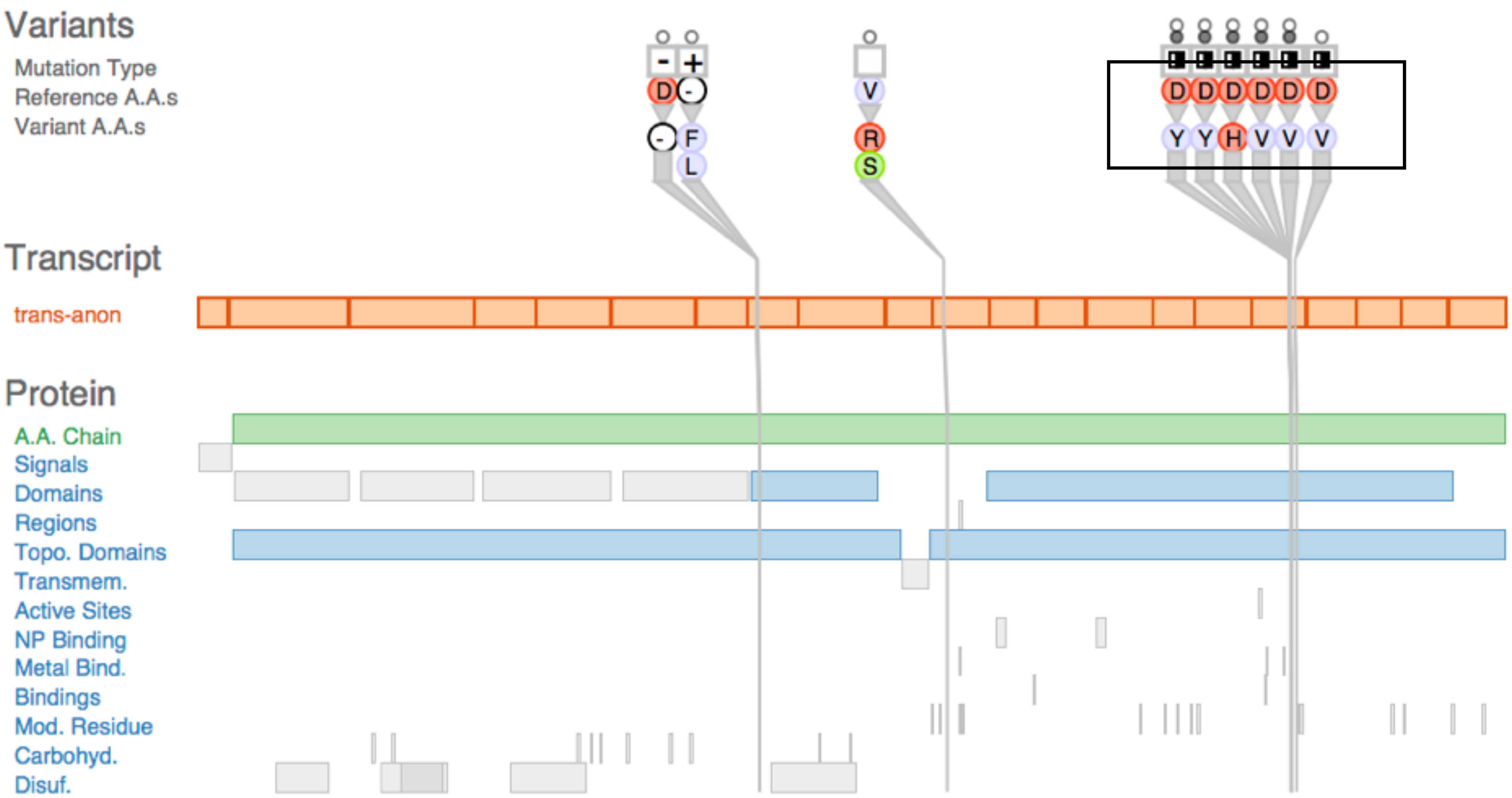
Known leukemia gene: Several functional protein regions affected



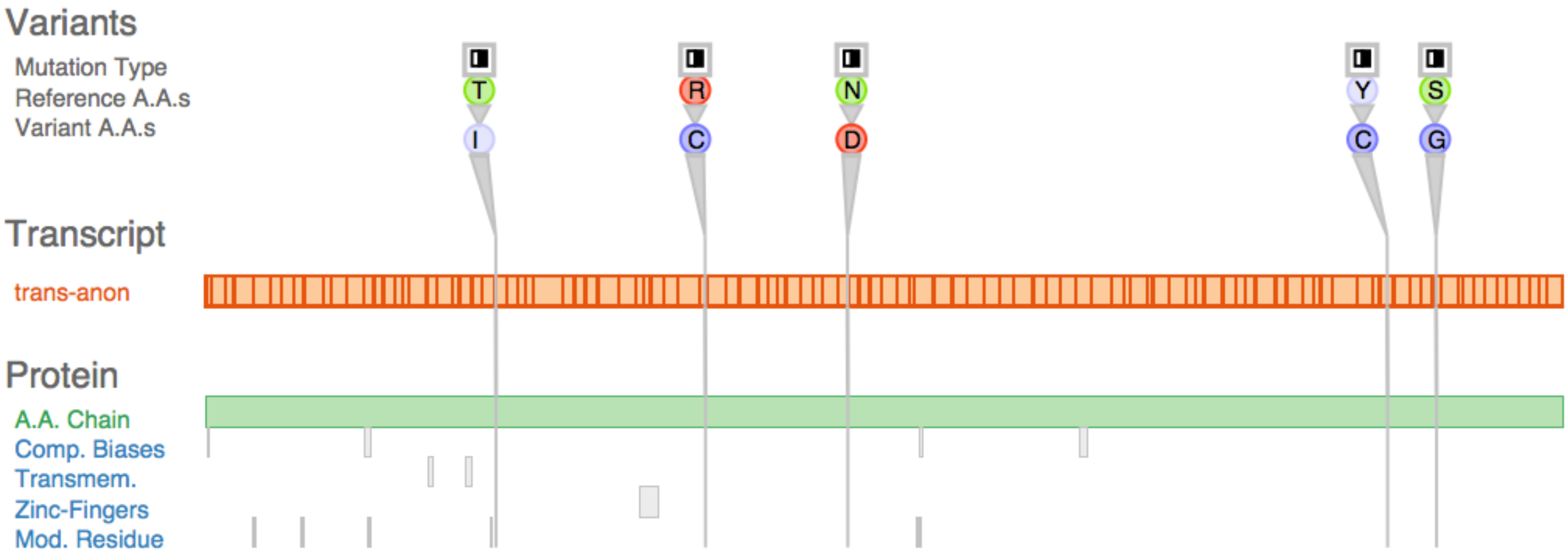
New finding: Good candidate with high metric score



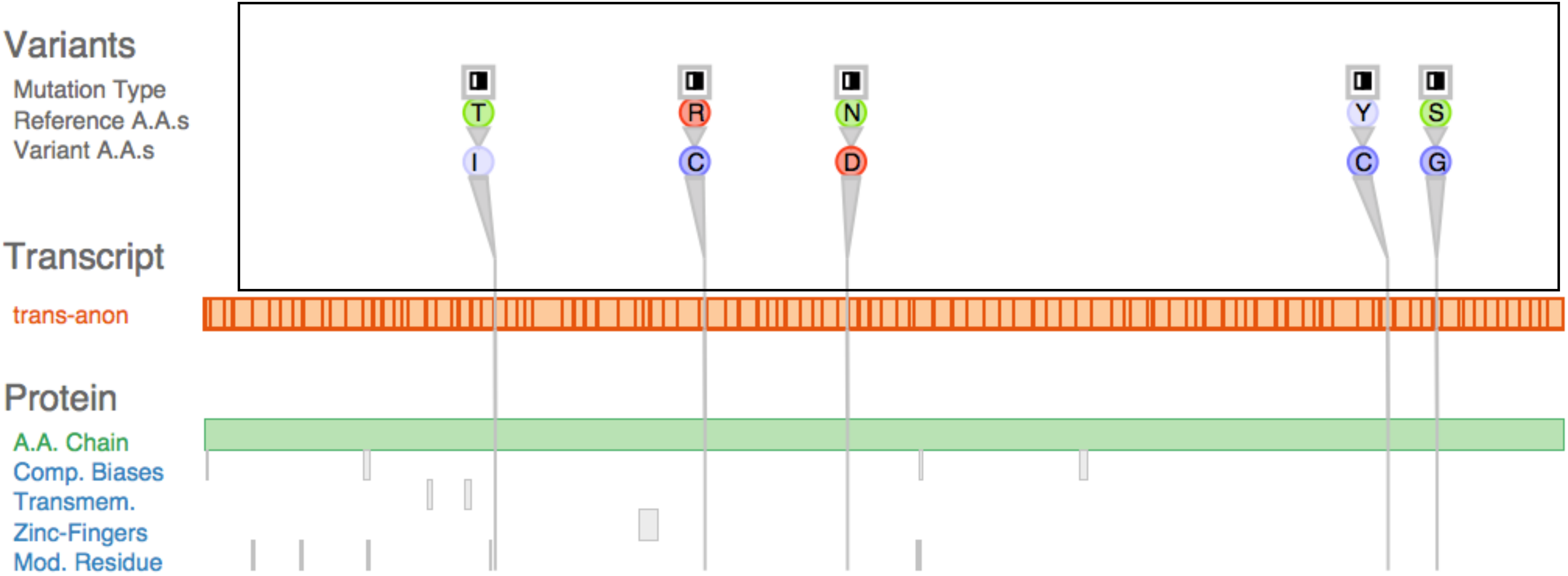
New finding: Protein chemical class change evident



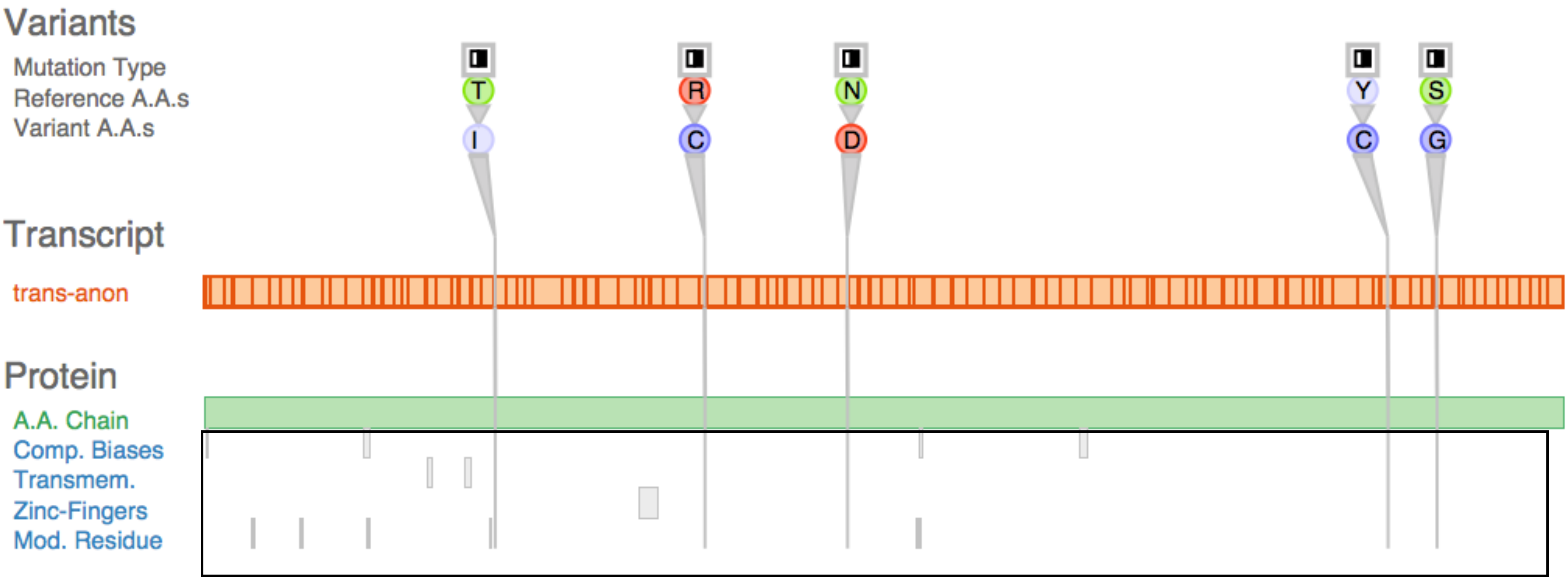
Low scoring gene: in contrast



Low scoring gene: No collocation of variants



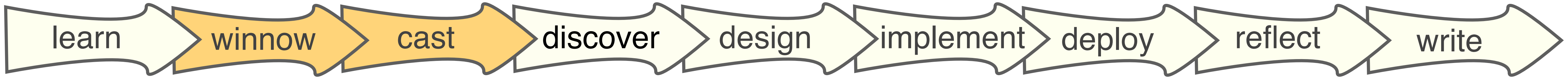
Low scoring gene: Mostly unaffected protein regions



Methods

Phase1:Winnow and Cast

5 months



- embedded within GSC for all stages
- winnow stage
  - considered and ruled out many potential collaborators
- cast stage
  - gatekeeper (PI)
  - two front-line analysts (postdocs)

more at:

Design Study Methodology: Reflections from the Trenches and from the Stacks.
Sedlmair, Meyer, Munzner. IEEE TVCG 18(12): 2431-2440, 2012 (Proc. InfoVis 2012).

Phase 2: Core Design

5 months

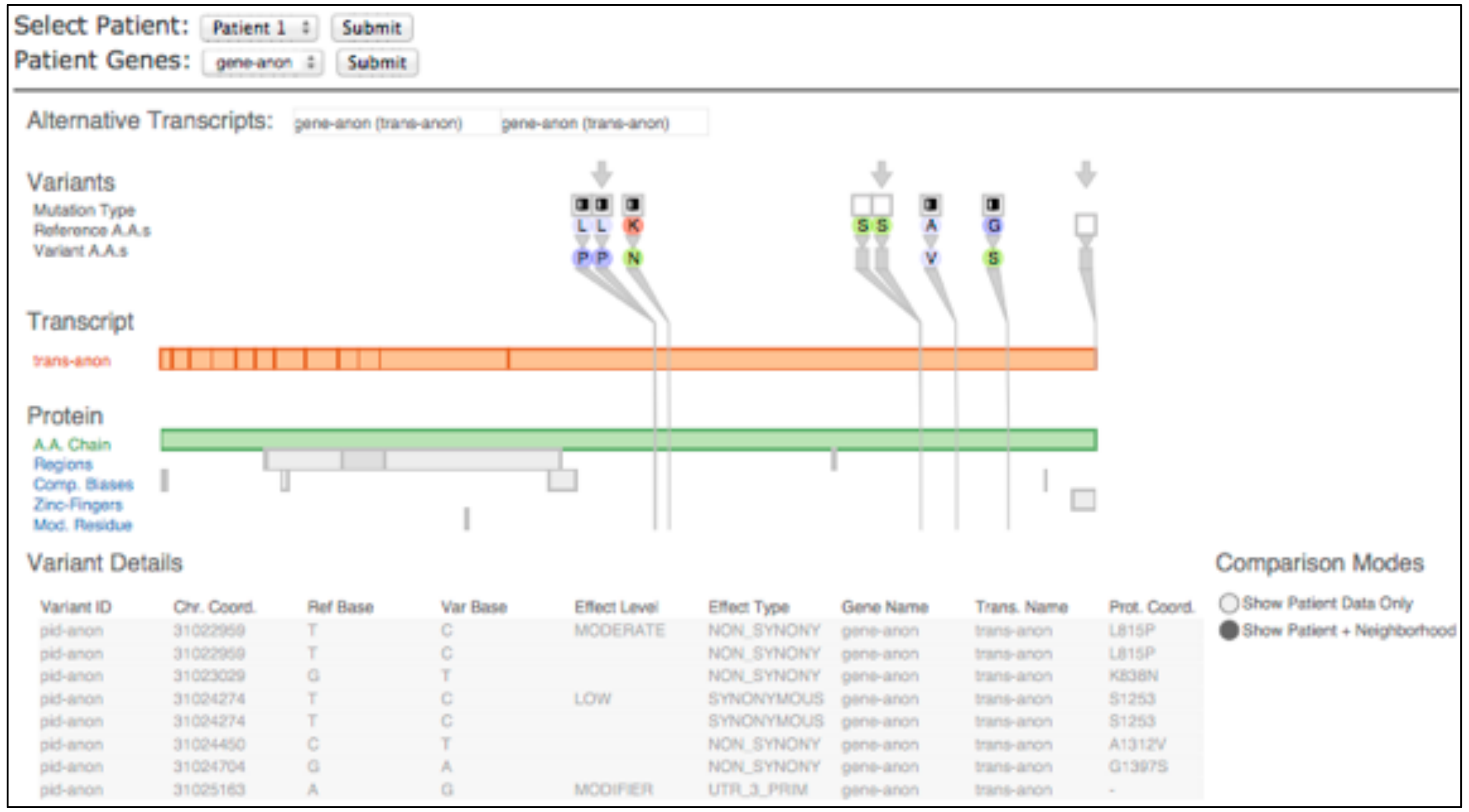
- main task abstraction
  - discover gene
- semi-structured interviews
  - every week for 1 hr
- iterative refinement
  - 8 data sketches deployed
  - rapid prototyping to show real data ASAP
  - refine utility & usability

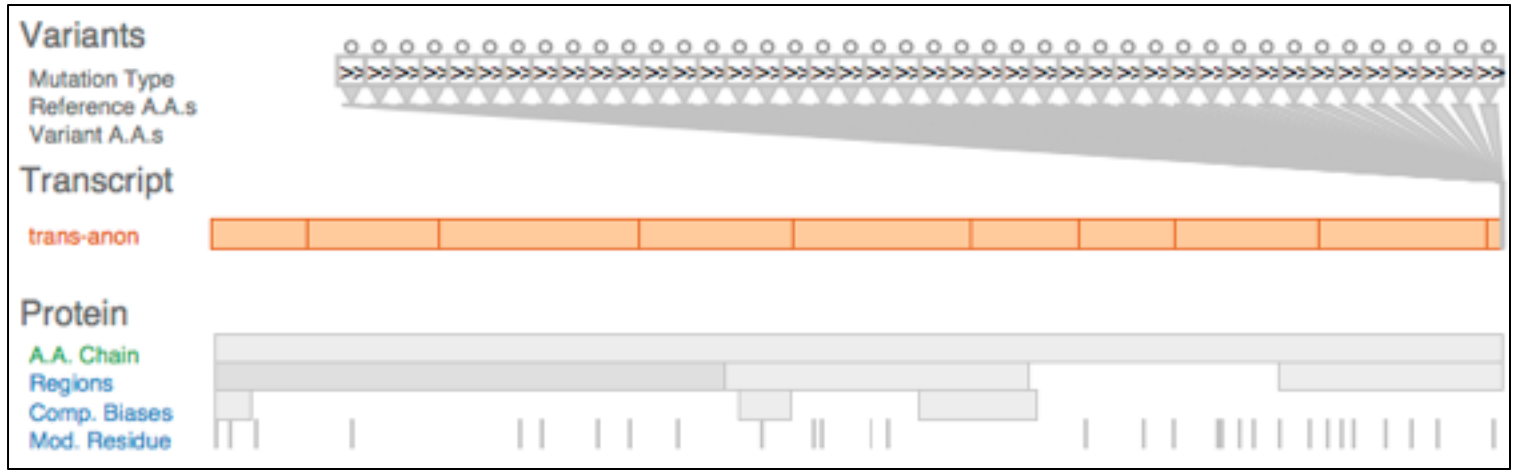
Human-centered approaches in geovisualization design: investigating multiple methods through a long-term case study.
Lloyd and Dykes. IEEE TVCG (Proc. InfoVis), 17(12):2498–2507, 2011.

Phase 3: Two More Tasks

1 month

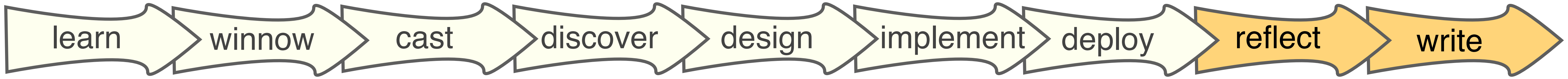
- two new analysts
  - connected by enthusiastic gatekeeper
- new task abstractions
  - compare patients
  - debug pipeline
- transferrable with minimal changes





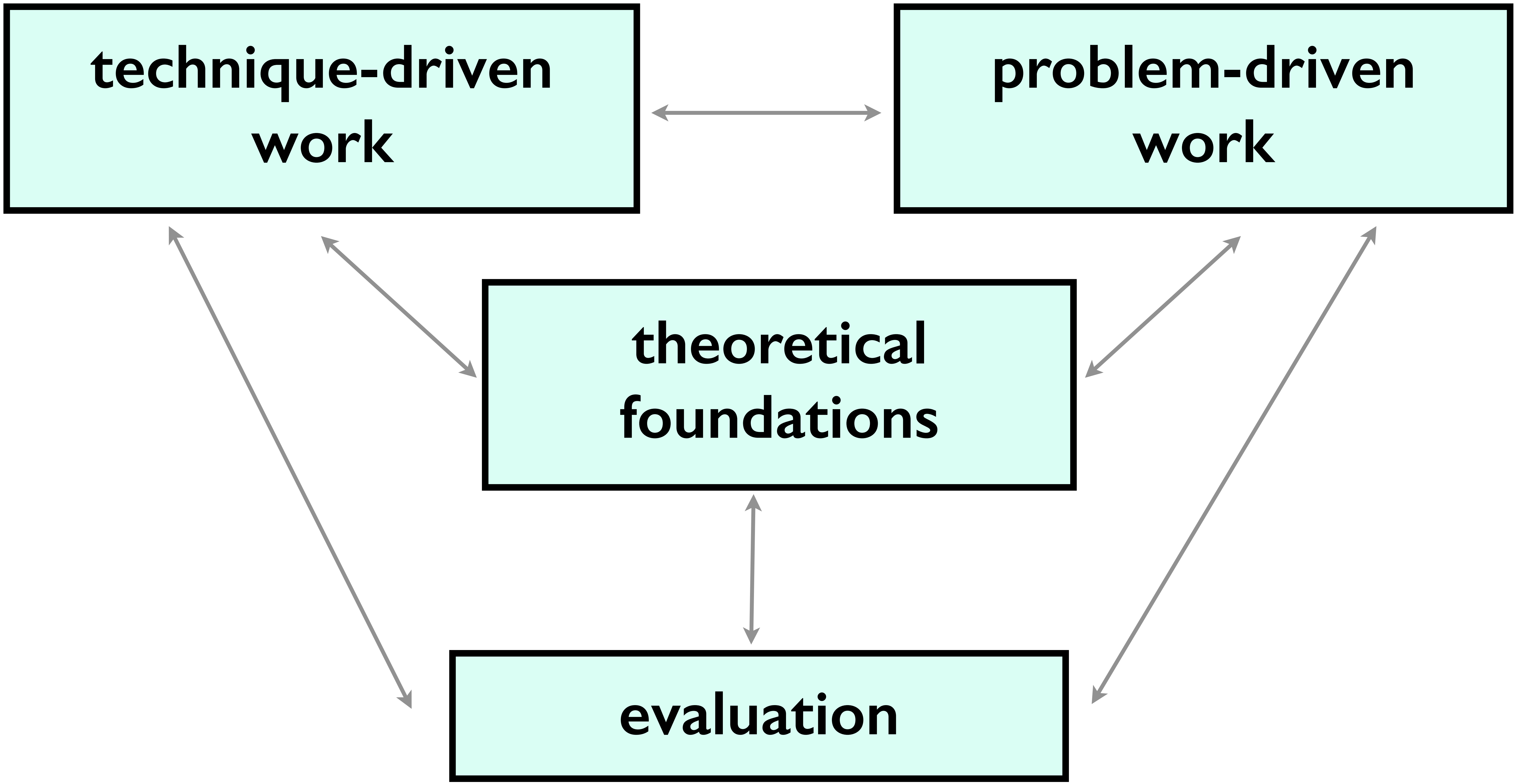
Phase 4: Reflect and write

3 months



- abstraction innovation
  - data abstraction: highly filtered *transcript coordinates* (vs genome coordinates)
- guidelines
  - specialize first, generalize later
    - good for domains with complex data
  - high-level considerations
    - identifying scales of interest
    - what to visually encode directly vs what to support through interaction
    - when (and how) to eliminate navigation

A quick taste of other work!



Problem-driven: Genomics

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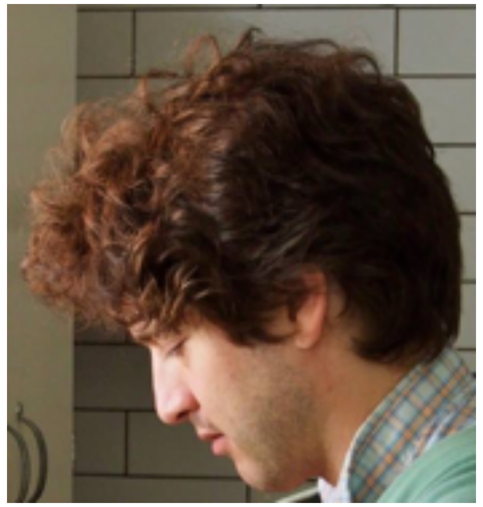
Aaron Barsky



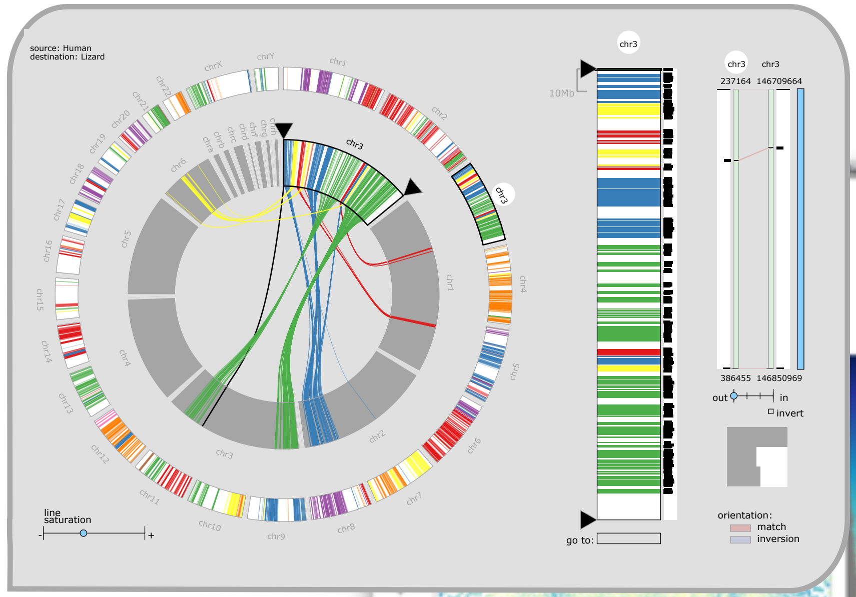
Jenn Gardy (Microbio)

Robert Kincaid (Agilent)

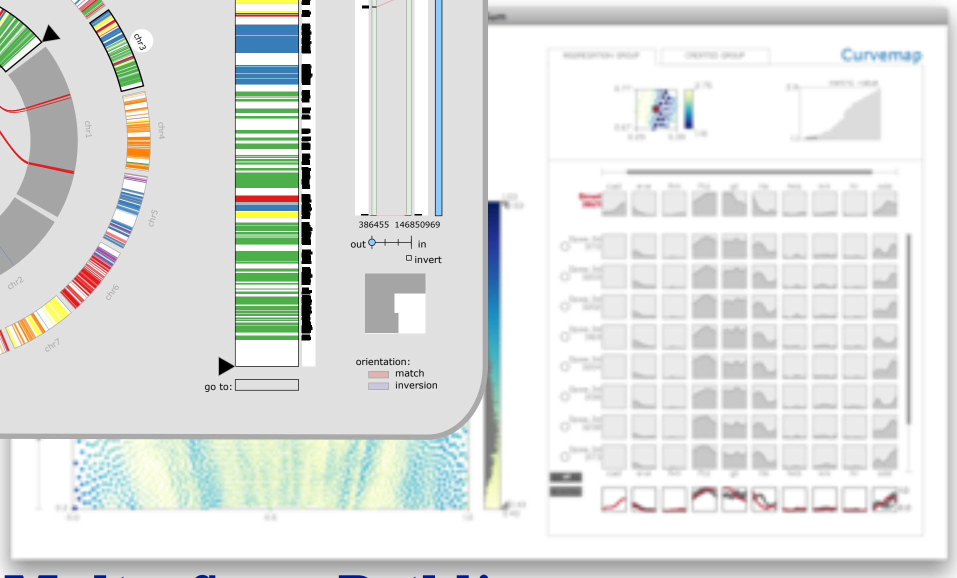
Cerebral

Miriah Meyer

Hanspeter Pfister (Harvard)



MizBee



MulteeSum, Pathline

Problem-driven: Genomics, fisheries

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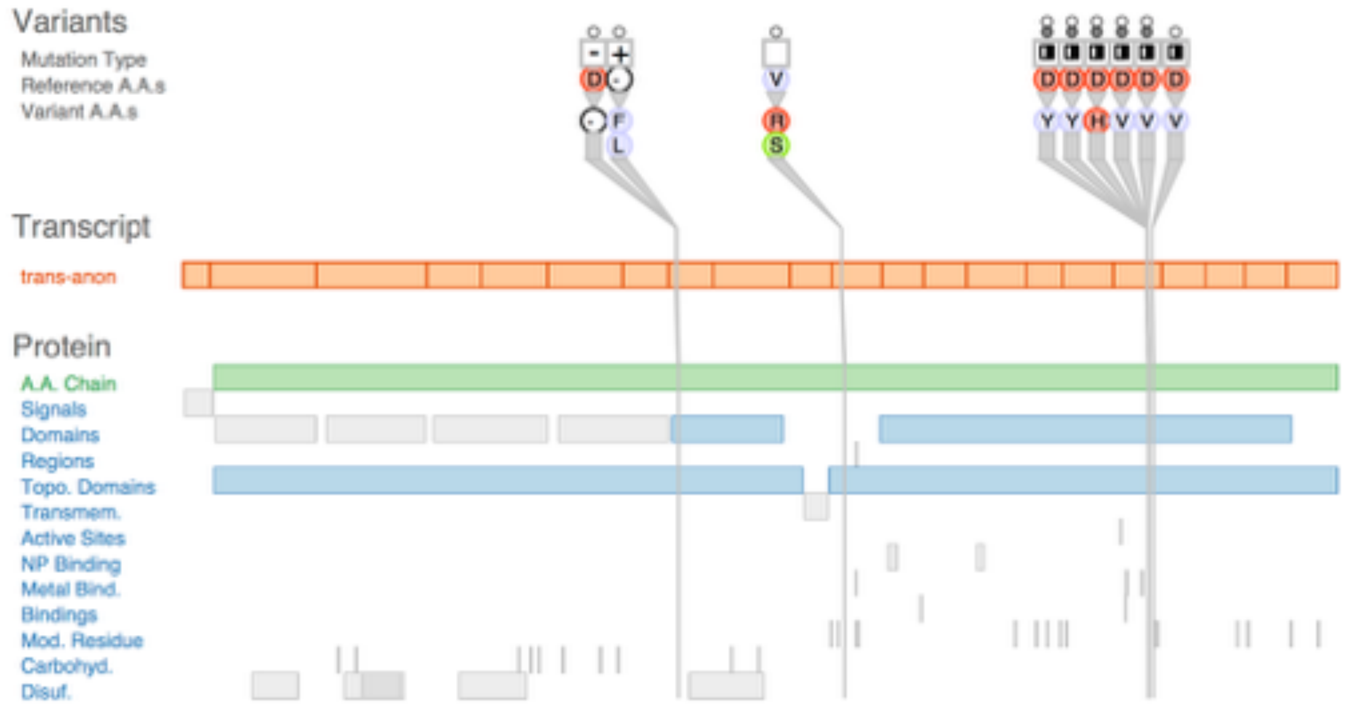
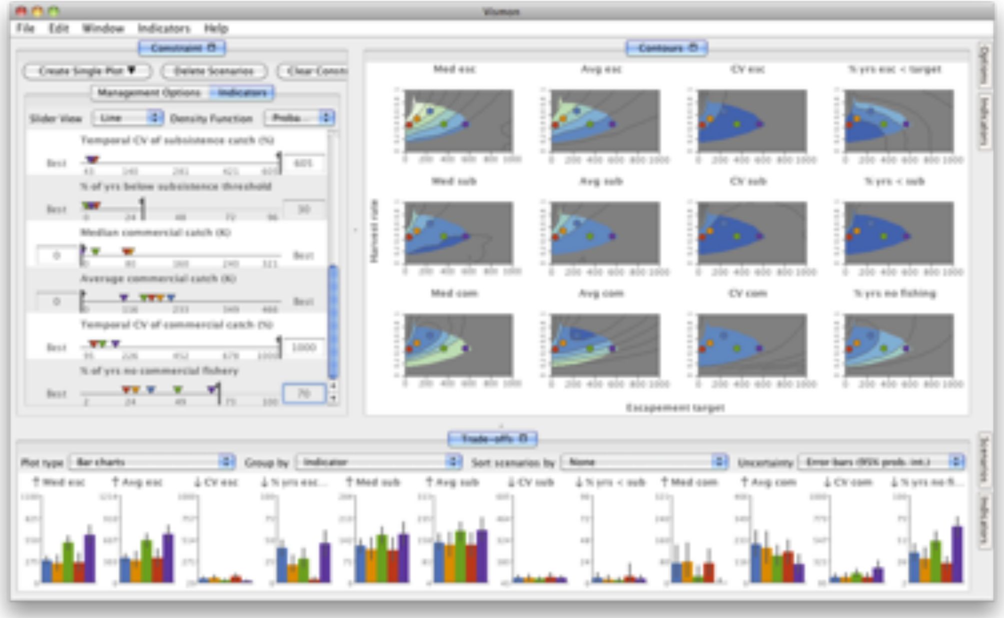
Joel Ferstay

Cydney Nielsen (BC Cancer)



Variant View



Vismon

Maryam Booshehrian

Torsten Moeller (SFU)

Problem-driven: Tech industry

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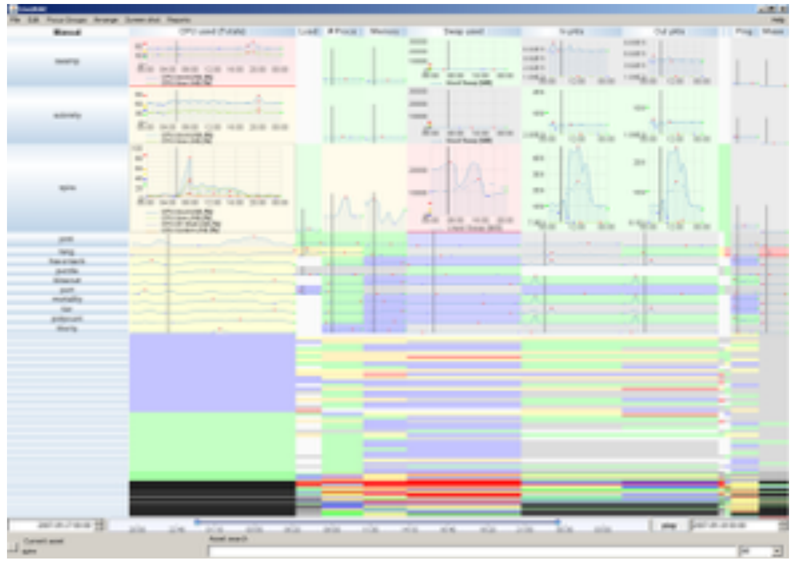
SessionViewer: web log analysis

Heidi Lam

Diane Tang (Google)

Peter McLachlan

Stephen North (AT&T Research)



LiveRAC: systems time-series

Problem-driven: Journalism

T F E P

Matt Brehmer

Stephen Ingram

Jonathan Stray
(Assoc Press)

Overview

Technique-driven: Graph drawing

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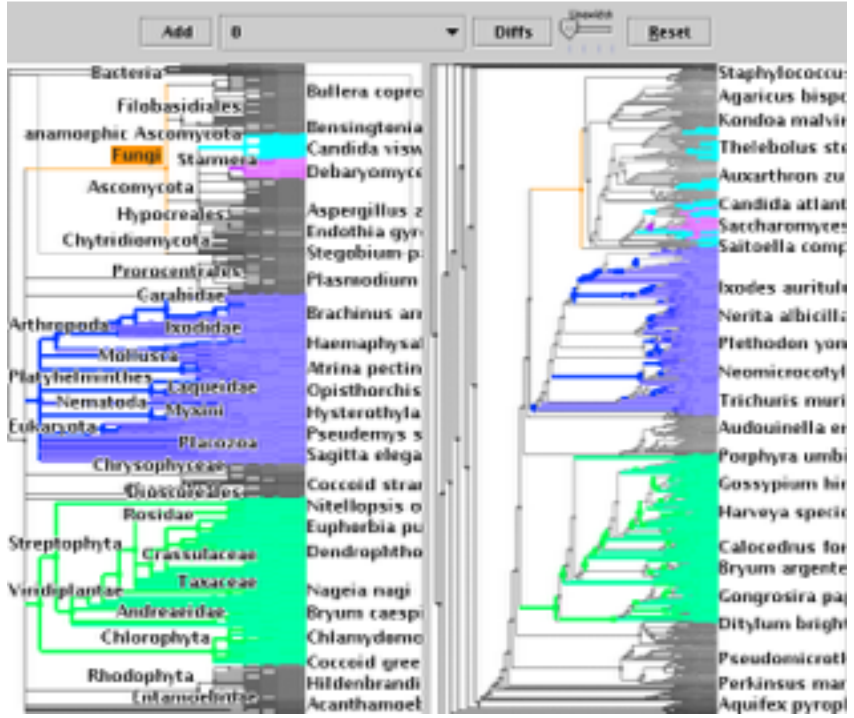


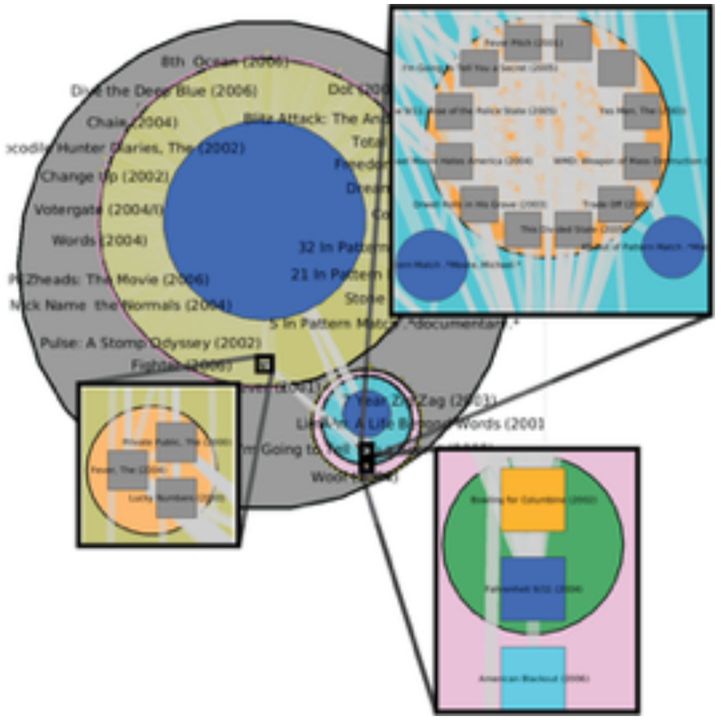
TreeJuxtaposer

James Slack

Kristian Hildebrand

Daniel Archambault

David Auber (Bordeaux)



TopoLayout
SPF
Grouse
GrouseFlocks
TugGraph

Evaluation: Graph drawing

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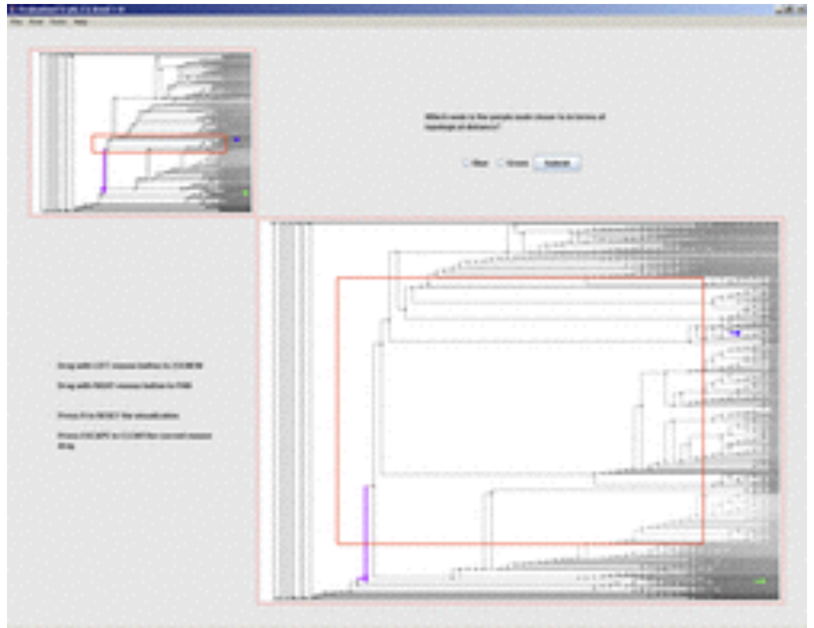
Dmitry Nekrasovski

Adam Bodnar

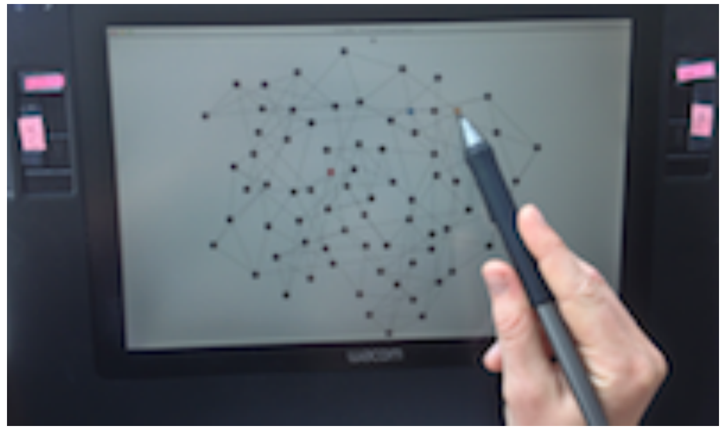
Joanna McGrenere (UBC)



Stretch and squish navigation

Jessica Dawson

Joanna McGrenere (UBC)



Search set model of path tracing

Technique-driven: Dimensionality reduction

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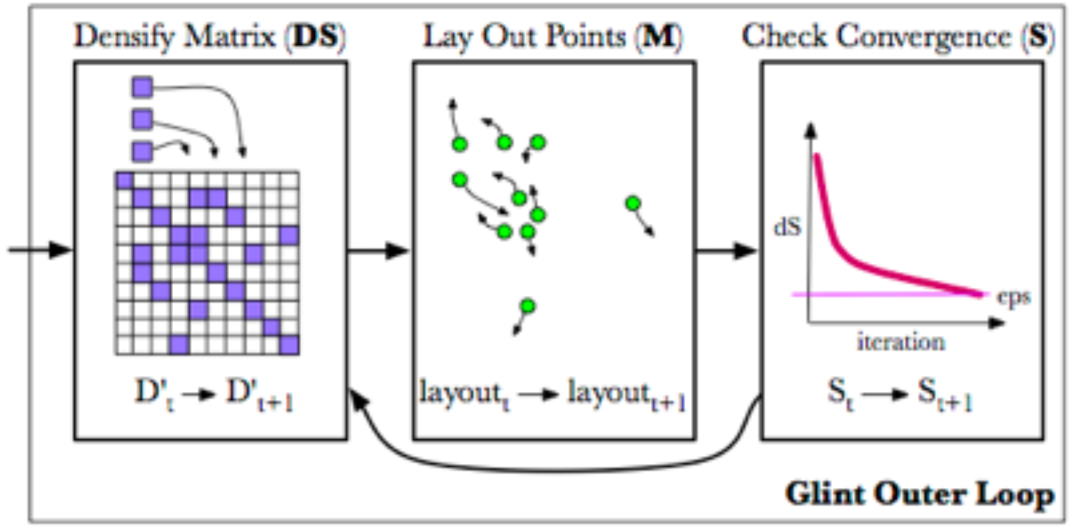
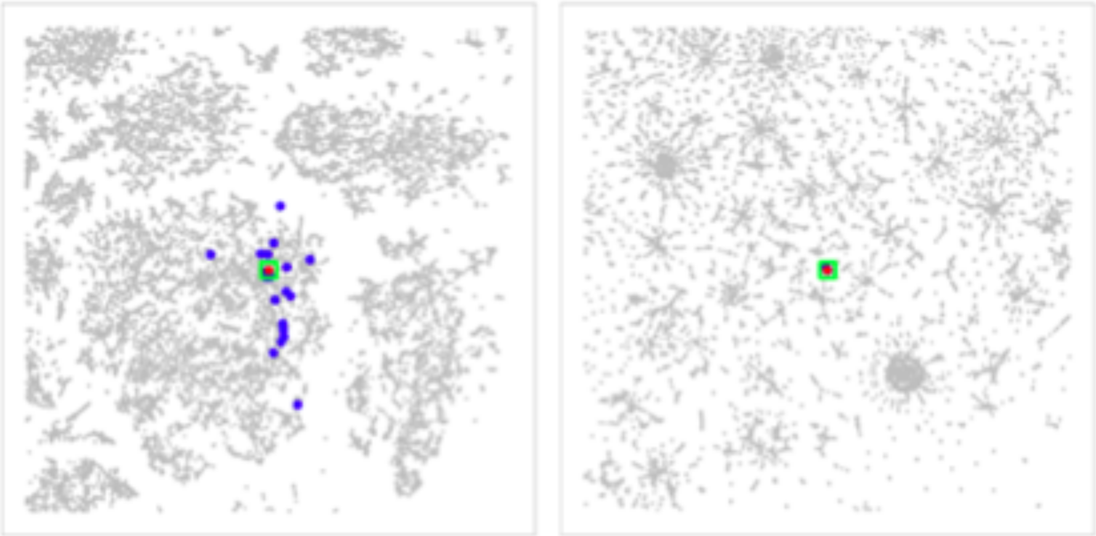
Stephen Ingram

Glimmer

DimStiller



Glint

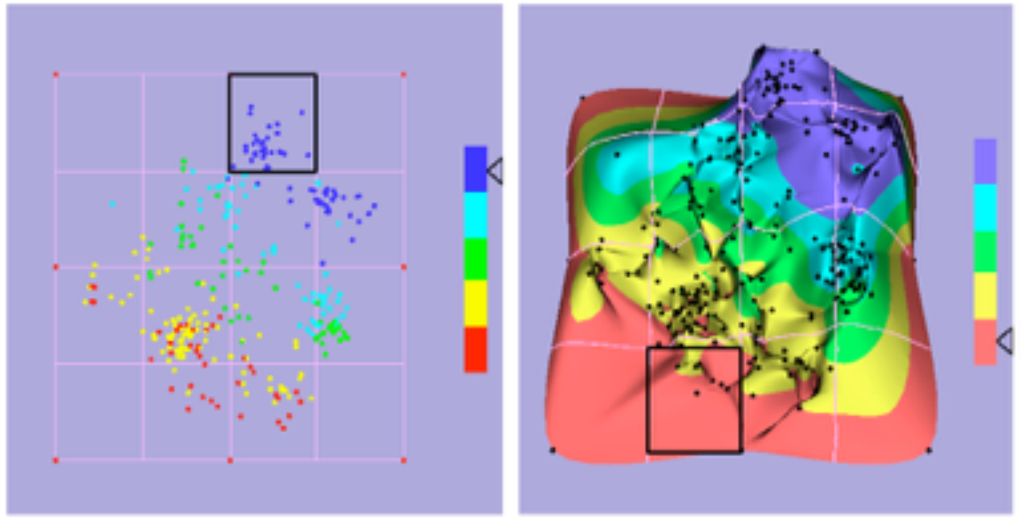


QSNE

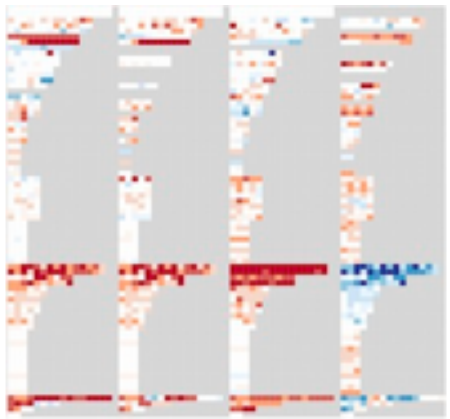
T F E P

Evaluation: Dimensionality reduction

Melanie Tory



Points vs landscapes for dimensionally reduced data



Guidance on DR & scatterplot choices

Michael Sedlmair

Melanie Tory (UVic)

Taxonomy of cluster separation factors

Evaluation: Focus+Context

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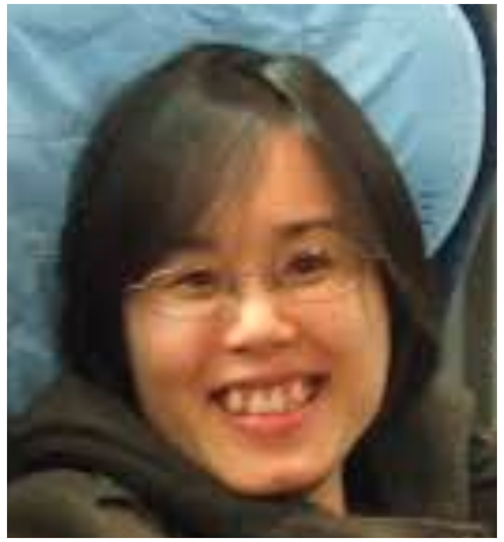
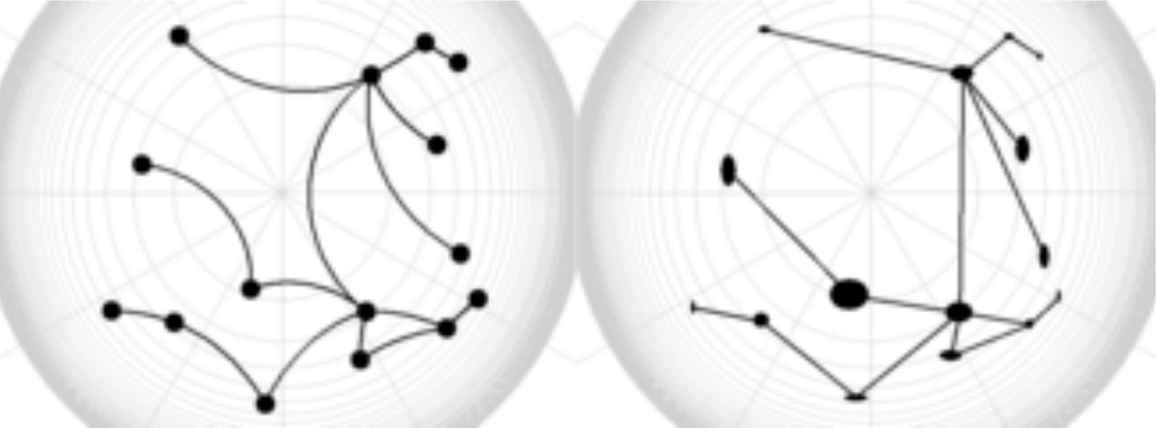
Heidi Lam

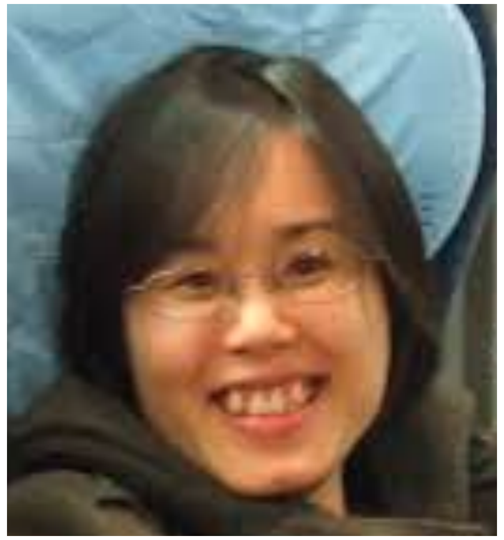


Ron Rensink
(UBC)

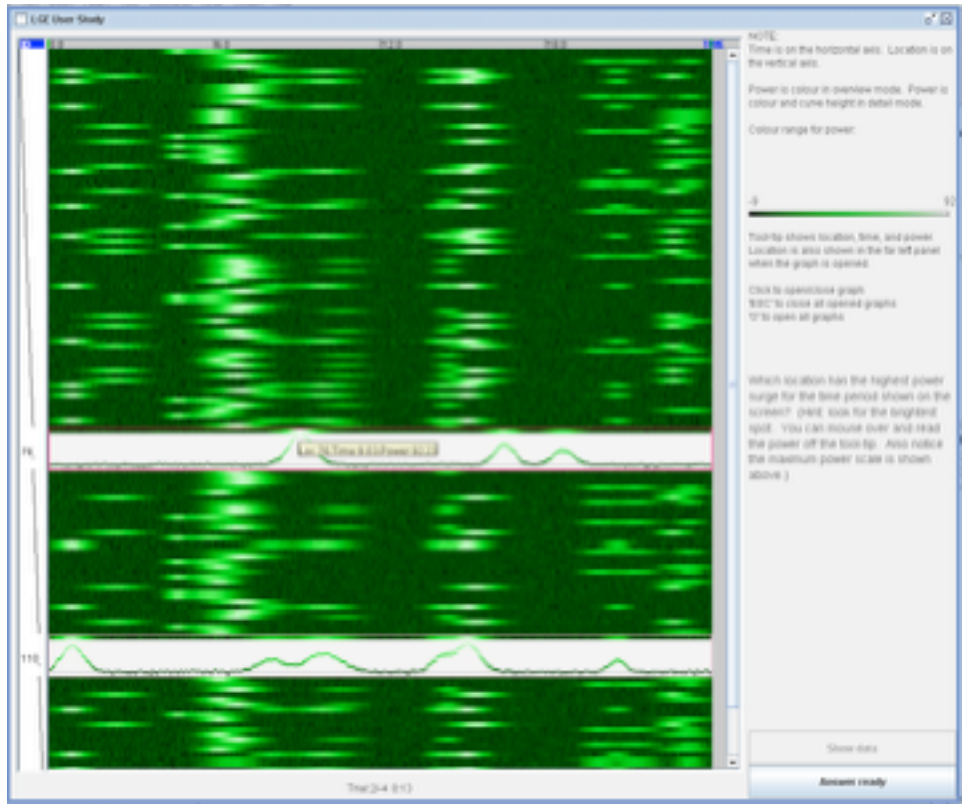


Distortion impact on search/memory

Heidi Lam



Robert Kincaid
(Agilent)



Separate vs integrated views

Curation & Presentation: Timelines

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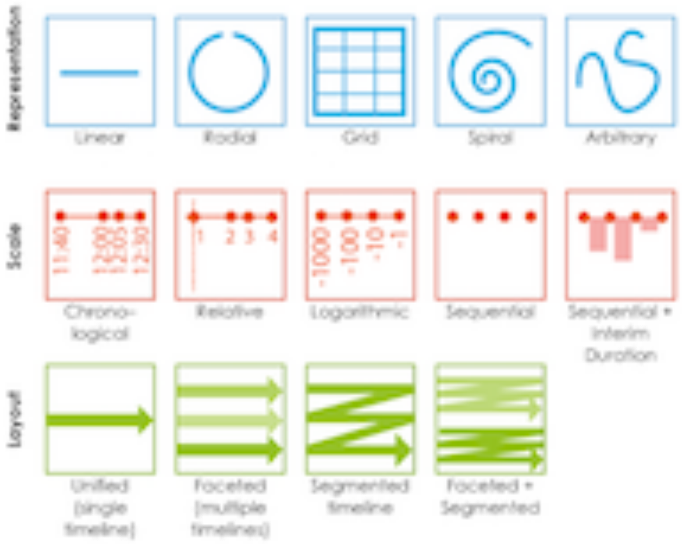
TimeLineCurator

https://vimeo.com/123246662



Timelines Revisited

timelinesrevisited.github.io/

Johanna Fulda
(Sud. Zeitung)

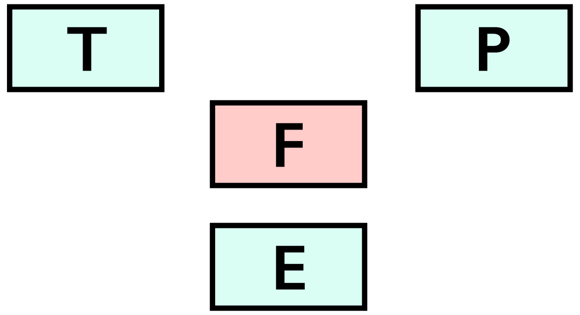
Matt Brehmer

Bongshin Lee
(Microsoft)

Benjamin Bach
(Microsoft)

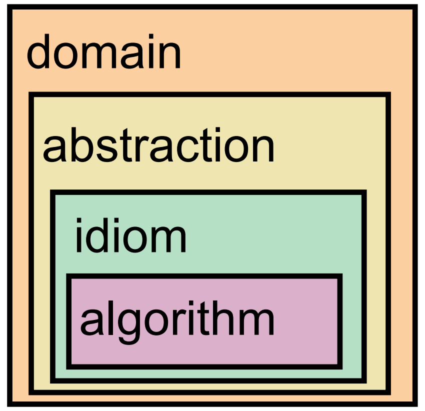
Nathalie Henry-Riche
(Microsoft)

Theoretical foundations

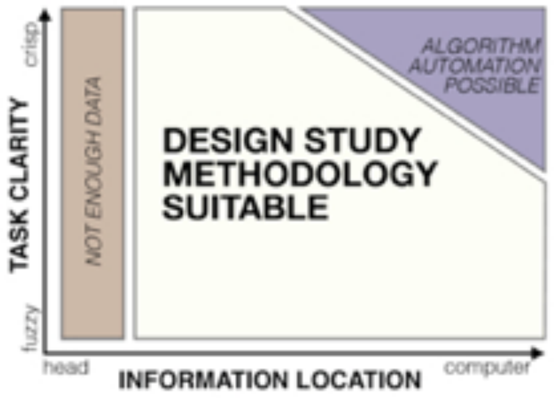


- Visual Encoding Pitfalls
  - Unjustified Visual Encoding
  - Hammer In Search Of Nail
  - 2D Good, 3D Better
  - Color Cacophony
  - Rainbows Just Like In The Sky
- Strategy Pitfalls
  - What I Did Over My Summer
  - Least Publishable Unit
  - Dense As Plutonium
  - Bad Slice and Dice

Papers Process & Pitfalls



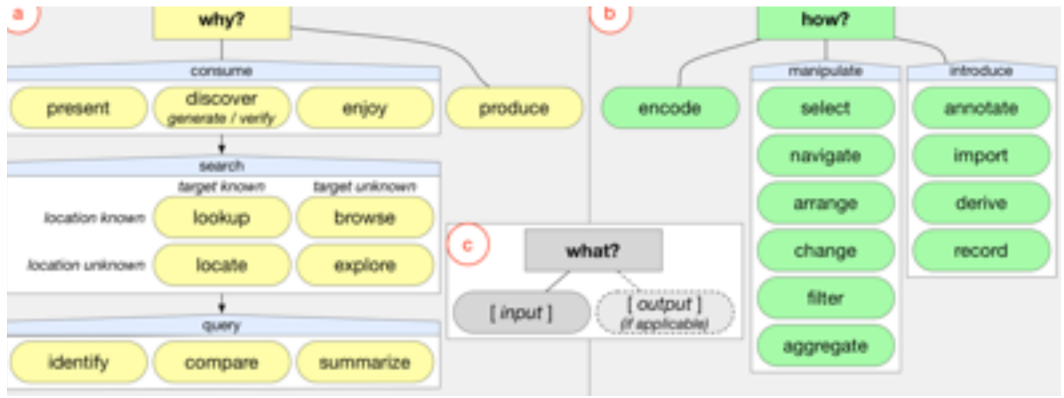
Nested Model



Design Study Methodology

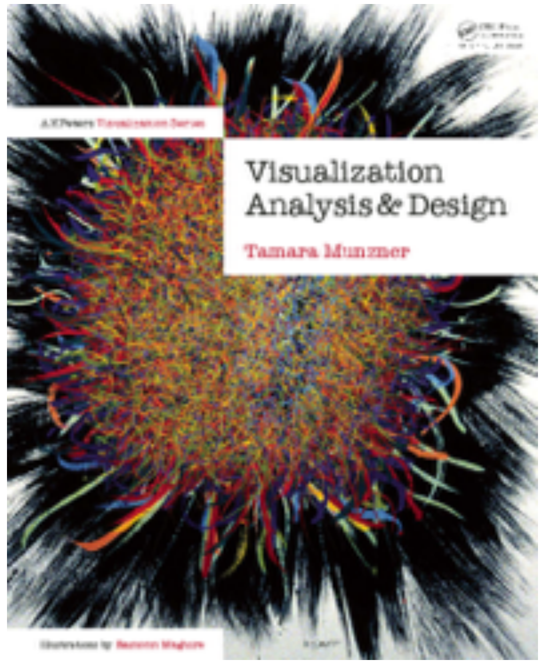
Michael Sedlmair

Miriah Meyer



Abstract Tasks

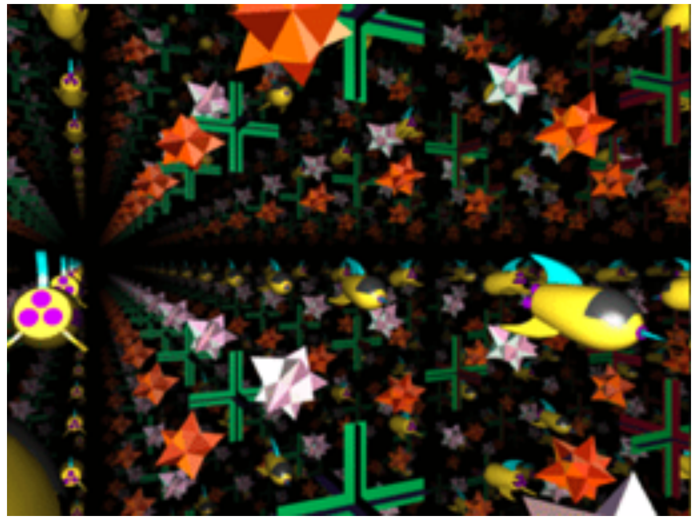
Matt Brehmer



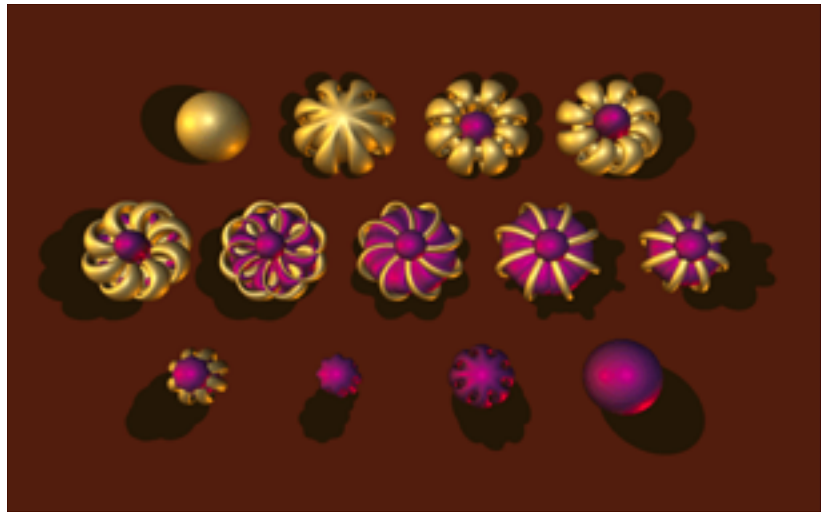
Visualization Analysis & Design

Geometry Center 1990-1995

Geomview



The Shape of Space



Outside In

Charlie Gunn

Stuart Levy

Mark Phillips

Delle Maxwell

Wrap-up

- models and methods for design and validation
  - collaboration incentives for vis and bio
- example biovis project
  - Variant View
- methodological dream:
  user-centered design spreading from vis to biovis to bioinformatics
  - task/requirements analysis for *all* tools, not just visual ones
  - focus on both utility and usability

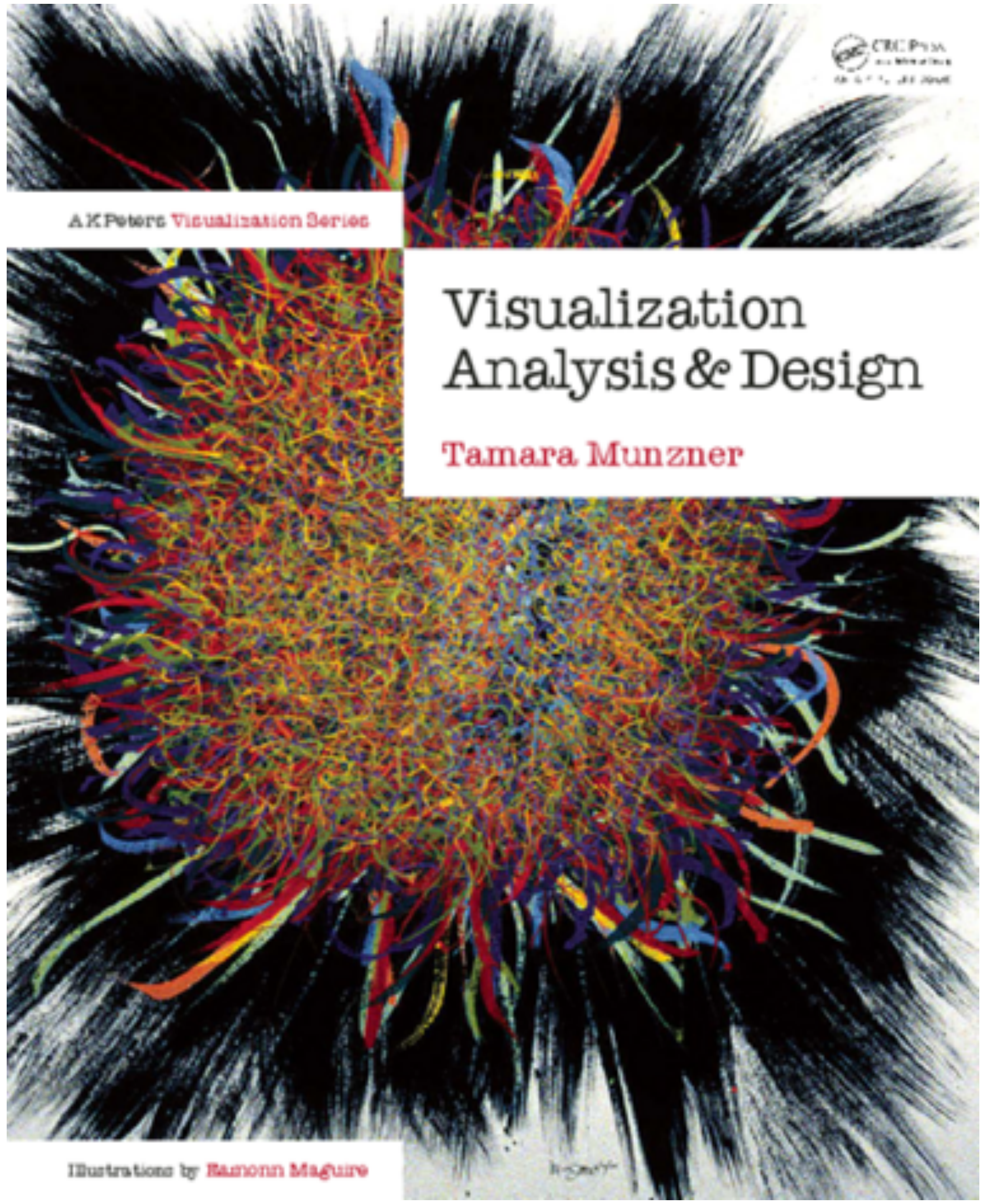
More information

@tamaramunzner

- this talk
  http://www.cs.ubc.ca/~tmm/talks.html#clayton17

- papers, videos, software, talks, courses
  http://www.cs.ubc.ca/group/infovis
  http://www.cs.ubc.ca/~tmm

- theoretical foundations: book
  (+ free tutorial/course lecture slides)
  http://www.cs.ubc.ca/~tmm/vadbook
  – 20% promo code for book+ebook combo: HVN17
  – http://www.crcpress.com/product/isbn/9781466508910



Visualization Analysis and Design.
Munzner. A K Peters Visualization Series, CRC Press, Visualization Series, 2014.