CMR reporting – clinical practice, unmet need

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DOI

Corelab director (using AI for pharma studies)

Clinical care: the clinic room

Make/confirm diagnosis(es)

- Accuracy:
  - sub-types & exclude phenocopies
  - Know what normal is

Assess symptoms

- mechanisms & plan treatment

Evaluate prognostic risks

- SCD, stroke, heart failure

Family screening

- genetics and altered diagnosis thresholds

Choose and agree on the right precision therapy

- mitigate/cure underlying pathophysiology

Monitor disease response

- Precision:
  - for interval change

Imaging key to cardiac diagnoses

Heart locked away in the chest

We almost never biopsy it

Only 2 blood biomarkers
– BMP, troponin

ECG/functional tests useful but remote from underpinning biology

Genetics
- only now emerging
- tells you lifetime risk

Diagnosis + therapy = improved outcomes

The CMR report at the heart of care

- signalling two things:
  - the findings
  - uncertainty
- BUT

  Clinicians don't just report findings – trying to influence care

  Pre-test probability (Bayes' theorem)

  - patient biology, other results, barriers to testing (too high/too low)

  Measurement imprecision

  -CMR, other imaging

  Distance of measurements from biology and pathways

  Poor Standardization

  Poor integration with other data

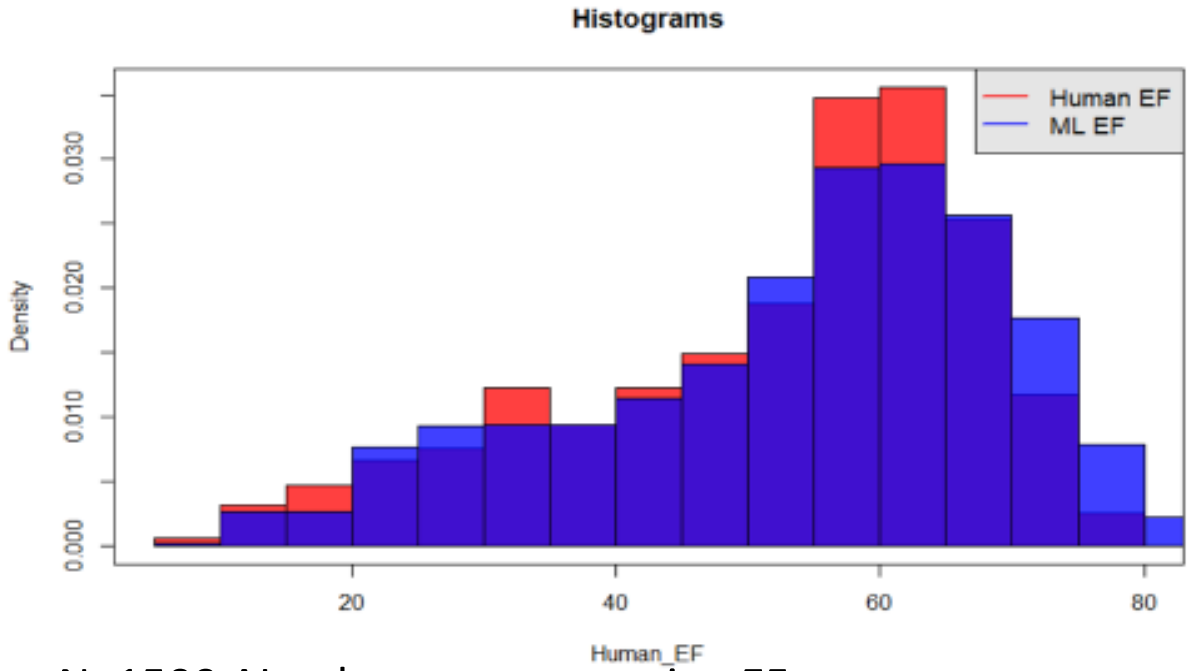
  Poor linking to therapy

Human reporting behaviour

Clinicans

- not objectively reporting
  - eg the ejection fraction
- trying to influence outcomes
  - for this patient
  - for the service

Humans distort results and vary attention



N=1500 AI vs humans measuring EF

This model: more precise than humans

Yet

a) humans skew the graps at 35-40% and at 55-60%

b) Human EF was BETTER predictor than machine (!)

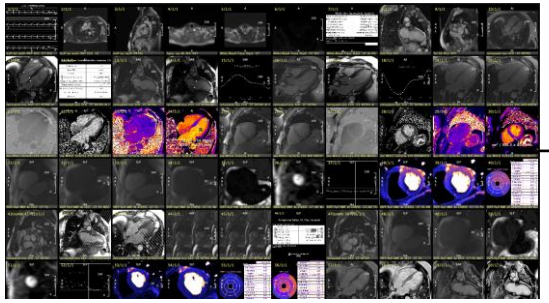
Davies R - unpublished

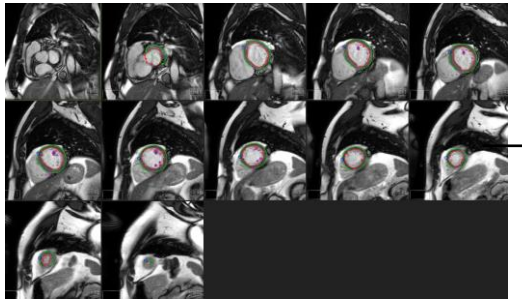
Current CMR workflows

Scan request

Scan acquisition

Reporting software
Reliant on **high spec hardware** with **co-managed server**





Manual acquisition
2 Expert radiographers
(45 minutes)

Image manipulation
Manual data entry
(15 minutes)

Manual measurements
(10 minutes)

Expert interpretation
(10 minutes)

Total acquisition timeAT/ scan = 45 mins
Capacity per scanner/ day = 13 scans
Volume/scanner/year = 3,315

Total reporting time = 35 mins
Capacity per consultant 4 hour session = 6.2 scans
Total scans per year about 272 scans per session

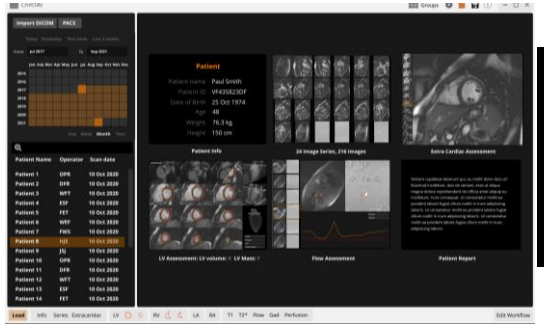
Future workflows

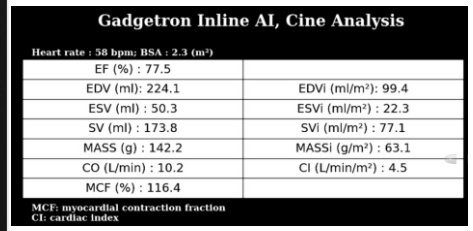
Scan request

Scan acquisition

AI deployed acquisition
(1 Expert radiographer)
(30 mins)

Reporting software
Reliant on **high spec hardware** with **co-managed server**





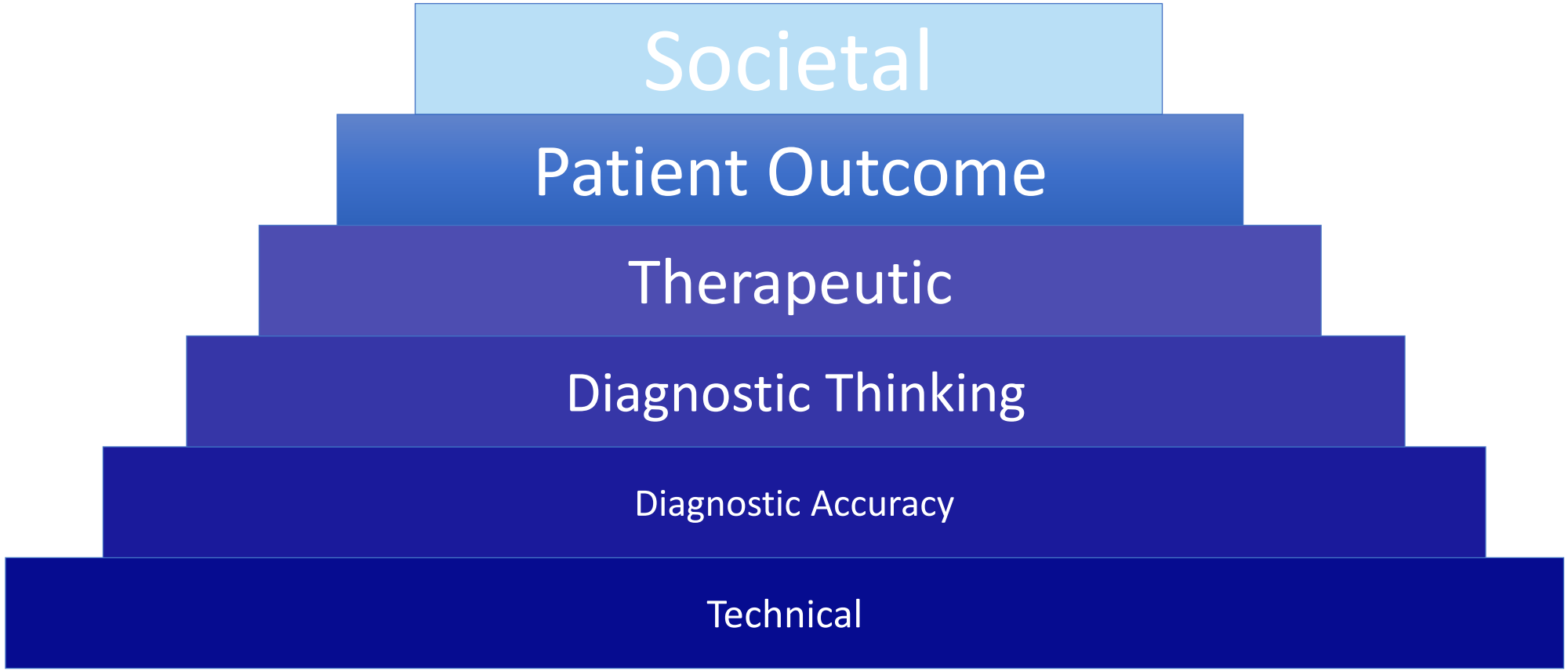
Automated image manipulation
AI measurements with human QC
(1 minute)

Expert interpretation
(10 minutes)

Total TAT/ scan = 30 mins
Capacity per scanner/ day = 19 scans
Volume/scanner/year = 4,875
(7 day week working = 6,650)

Total reporting time = 11 mins
Capacity per consultant 4 hour session = 15 scans
Total scans per year about 675 scans per session

Improve outcomes?
The Efficacy of Diagnostic Imaging



Fryback and Thornbury 1991

Need to understand

The normal heart

The abnormal heart

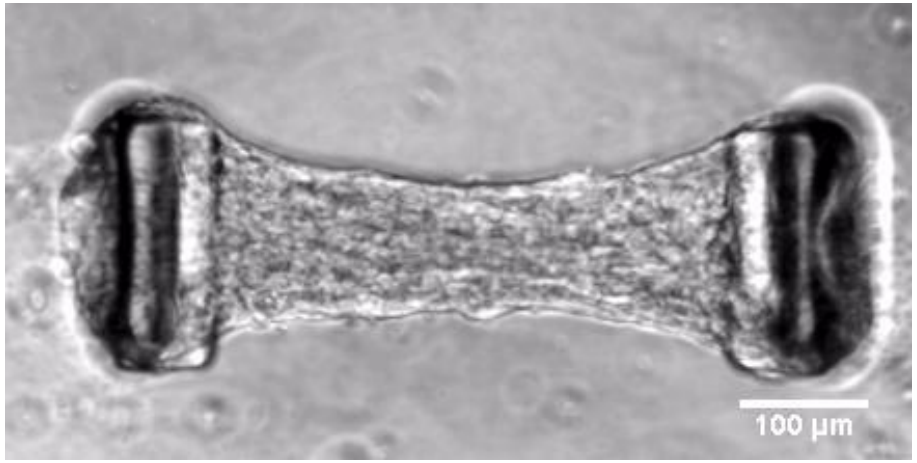
Measurement science

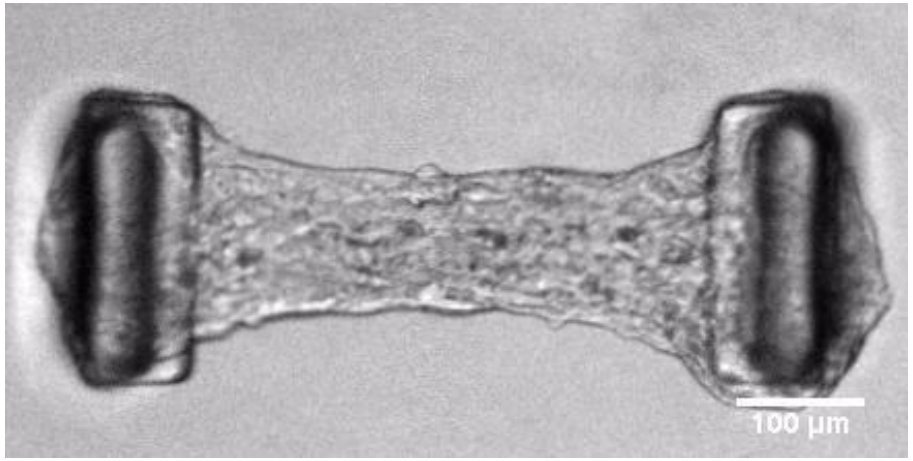
Existing tests

Existing care

What does the heart have to do? (My list)

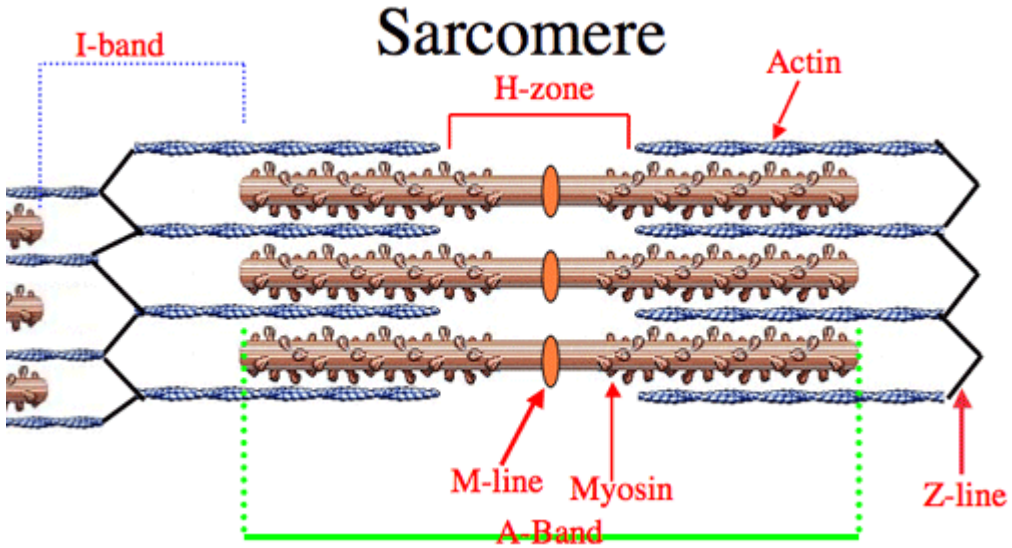
Be built
Grow
Low energy at rest
High output at stress
Adapt
Evolutionary toolkit





Normal vs titin

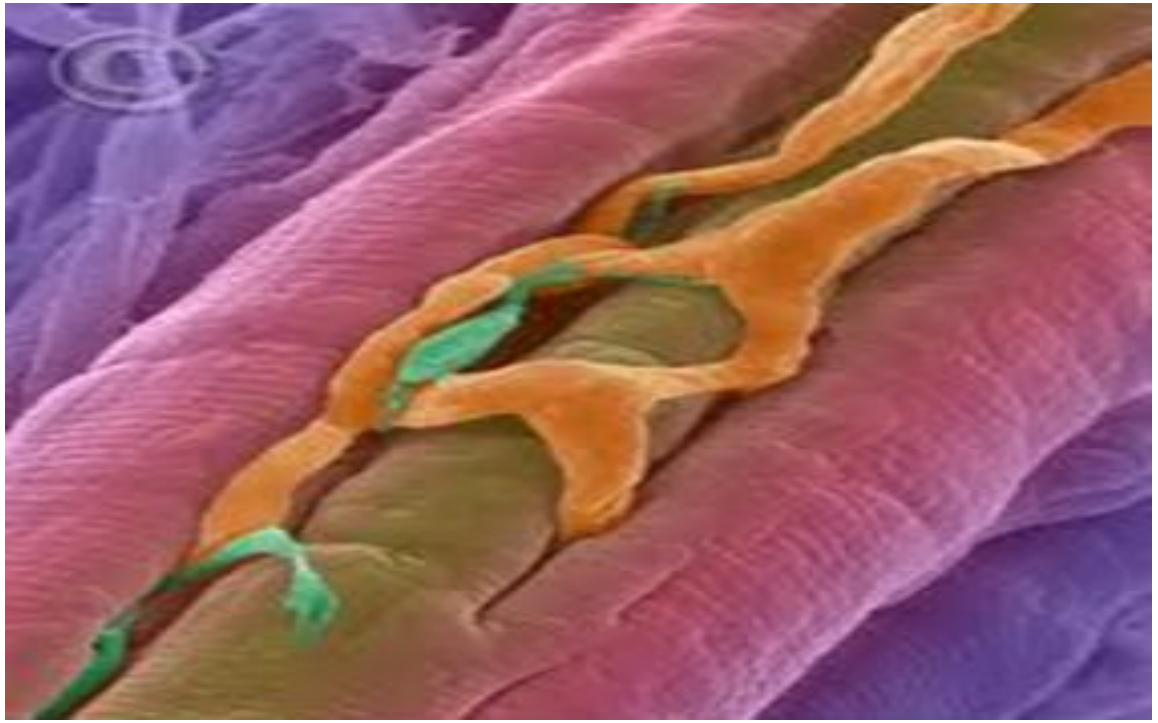
The Myocyte



~13 contractile proteins
5000 proteins
Of ~26000 genes
Mutate each one: 15% - cardiac phenotype

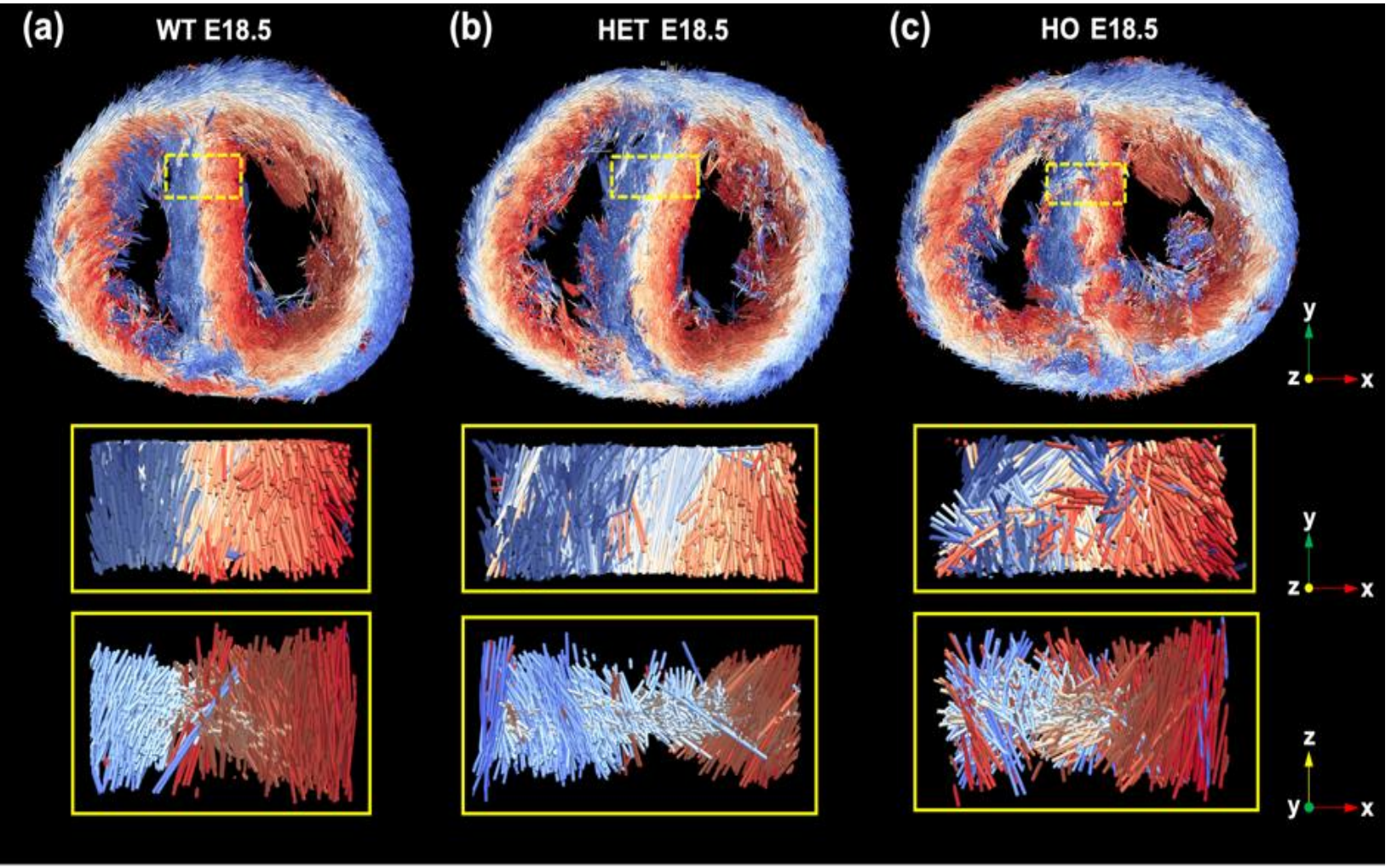
A pair of cells: the Myocyte and Capillary

Fundamental building block

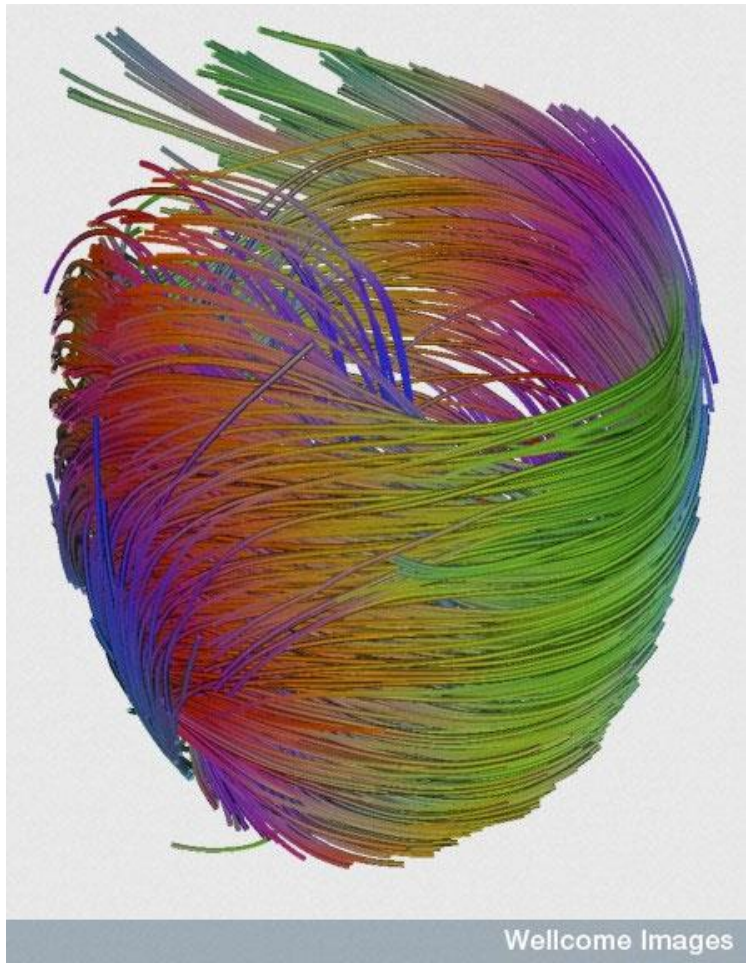


Am J Respir Crit Care Med. 2017 Oct 15;196(8):1075-1077.
Right Ventricle Vasculature in Human Pulmonary Hypertension Assessed by Stereology.

Myocytes into Fibrils



Myoarchitectural disarray of hypertrophic cardiomyopathy begins pre-birth

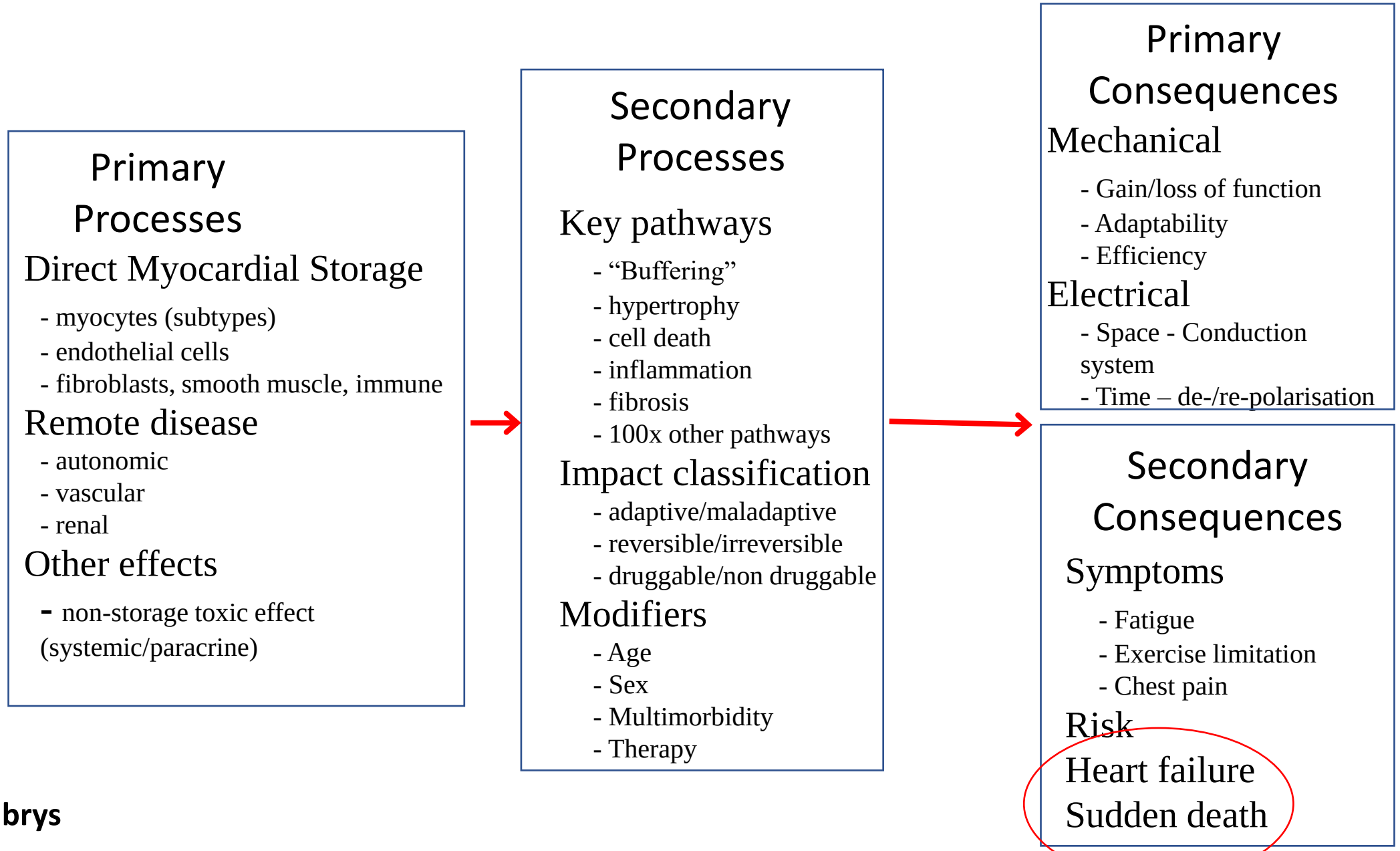


The beating heart

Cardiac function

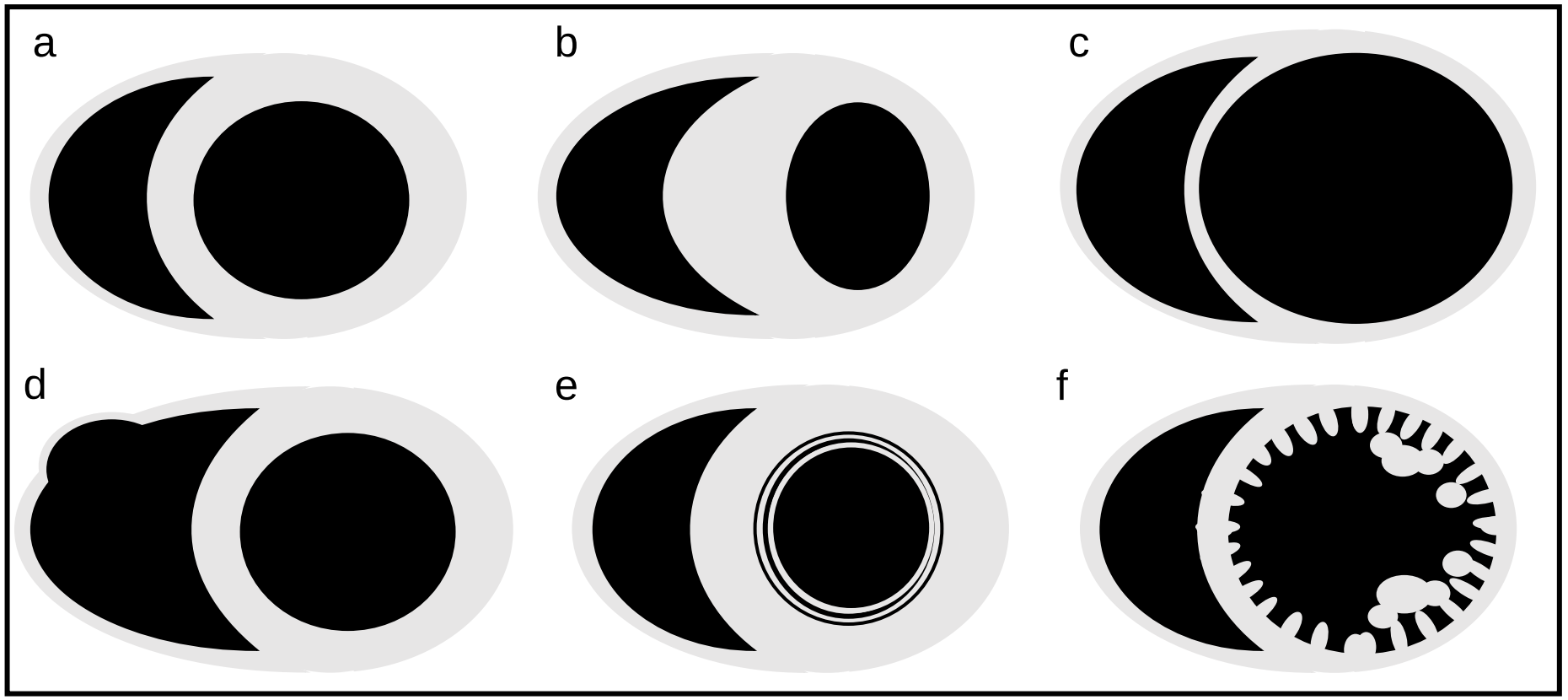
Acknowledgements: Heartworks

Disease – a framework



Here Fabrys

Current cardiology defined too much by Structure and function

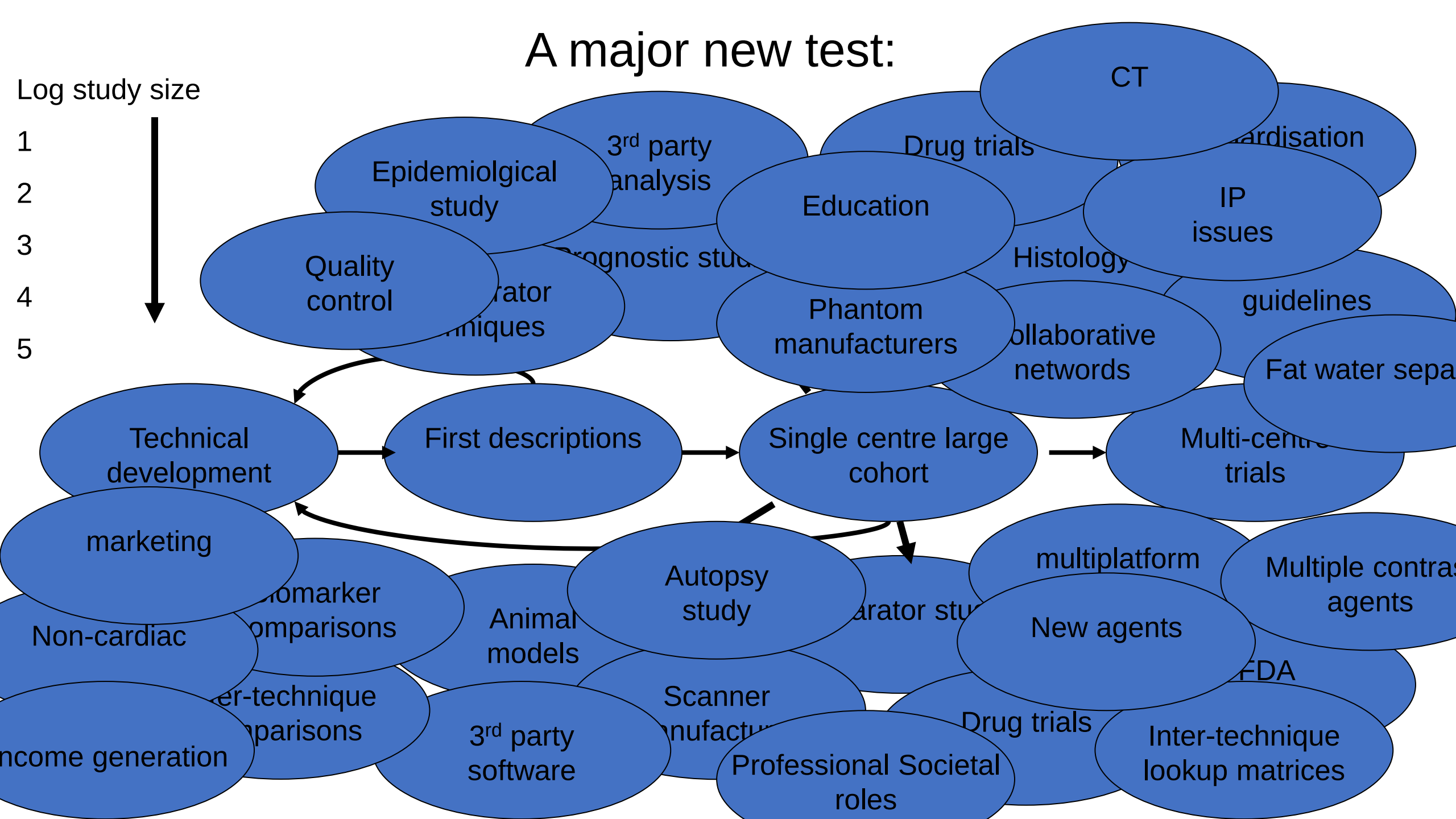


Structure/function a long way away from biology

Test measurement milestones

1. Technical development and theoretical basis of test
2. Direct comparison (eg biopsy, animal models, human autopsy)
3. Detection of changes in established disease compared to normals
4. Correlation with known cardiac markers of (eg echo, imaging parameters)
5. Correlation with known biomarkers (eg blood biomarkers)
6. Demonstration of the test in more than one clinical scenario
7. Demonstration of test sensitivity (early disease or with age)
8. Demonstration of the ability to track change (with time, after Rx)
9. Demonstration of predictive or prognostic value of the test
10. Standardisation of the test
11. Development of robust age/ethnic normal reference ranges
12. Changes in biomarker remain tied to the disease after treatment
13. Demonstration of the test as a surrogate trial endpoint.
14. Clinical use and regulatory approval of the test.
15. Proof test use improves clinical outcome

A major new test:



Understand Metrology - What is good test?

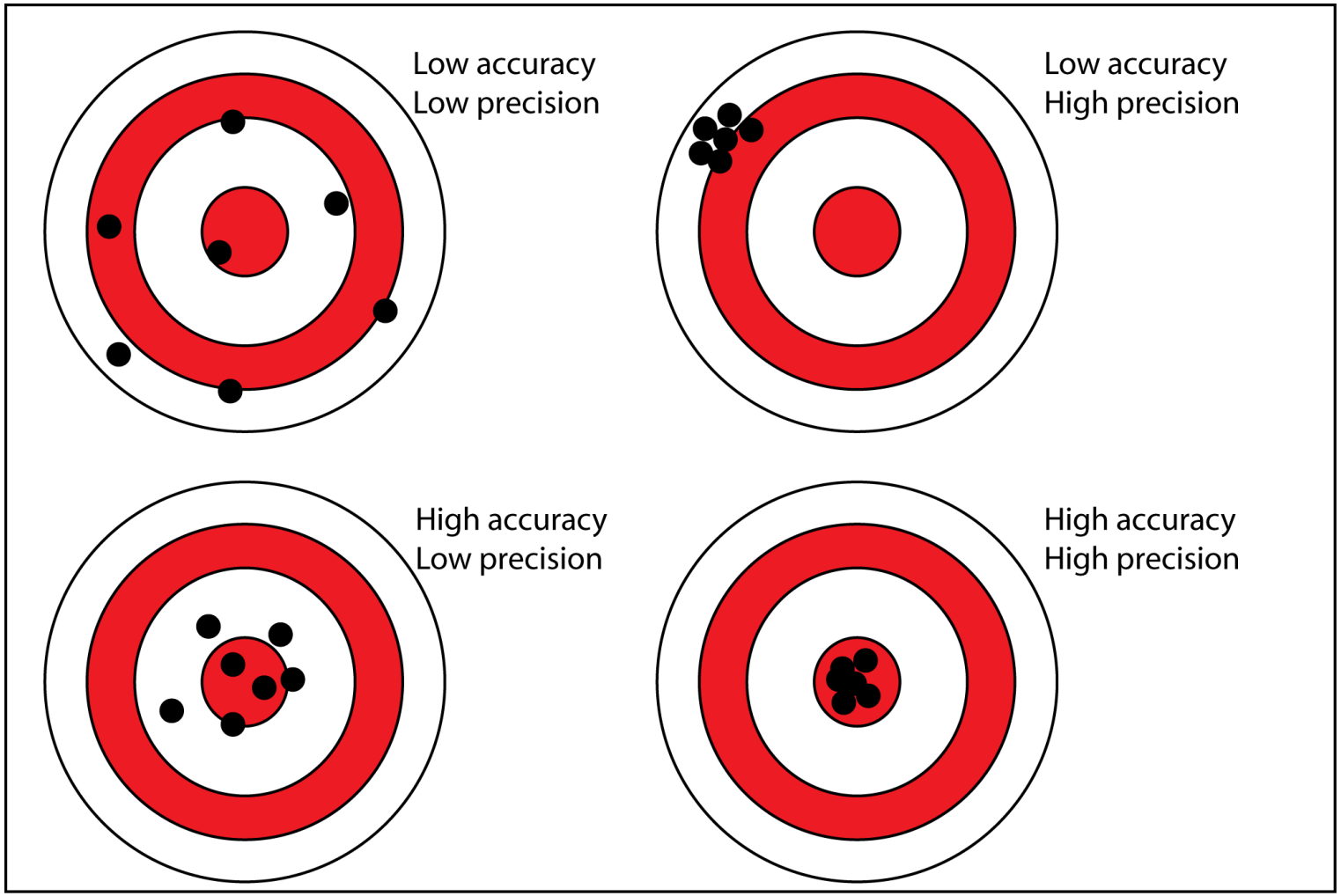
Truth standards - None for the heart

Plausibility
- Clinical does it look right? Agreement with clinician
  - cannot be “superhuman”
- Scientific
  - logical basis (eg of geometric assumptions)
- Social
  - cost/convenience/control/applicability/risk/availability

Precision
- Repeatability
  - interstudy not interobserver
  - smallest detectable difference,
  - power calculation

Biology - Correlations, predictive power
  - causality, treatment target, interval change

Accuracy vs Precision

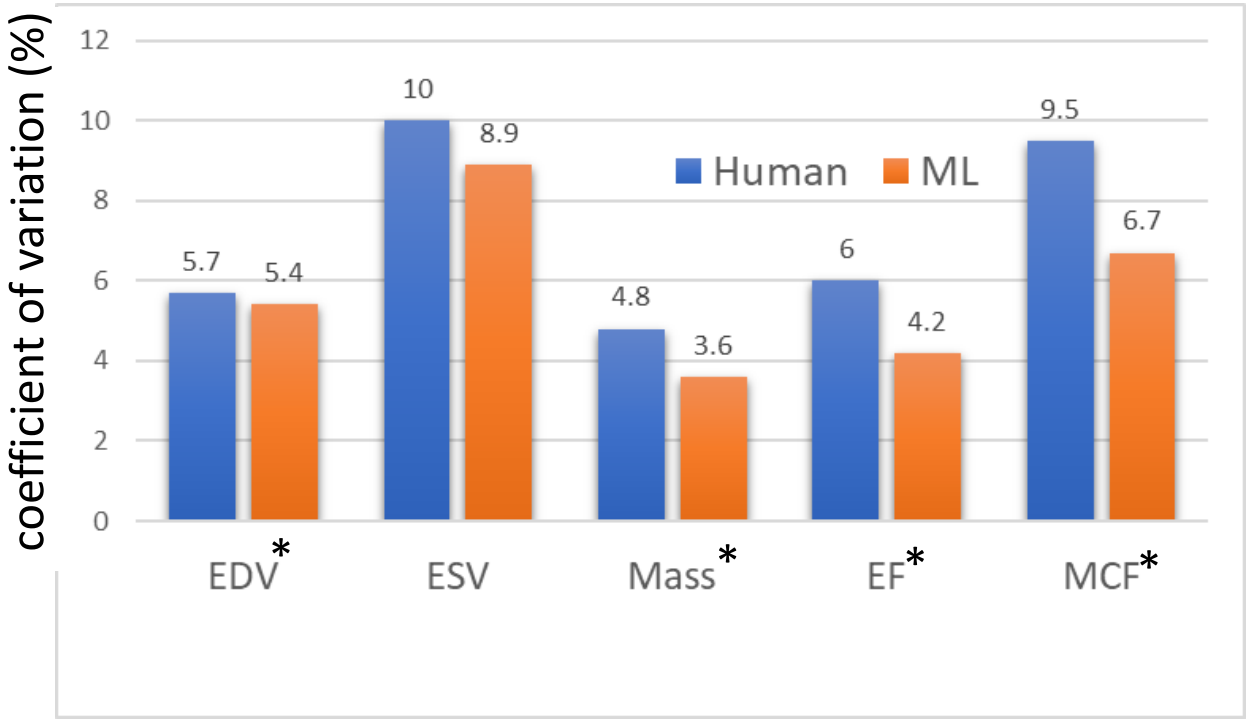


Where am I now?

Vs

Where am I heading?

Our tests not very good:
Here Precision: Scan Re-scan Repeatability



Cardio-toxicity definition: a 10% fall

Cardiology strategies

Ms AB

77yrs♀

2013

Breast Ca + mets
Her2 +ve

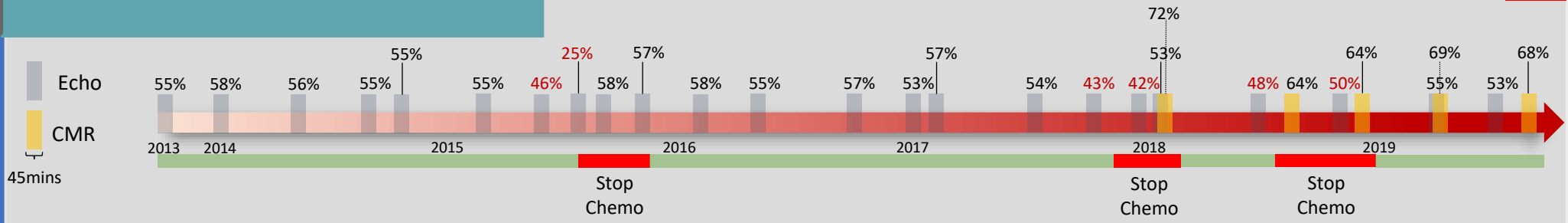
℞

Surgery + Chemo
then
Herceptin for life
+ cardiac monitoring

~55,000 patients pa
Infarction, heart failure, cardiomyopathy
1 million echos
100,000 CMR

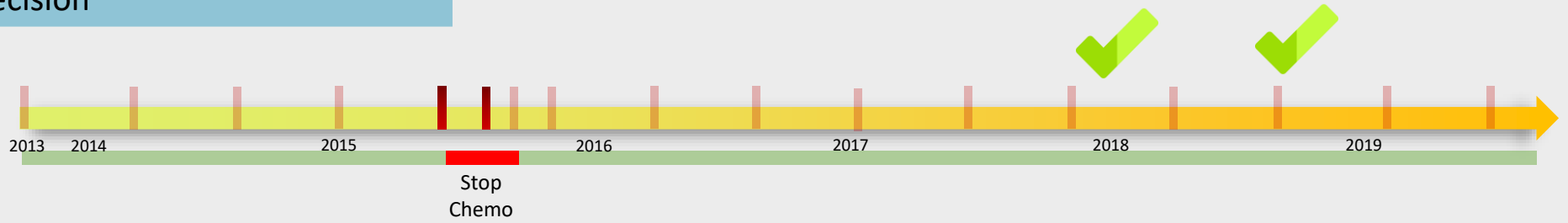
Current

3



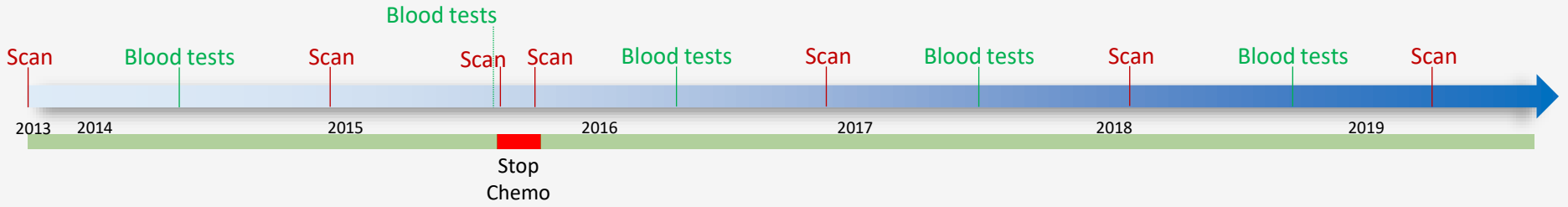
Future Phase 1

Machine analysis
+40% precision

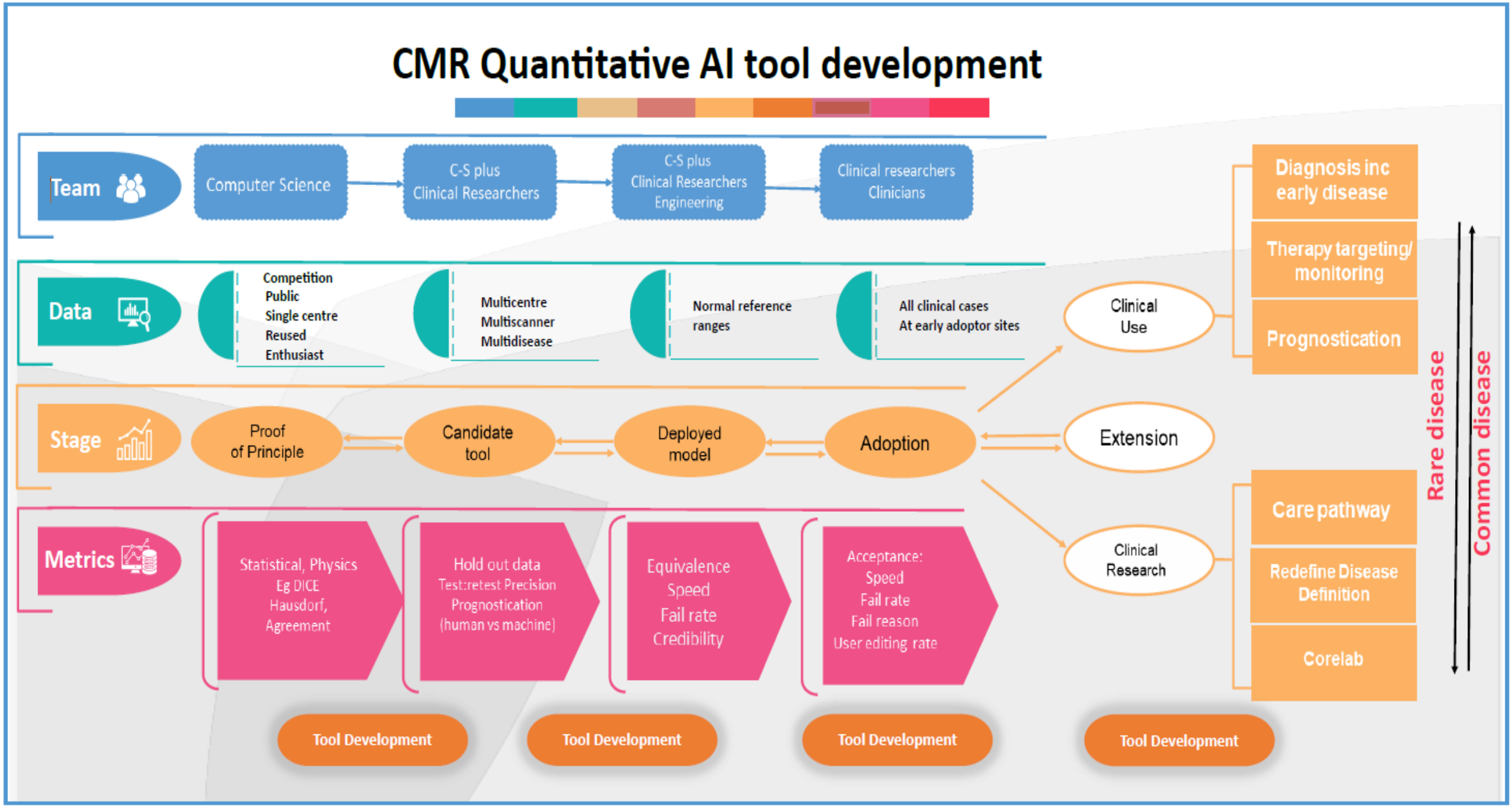


Future: Phase 2

+ Autonomous scanning
+ New imaging biomarkers



CMR Quantitative AI tool development



The CMR report

The data integration point between signal acquisition and the doctor:patient relationship

Bayes' theorem: Pretest probability + test change in probability

- Clear signal:
  - Above threshold: treat
  - Below threshold: no treat (discharge)
- Poor signal:
  - Repeat at Interval

Imaging timing: Two key processes:

- first visit: baseline description (diagnosis - accuracy)
- follow-up: depends on reason: either interval change (precision) or reassess (accuracy)

Clinician actions: two domains: for a patient; for the service

For the patient:	Comparison with thresholds: normal vs abnormal
	Communication of uncertainty
	Influence care decisions
For a service:	Efficiency, higher goals

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