INTERNATIONAL
CENTRE FOR
CIRCULATORY
HEALTH

Measurement variability

9th January 2012

Professor Simon Thom

"What gets measured, gets managed."

Peter Drucker

Epidemiological process

Counting	Cases and populations Measurement
Comparisons	Risk Methods - descriptive - analytic
Inference	Association and causality Generalisability
Action	Clinical / health policy Further research

What's abnormal?

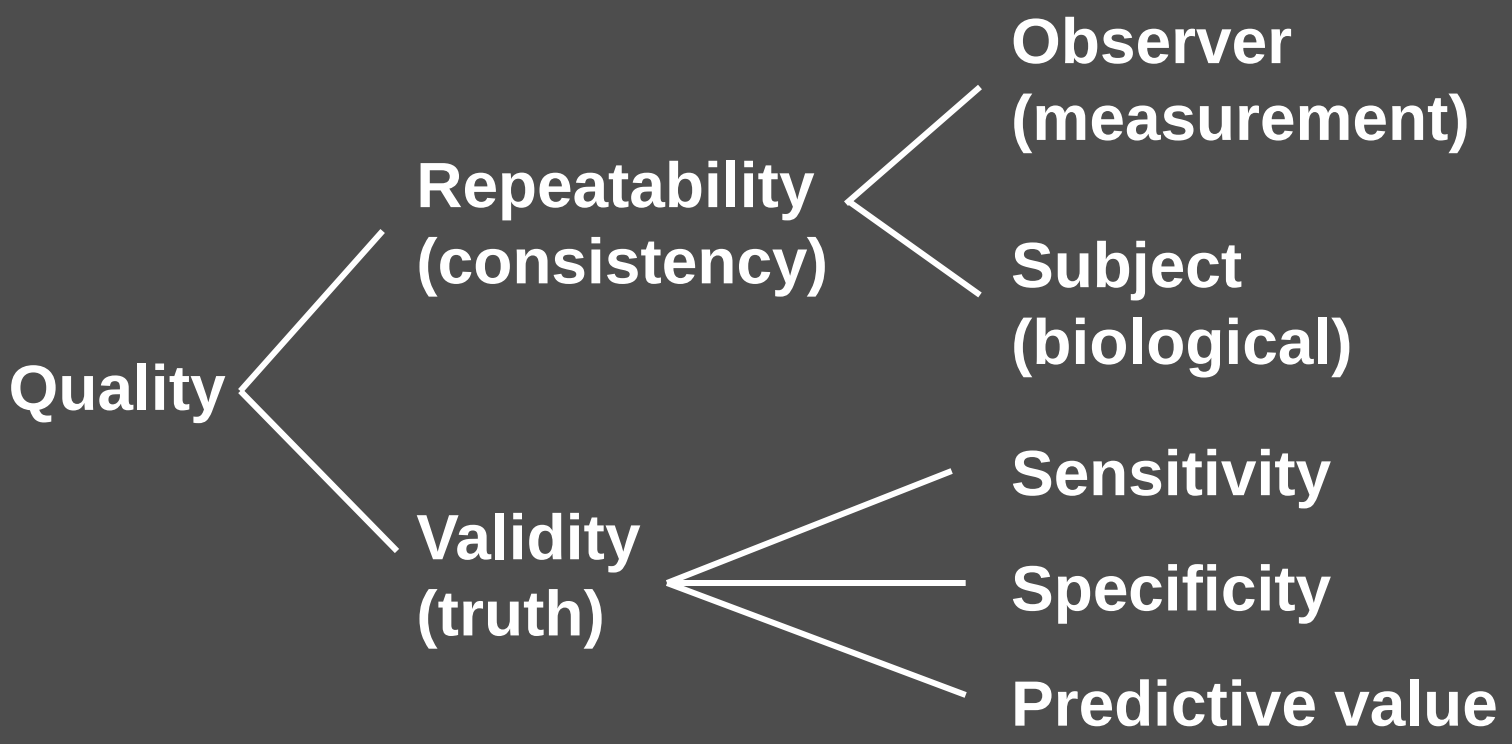
- Statistical
- Clinical
- Prognostic
- Practical

Quality of measurement

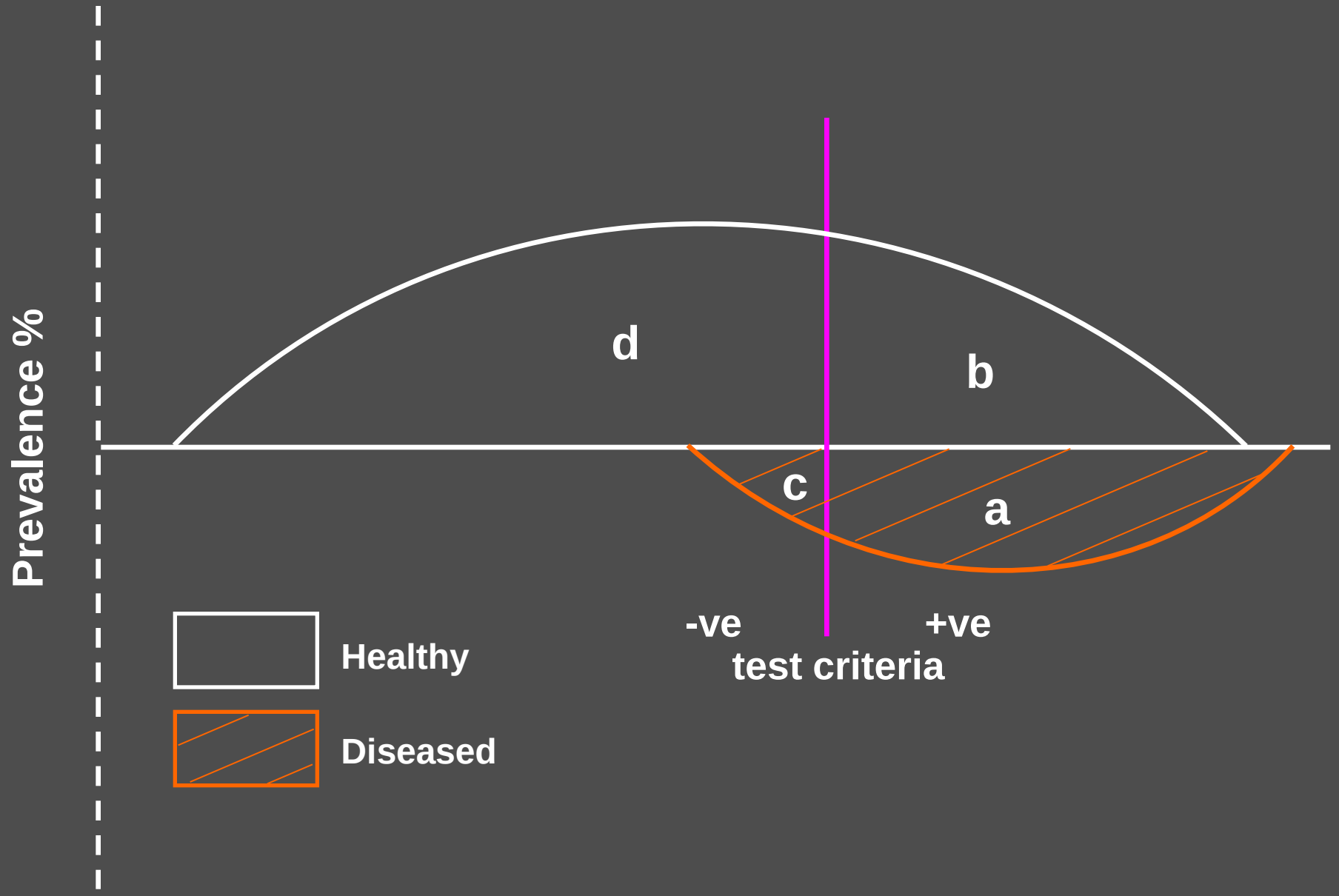
1 Repeatability / reliability
= how consistent

2 Validity
= how truthful

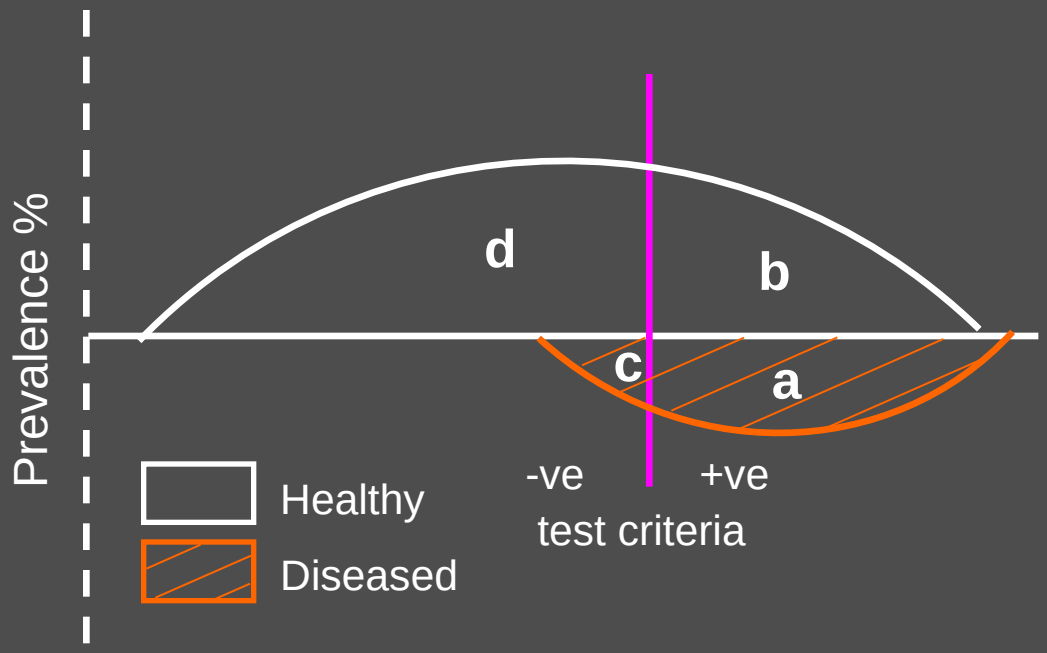
Quality of a measurement



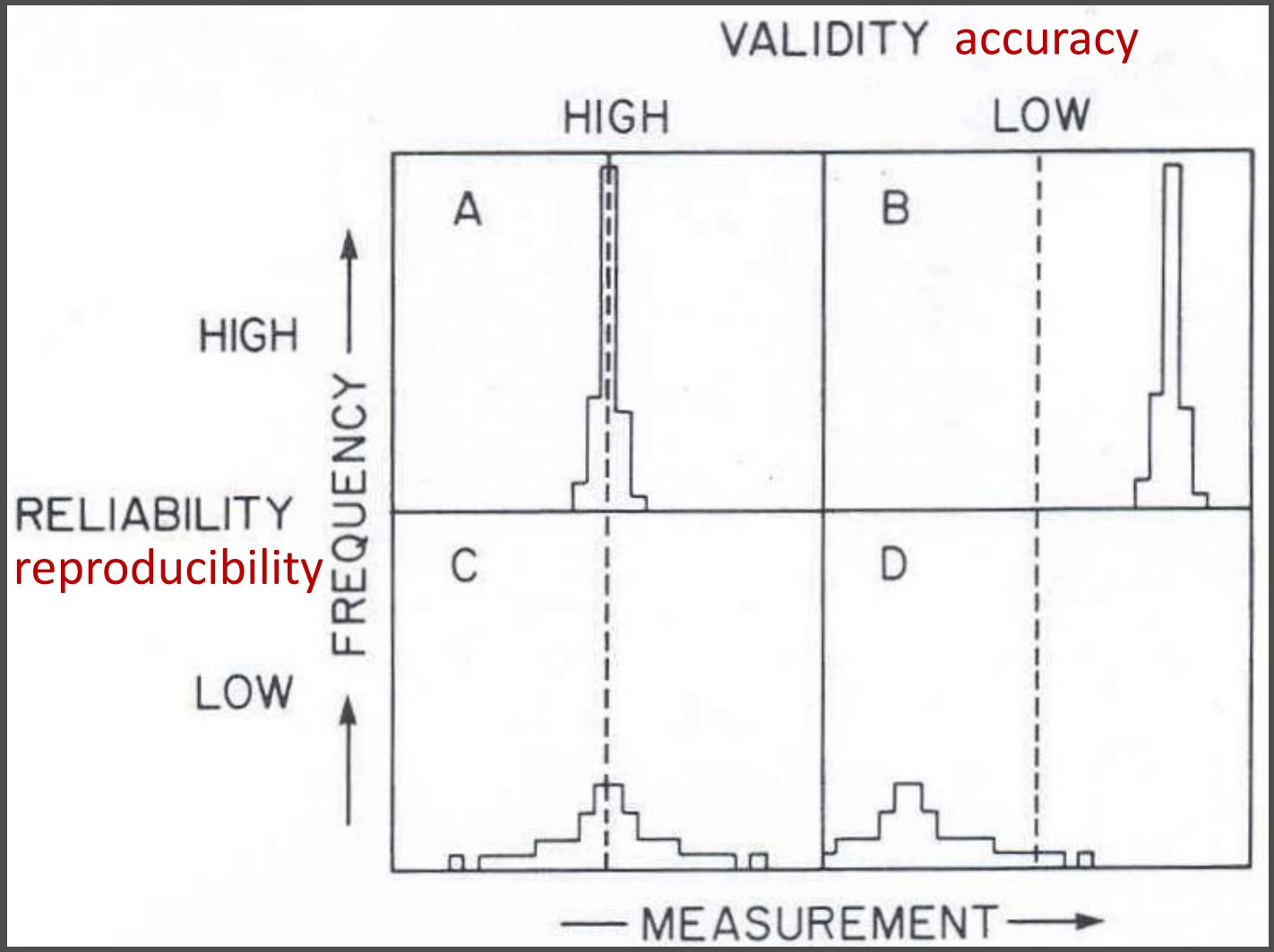
Sensitivity, specificity & predictive value



Sensitivity, specificity & predictive value



- Sensitivity is the proportion of true positives correctly identified by the test = a/a+c
- Specificity is proportion of true negatives correctly identified by the test = d/b+d
- Predictive value of a positive test is the likelihood that a person with a positive test has the disease = a/a+b
- Predictive value of a negative test is the likelihood that a person with a negative test does not have the disease = d/c+d



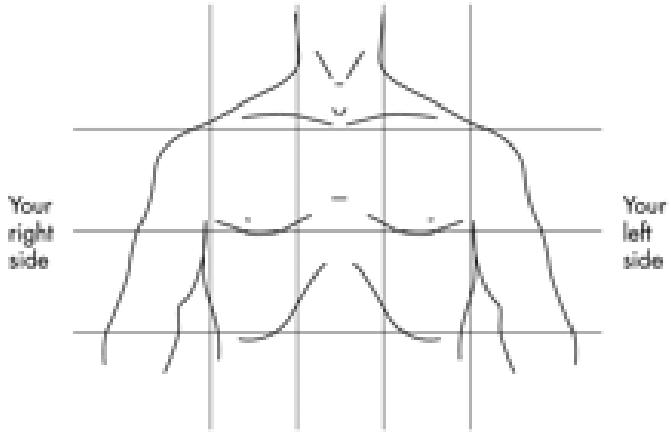
A, high validity & reliability. B, low validity & high reliability.
C, high validity & low reliability. D, low validity & reliability.

Dotted lines represent the true values

1 Do you ever have any pain or discomfort in your chest?

Yes/No

2 Where do you get this pain or discomfort?
Please mark **X** on the appropriate places



3 When you walk at an ordinary pace on the level does this produce the pain?

Yes/No/Unable

4 When you walk uphill or hurry does this produce the pain?

Yes/No/Unable

5 When you get any pain or discomfort in your chest on walking, what do you do?

Stop Slow down Continue at same pace Not applicable

6 Does the pain or discomfort in your chest go away if you stand still?

Yes/No

7 How long does it take to go away?

10 minutes or less
more than 10 minutes

Complete WHO Rose angina questionnaire.

The site must include either the sternum (any level) or the left arm and left anterior chest (defined as the anterior chest wall between the levels of clavicle and lower end sternum).

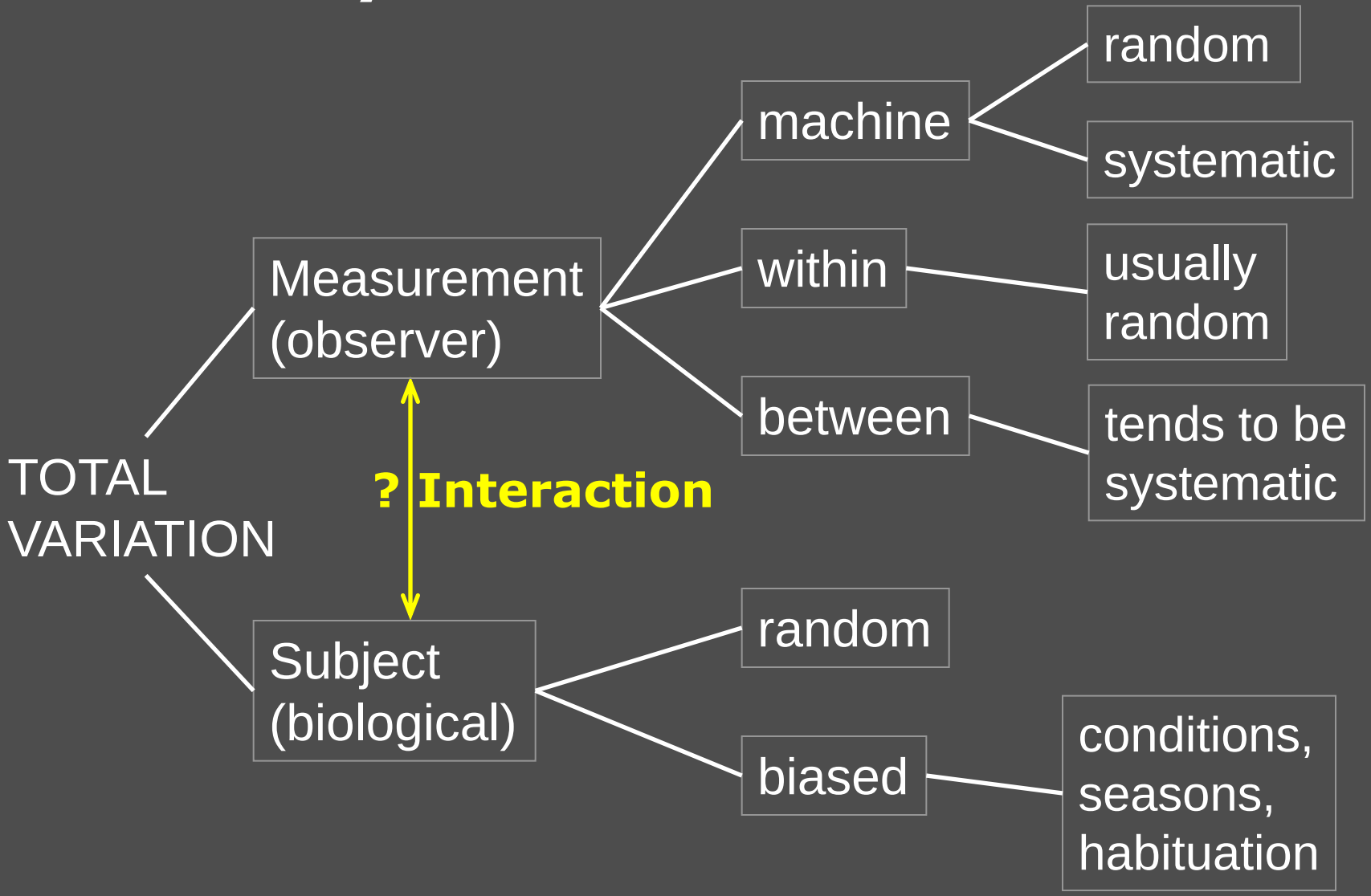
It must be provoked by either hurrying or walking uphill (or by walking on the level, for those who never attempt more).

When it occurs on walking it must make the subject either stop or slacken pace, unless nitro-glycerine is taken.

It must disappear on a majority of occasions in 10 minutes or less from the time when the subject stands still.

Rose GA, Blackburn H.
Cardiovascular survey methods.
WHO monograph 1986; **56**:1-188.

Variability of measures

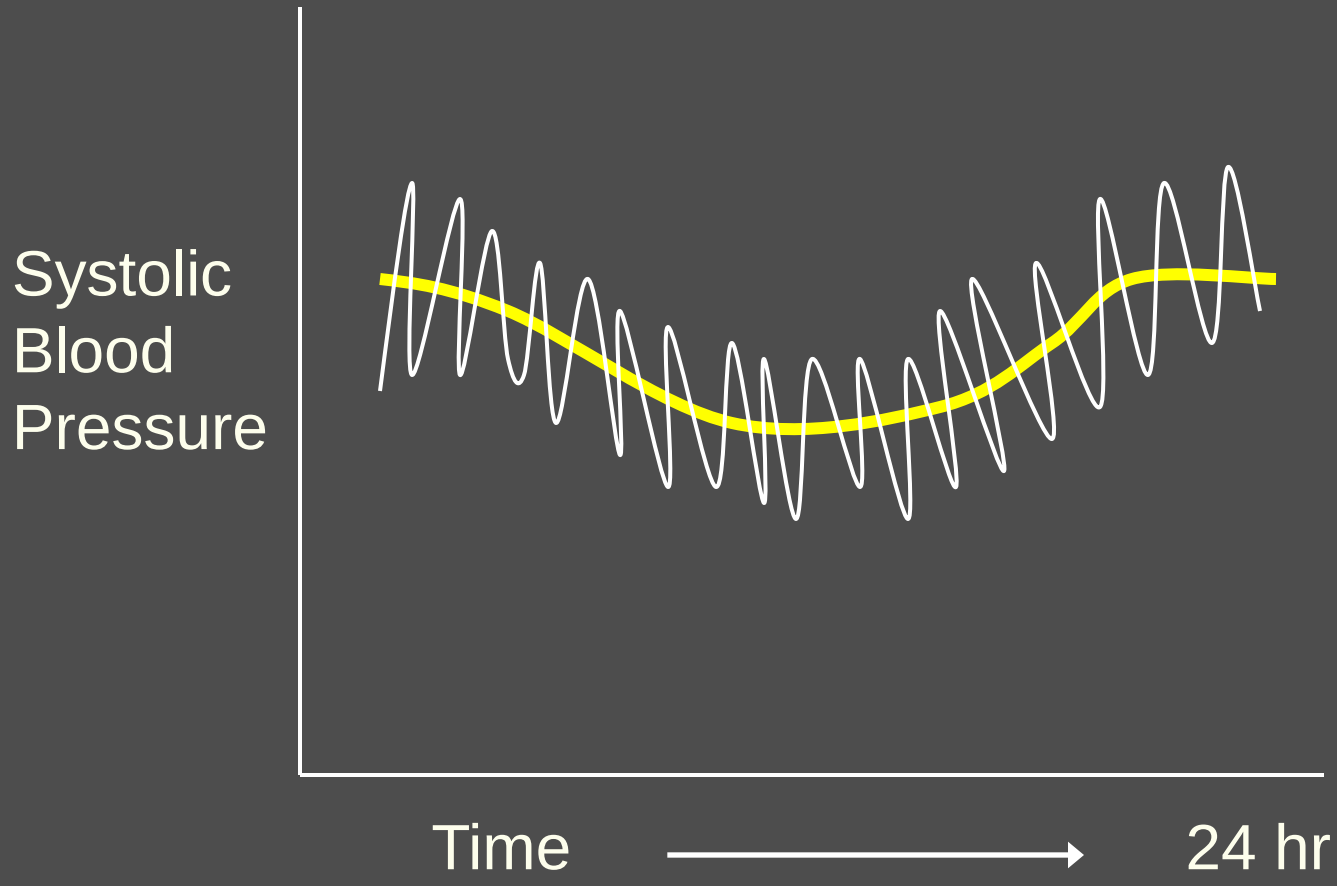


Measurement errors

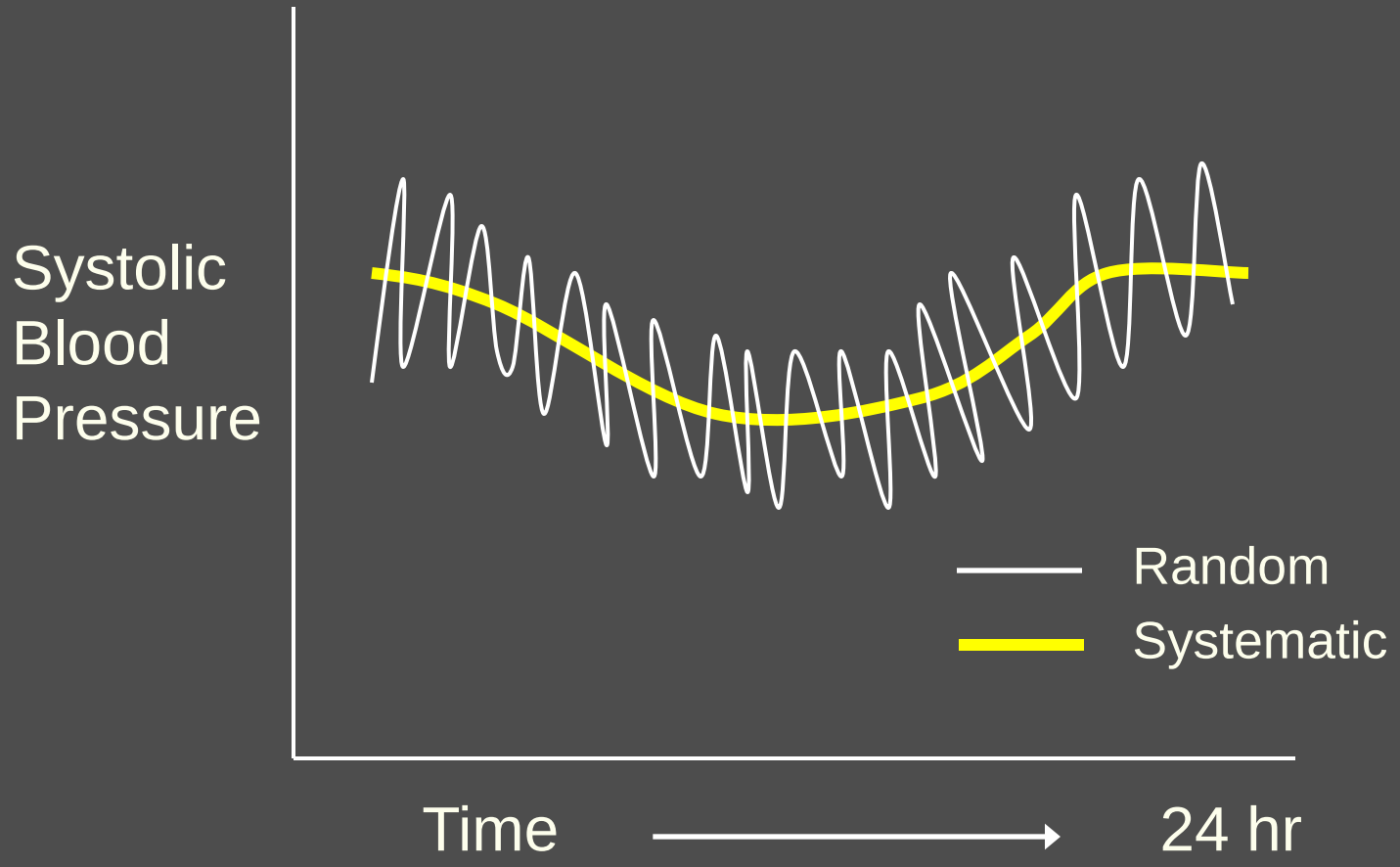
Random: could be in any direction;
not predictable

Bias: systematic deviation from the truth

Types of variability

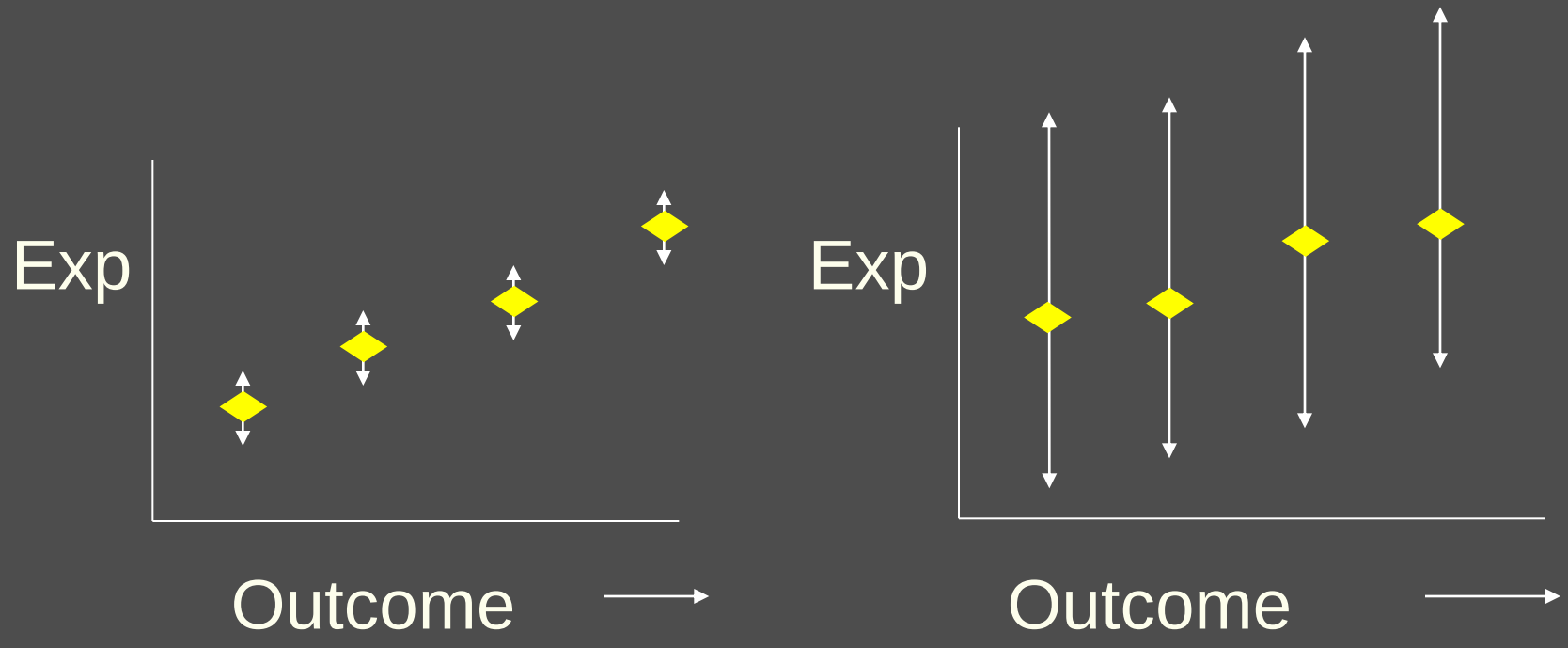


Types of variability

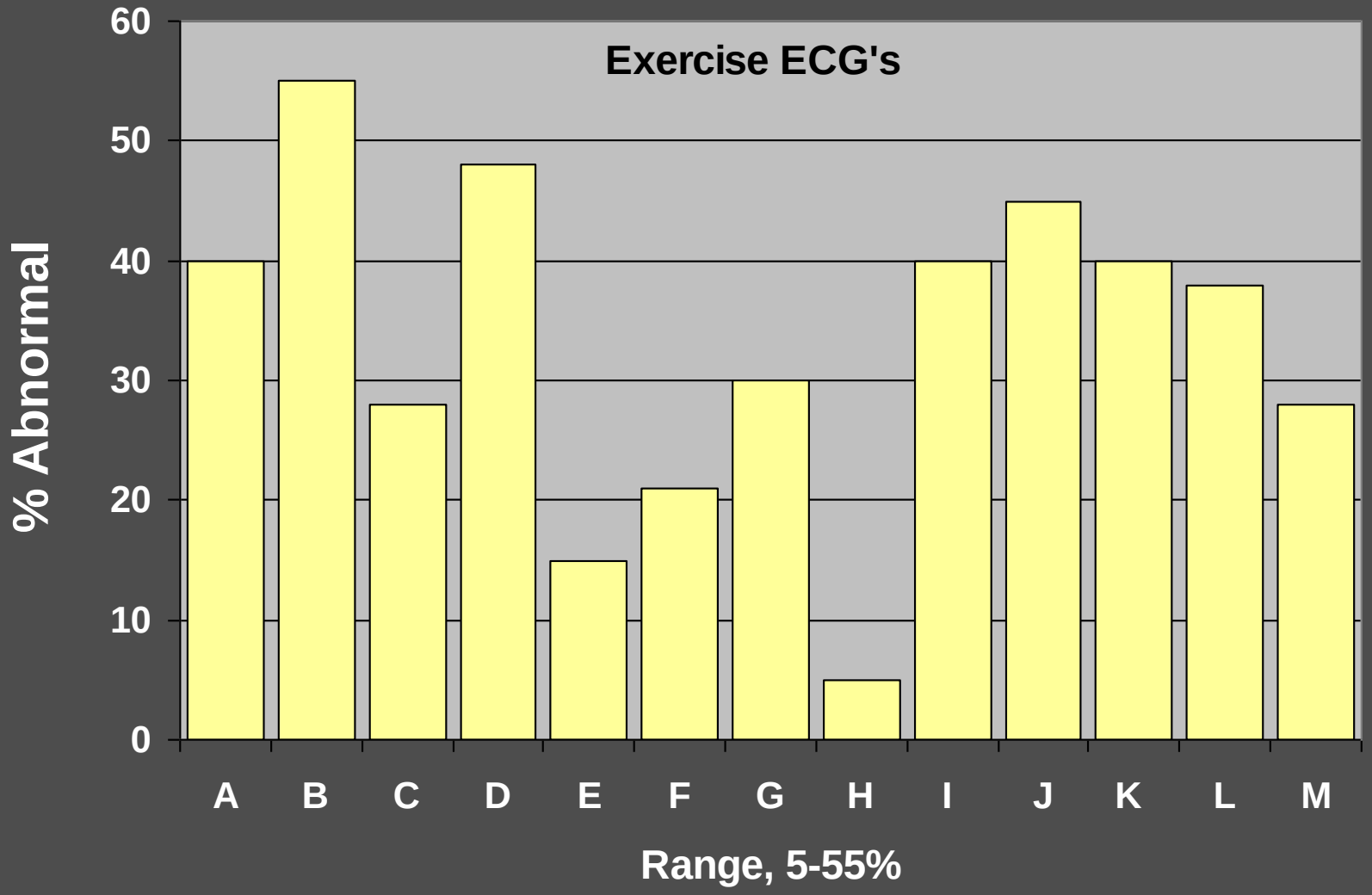


Random variability: LOSS OF POWER
Systematic variability: BIAS

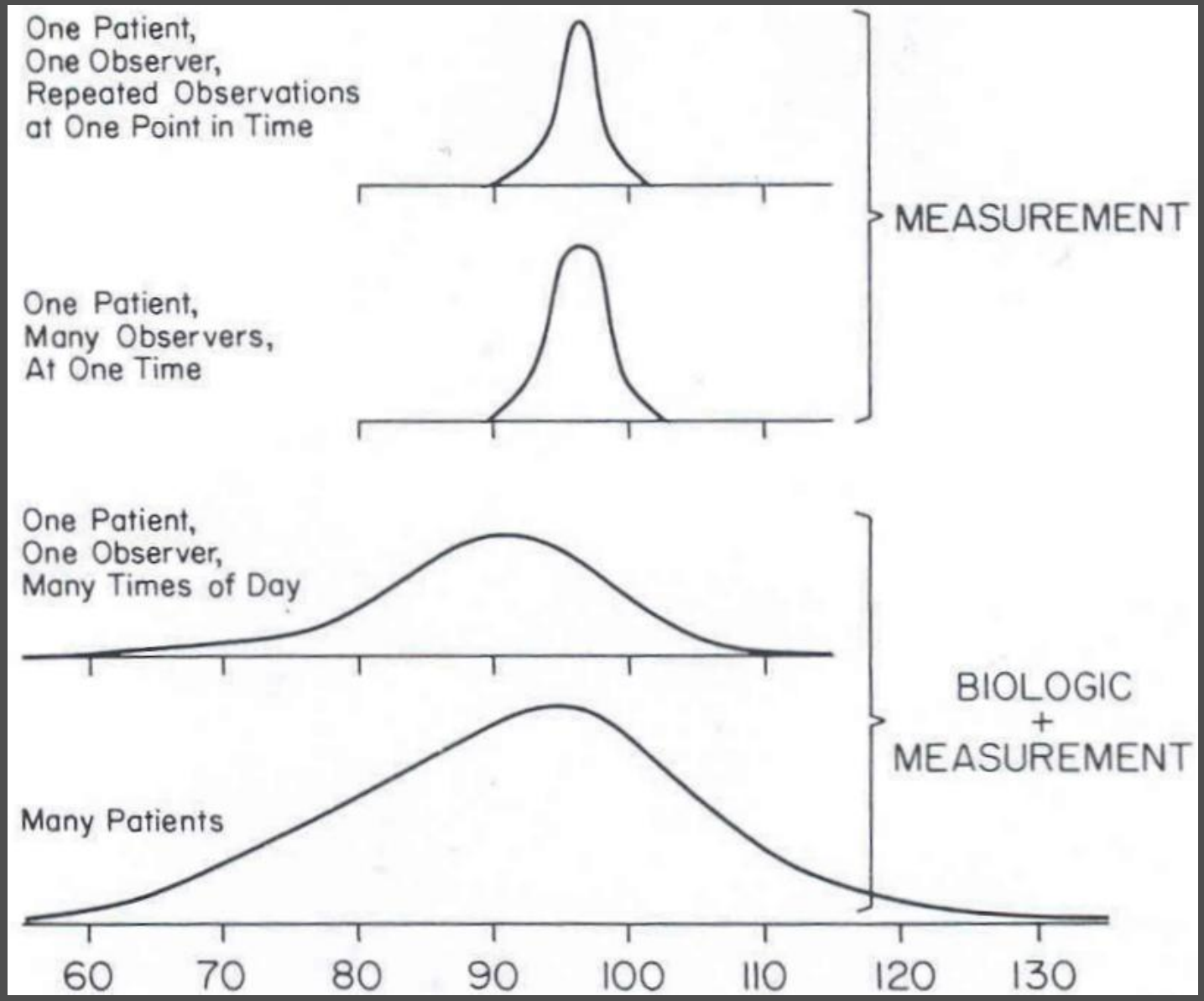
Random measurement error:
may reduce power to detect associations



Observer variability: percentage of exercise ECGs judged abnormal by 13 cardiologists, A - M



Conditions of measurement	Distribution of measurement	Source of variation



Diastolic BP

What is a case?

Prevalence of disease depends on defining criteria

Criteria required	Number of cases of MI
ECG only	152
ECG + pain	107
ECG + pain + enzymes	66

IPPSH 1985

Sources of variability in BP measurement

Recording of BP is one of the most important measurements in clinical medicine, but also one of the most unreliable because of it's variability.

Blood pressure measurement as done in clinical practice today is a very inaccurate procedure, yet one on which we make management decisions with serious far-reaching consequences for the patient.

O'Brien E, Lancet 1996; 348: 1569

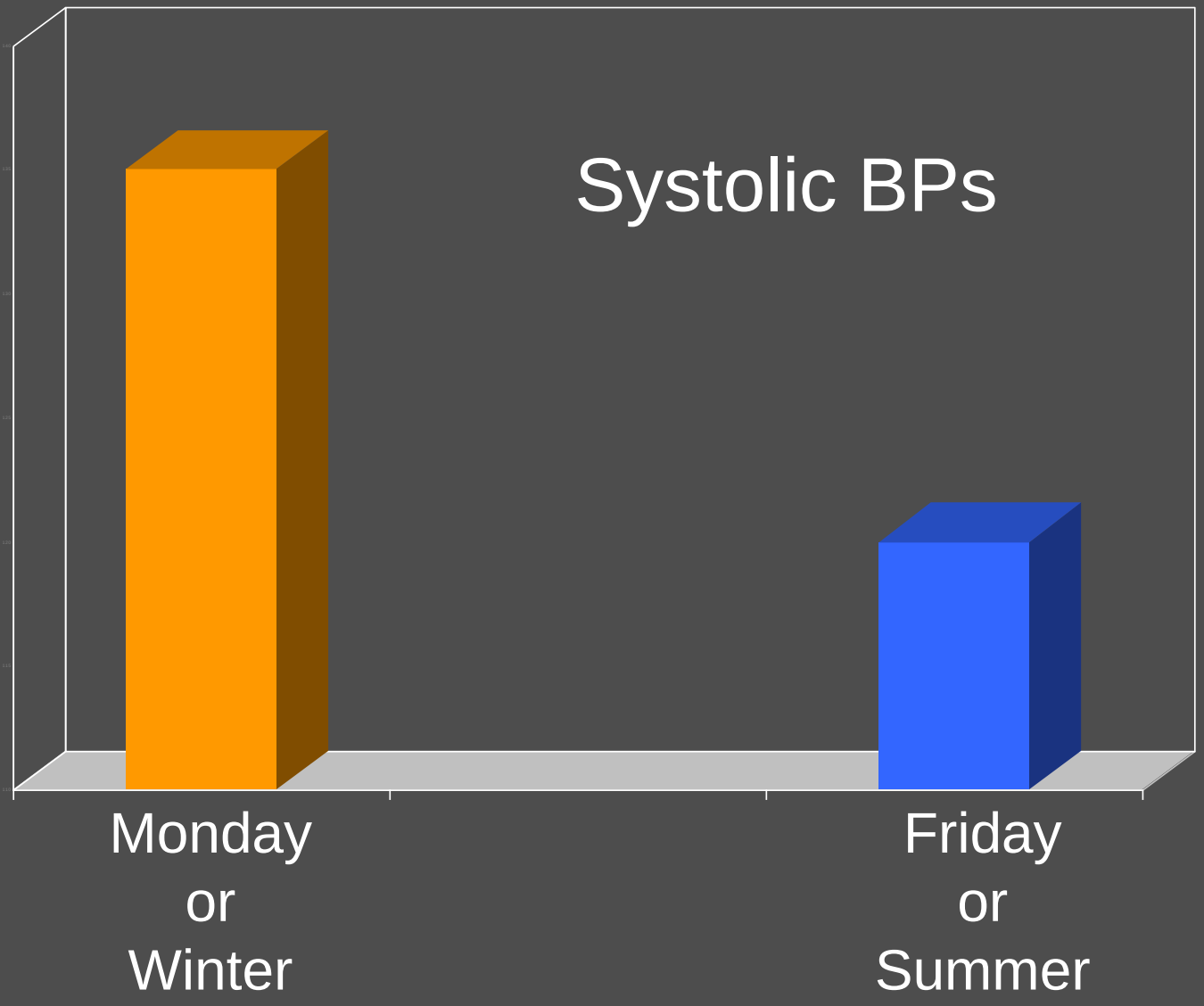
Components of biological variability

Short-term (beat-to-beat): influenced by heart rate, respiration – autonomic nervous system

Daytime: influenced by degree of mental & physical activity

Diurnal: 15 – 20% reduction with sleep

Weekly & seasonal variations in BP



Sources of BP variability & measurement error

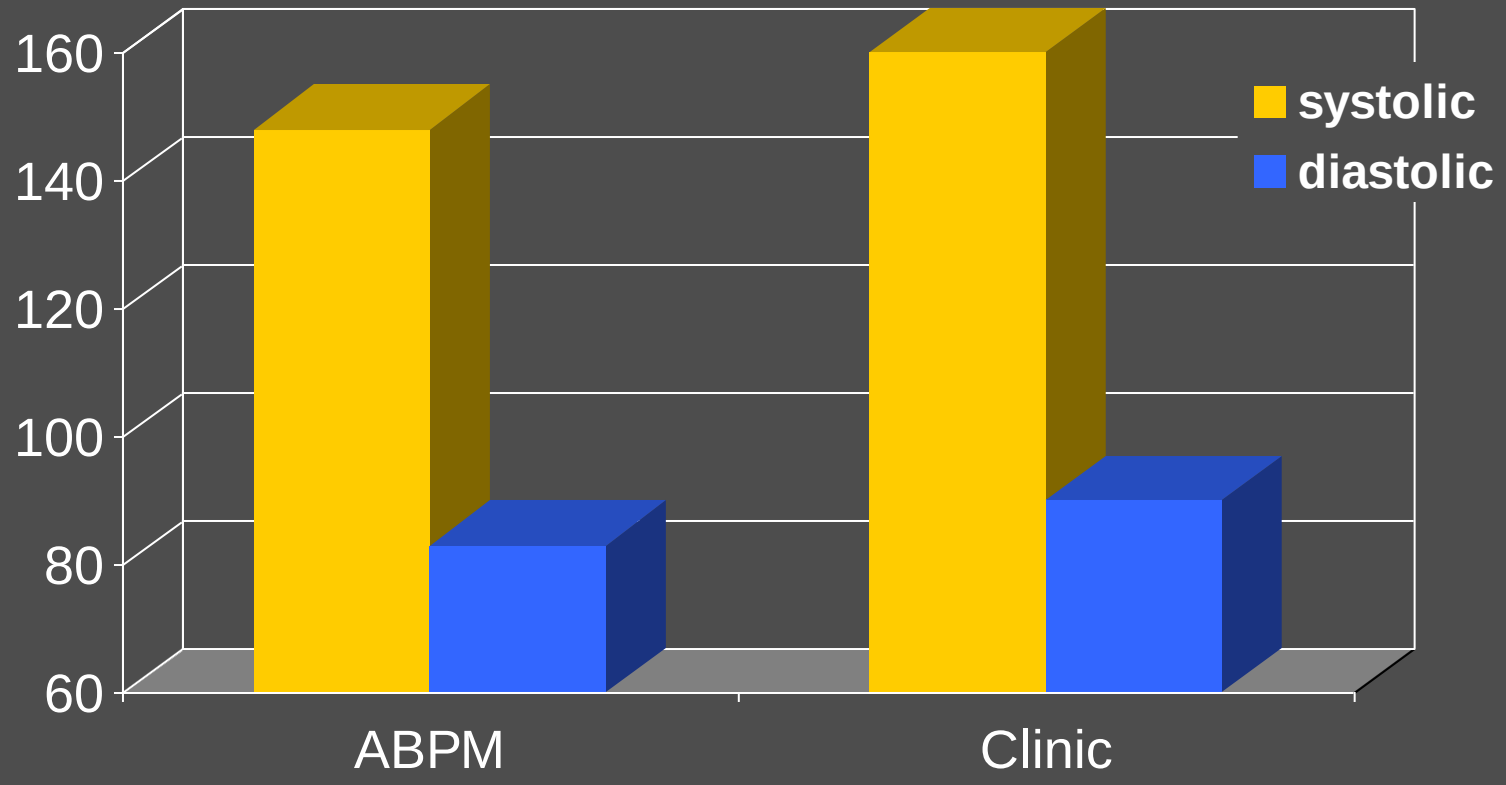
Within subject

- stress / emotion
- posture / arm position
- exertion
- diurnal variation
- smoking
- alcohol
- recent meal
- full bladder
- season
- arrhythmia (e.g. atrial fib)

Observer / instrument

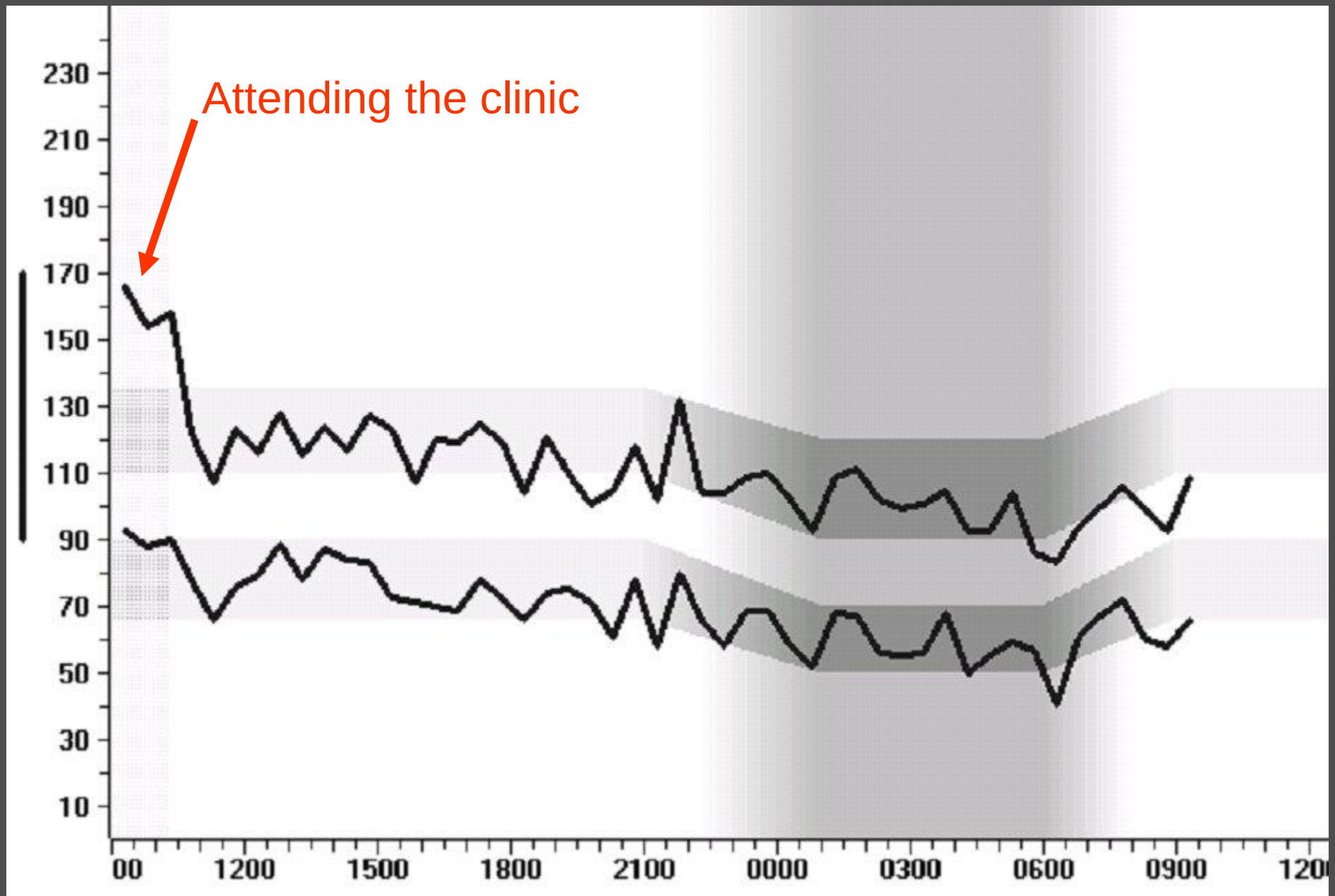
- cuff size relative to arm
- inflation / deflation rate
- observer – subject interaction
- observer bias
- digit preference
- end-point definition
- deafness

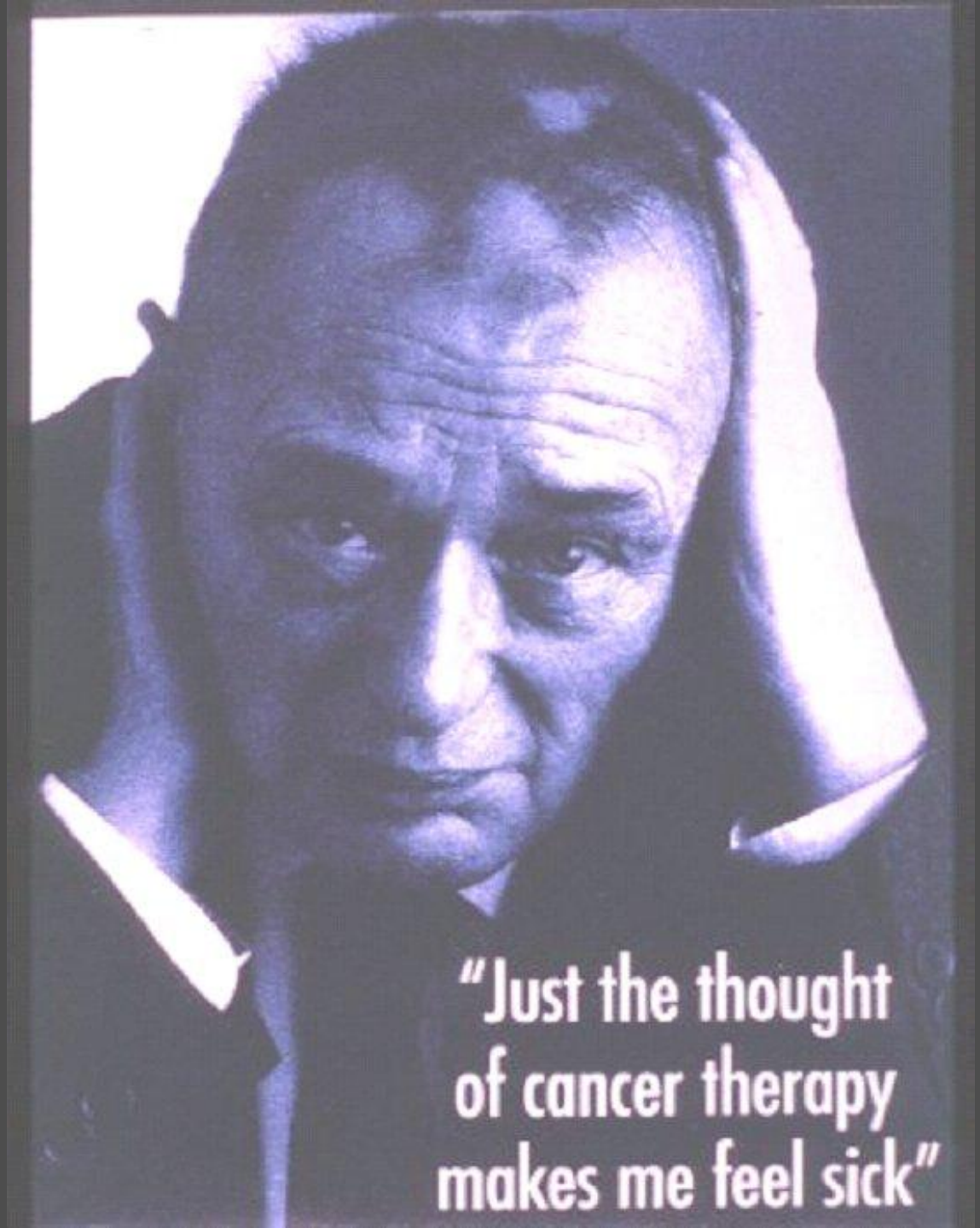
BP measured by ABPM is systematically lower than than clinic measurements



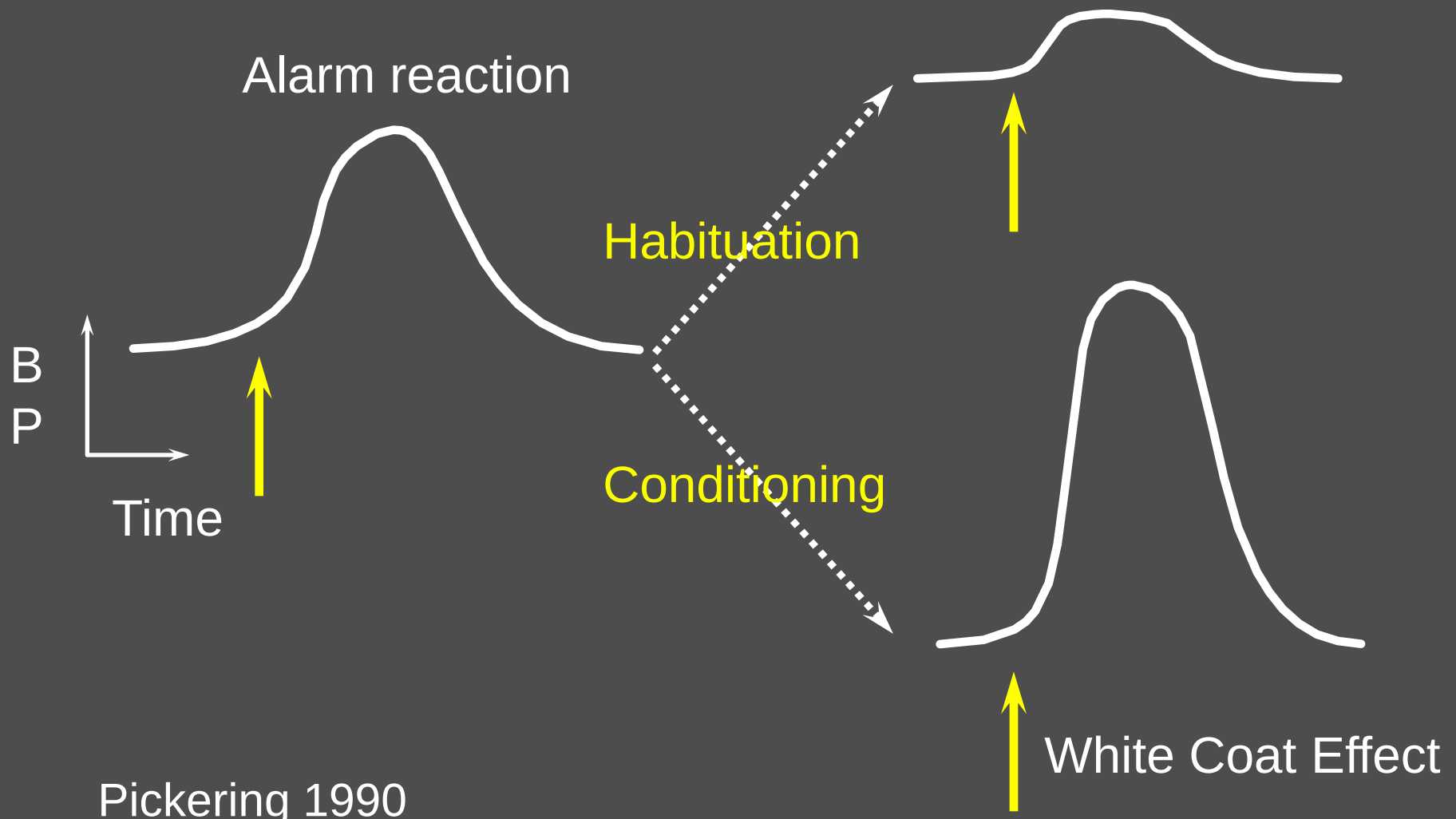
Average difference is approximately 12/7 mmHg

‘White-coat’ pattern of BP profile



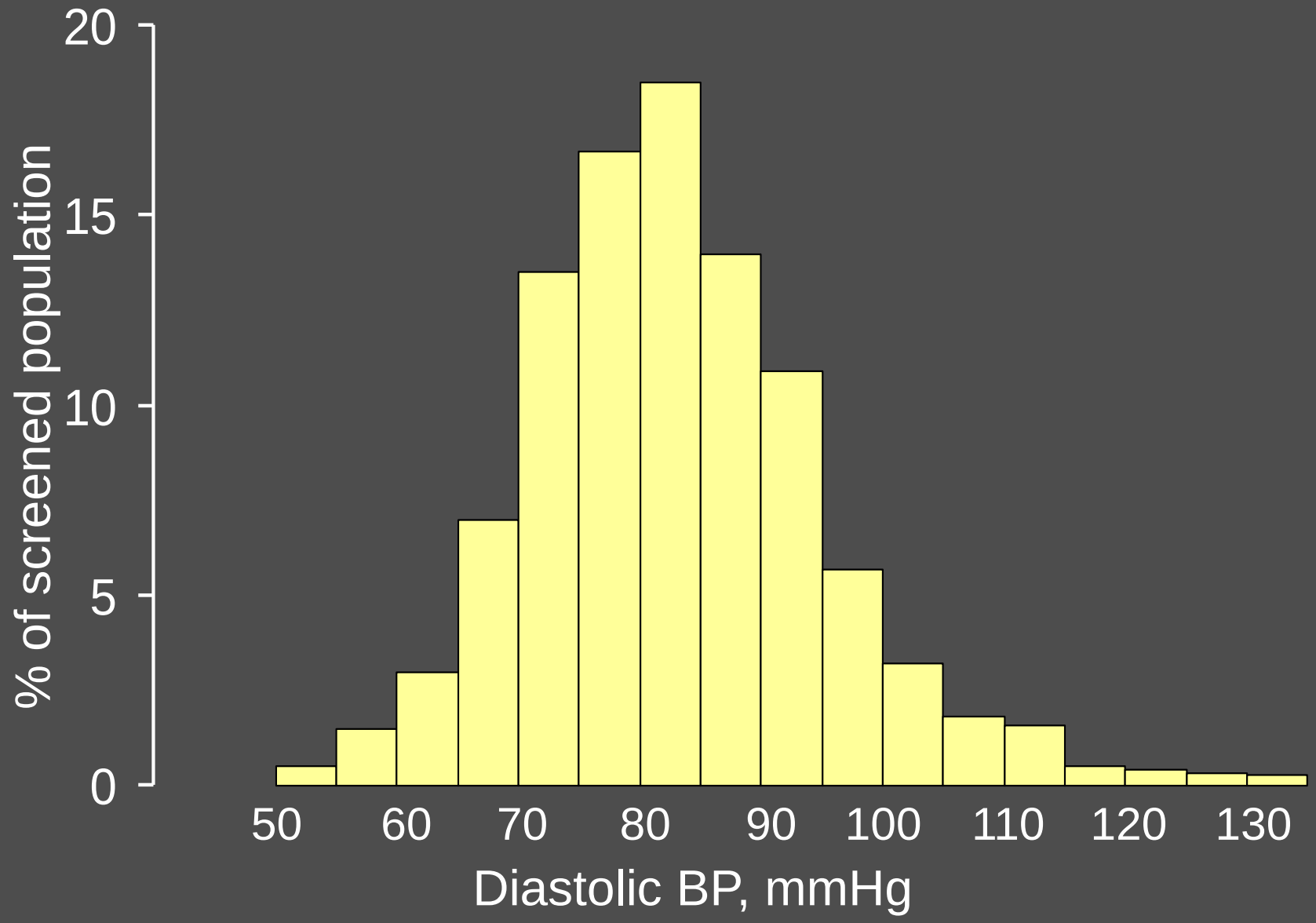

"Just the thought
of cancer therapy
makes me feel sick"

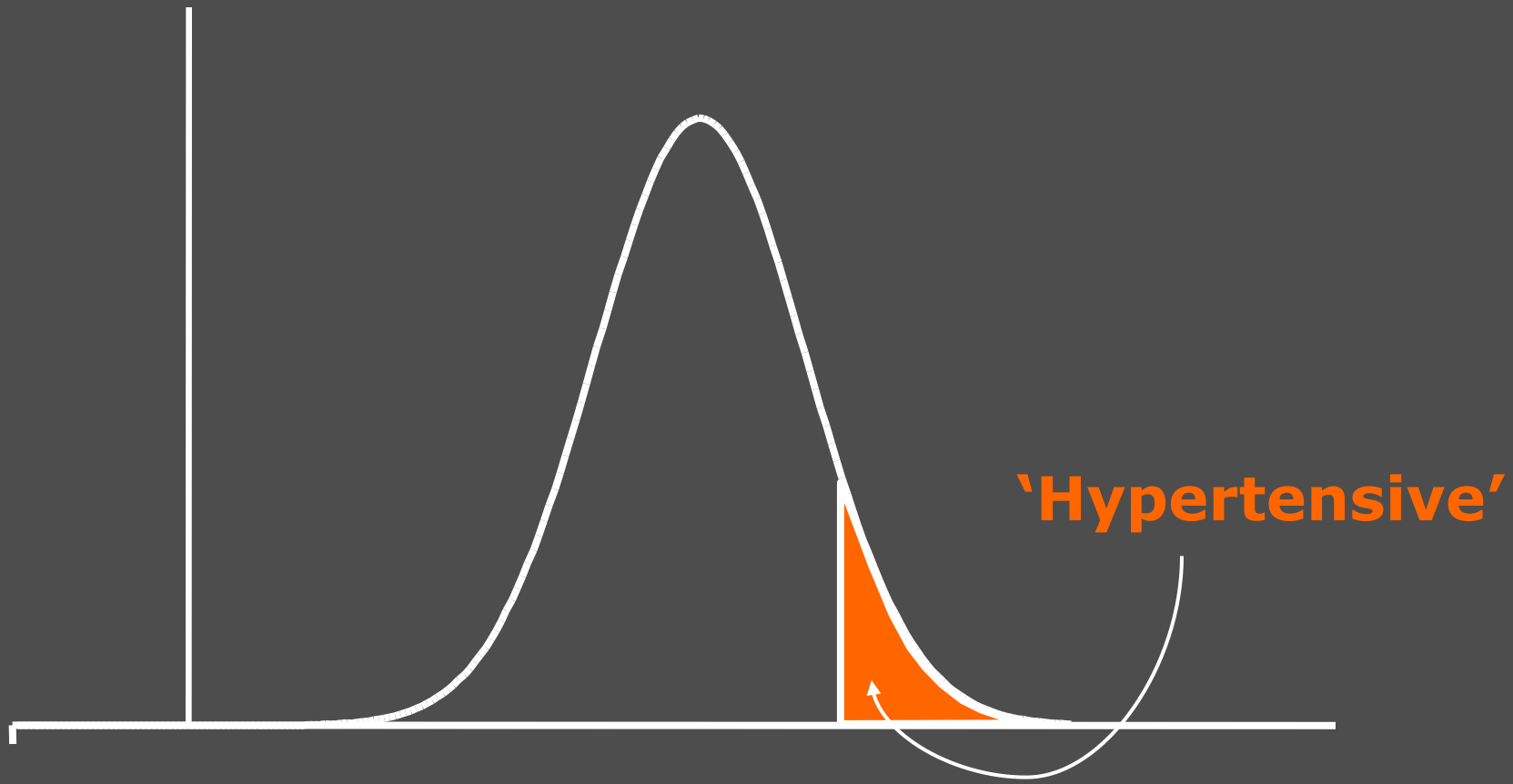
Development of the ‘white coat’ effect

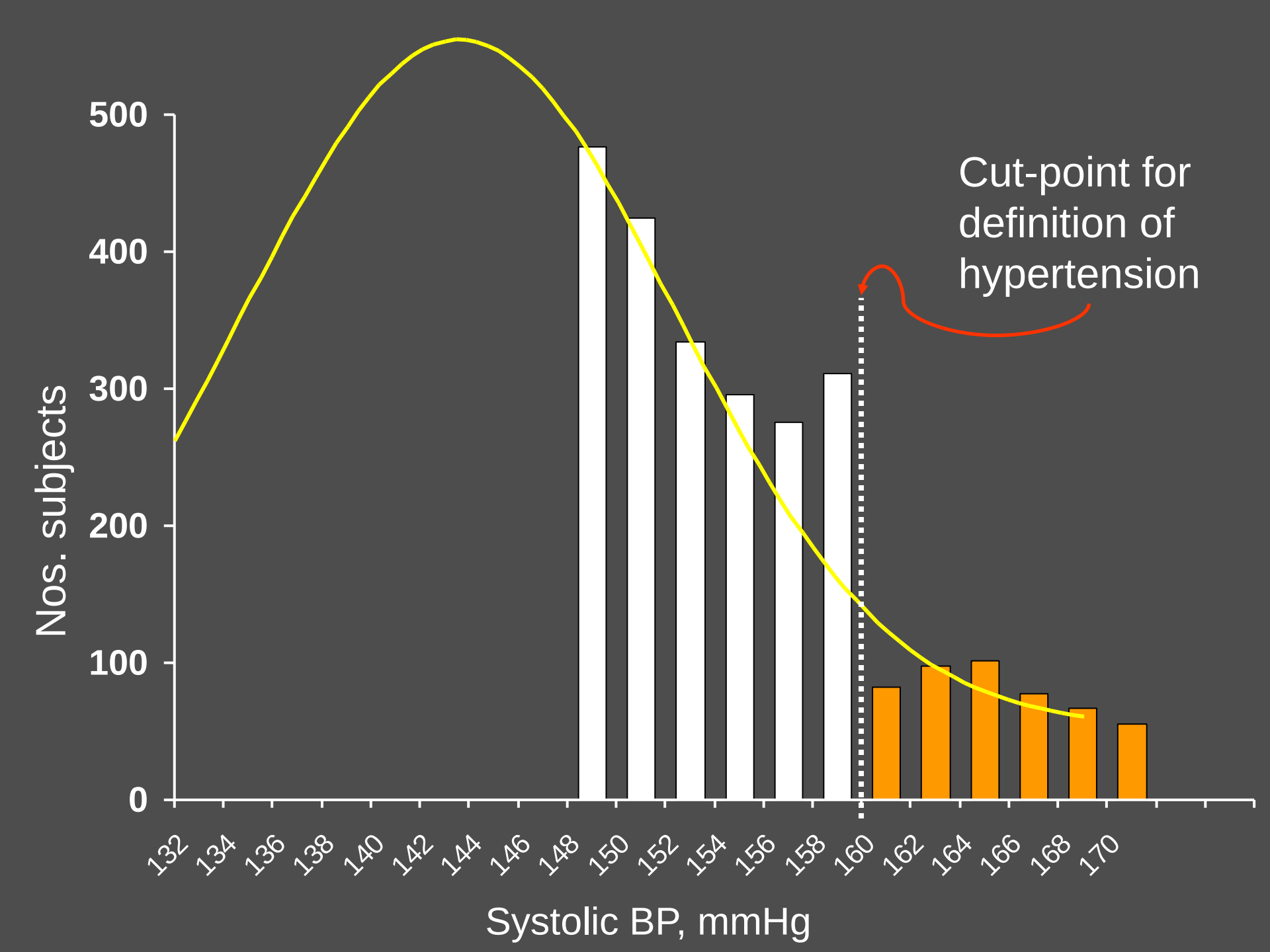


Pickering 1990

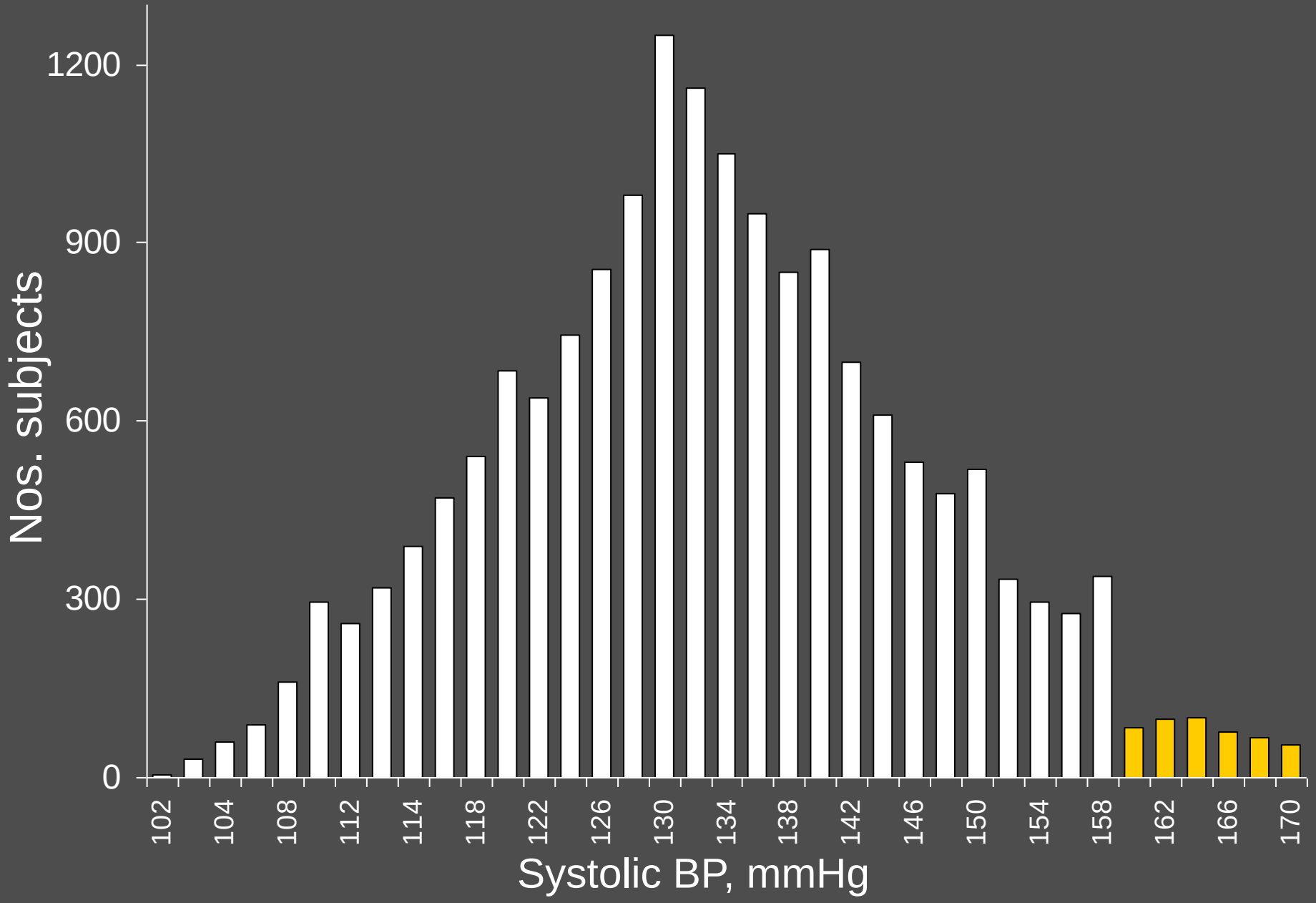
The 'normal' distribution of diastolic BP within a population
Systolic BP follows a similar pattern

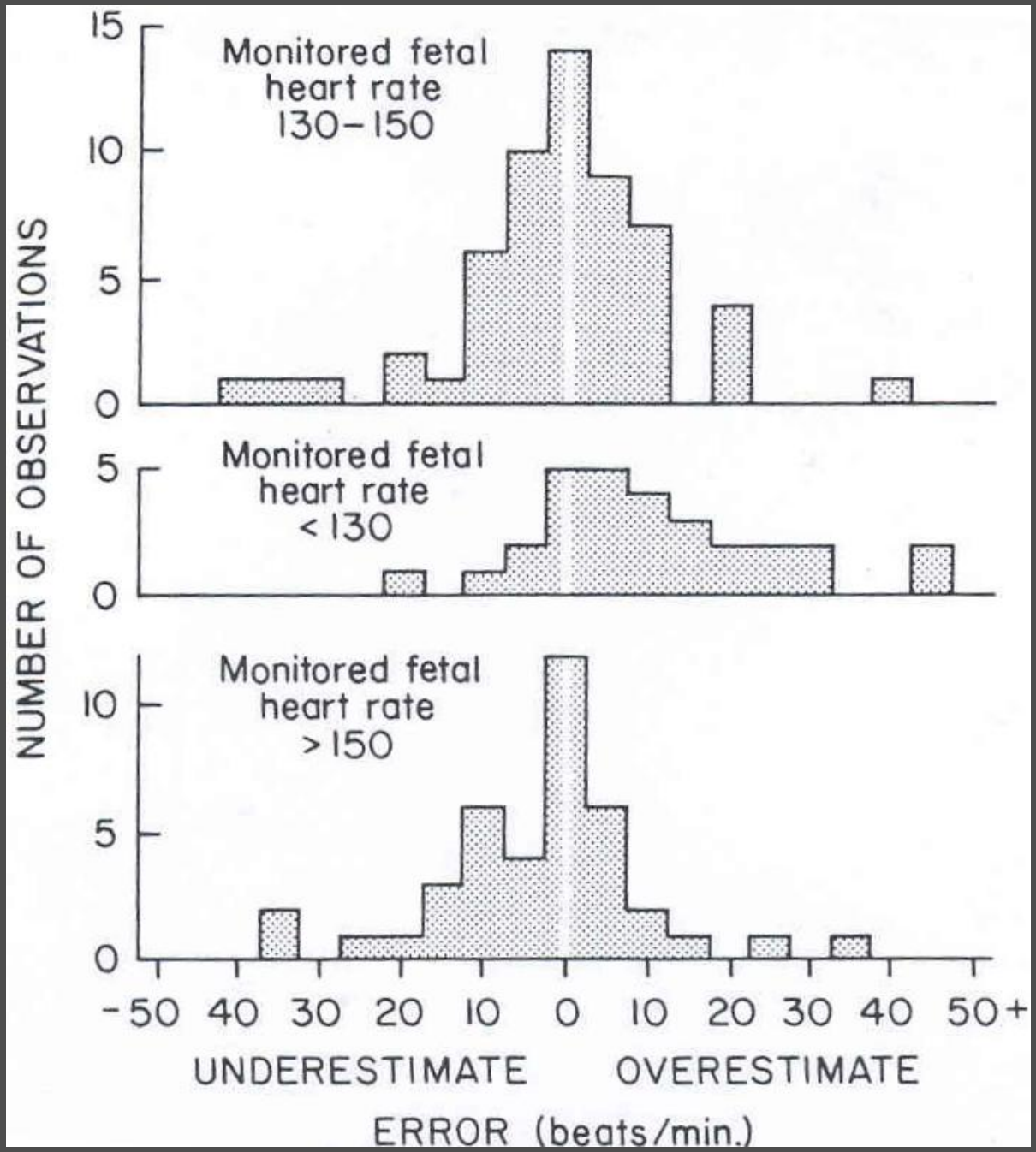



'Hypertensive'

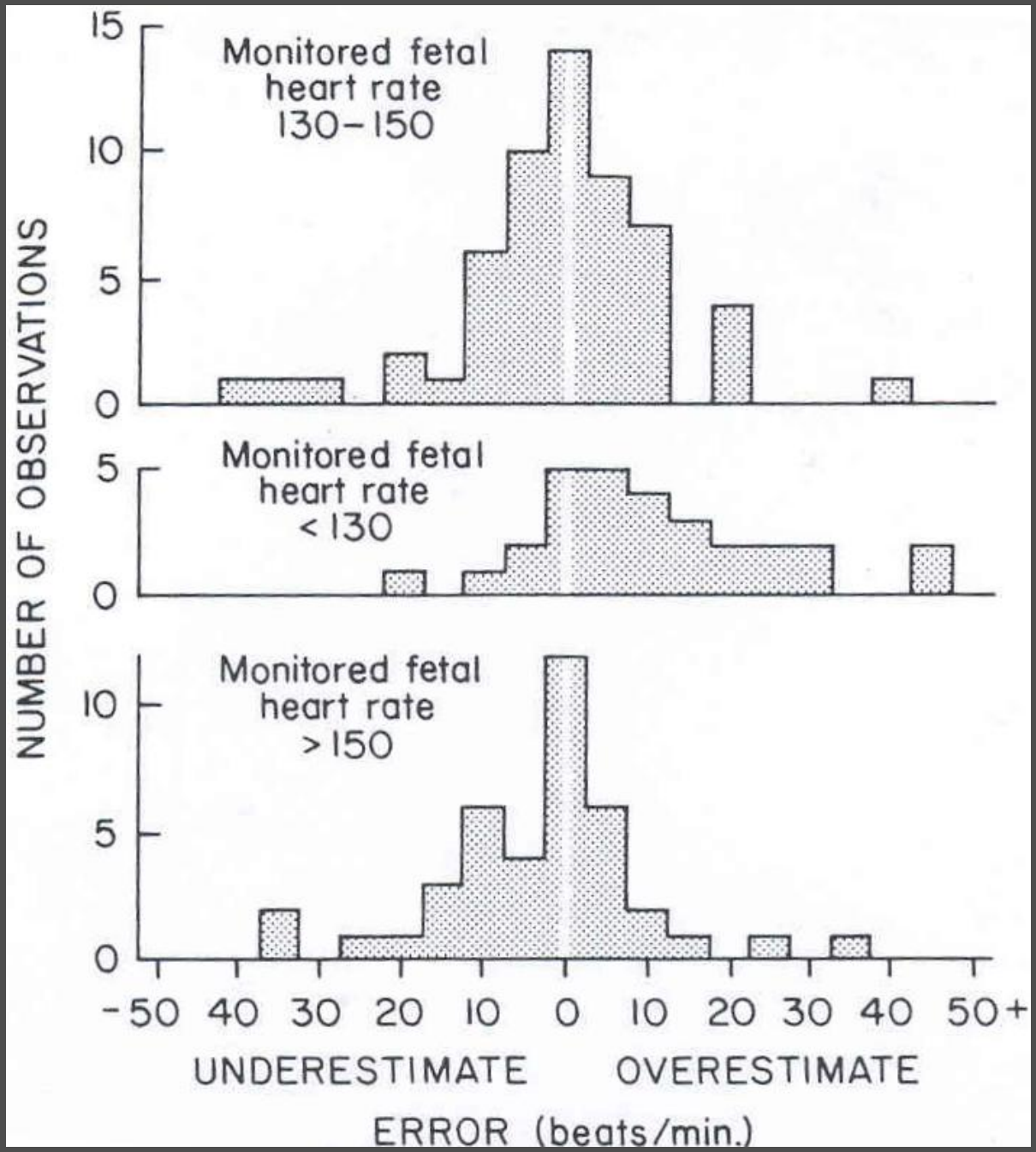

Cut-point for definition of hypertension
Nos. subjects
0
100
200
300
400
500
132
134
136
138
140
142
144
146
148
150
152
154
156
158
160
162
164
166
168
170
Systolic BP, mmHg

Digit preference (‘rounding’) in clinic BP measurements





Error in reporting FHR according to whether the true rate *(determined by electronic monitor)* is within the normal range, low or high.



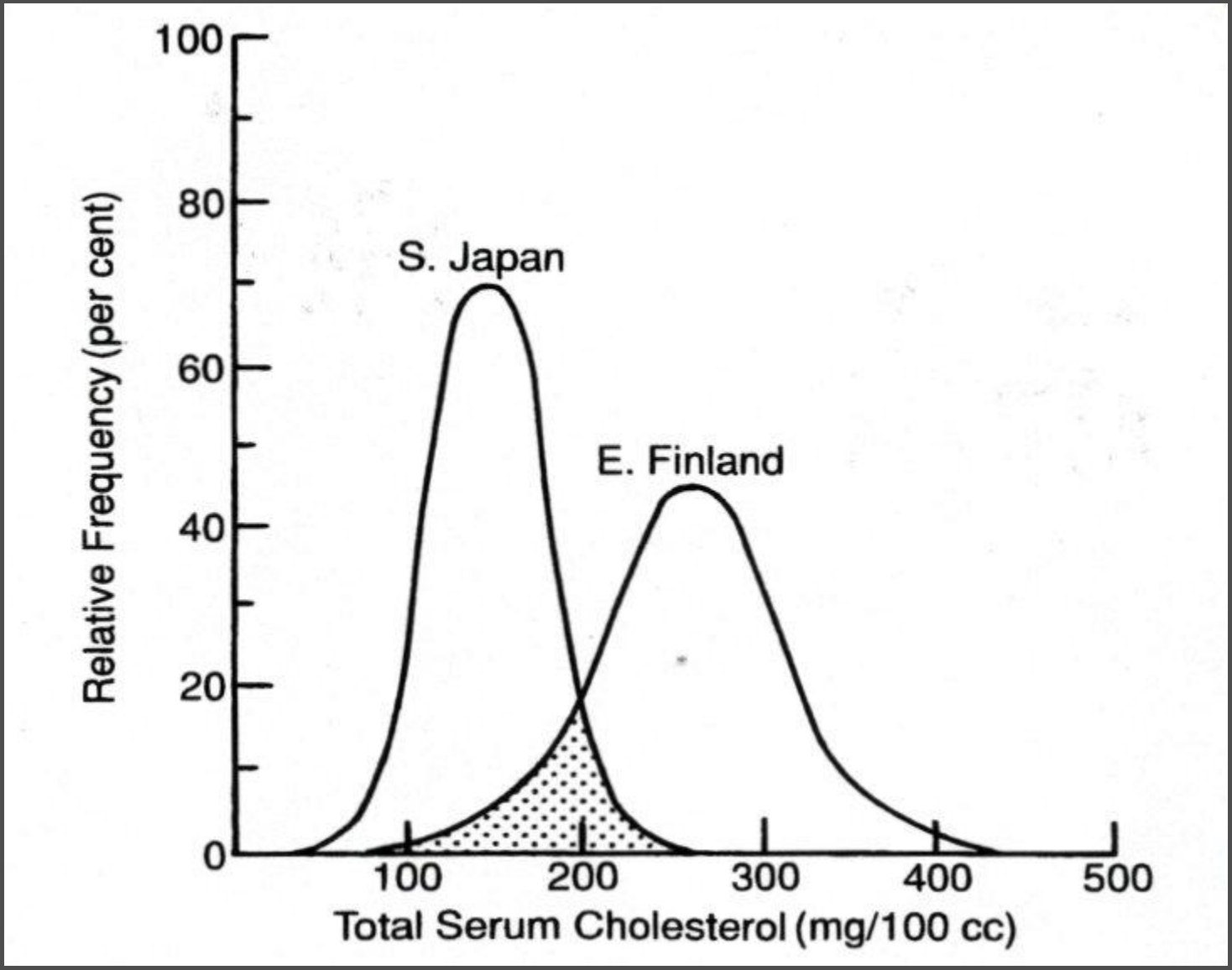
Observer bias

Error in reporting FHR according to whether the true rate *(determined by electronic monitor)* is within the normal range, low or high.

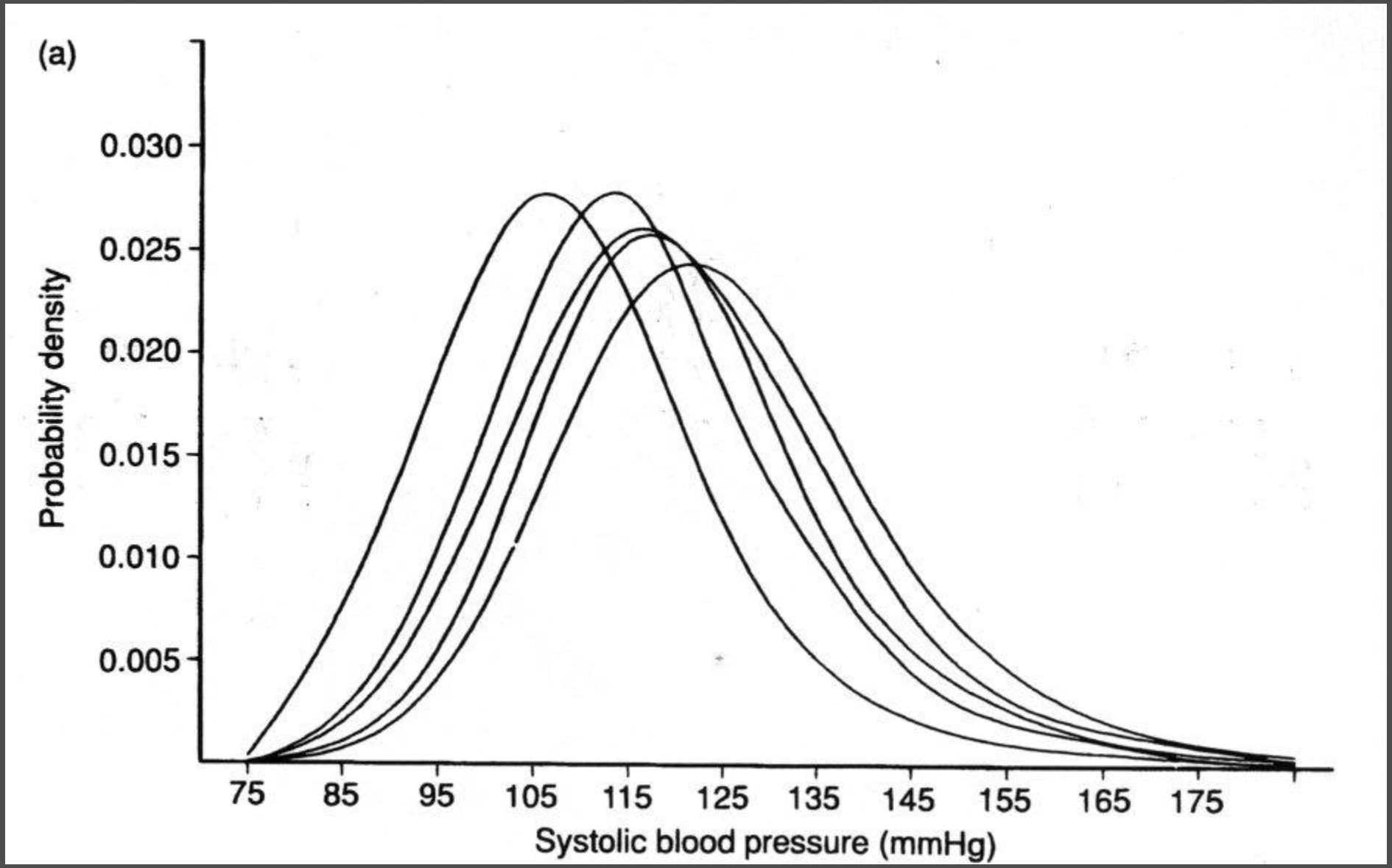
Procedures to reduce measurement errors

	Random	Systematic
1. Define what's measured	X	X
2. Objective technique	X	X
3. Define conditions of use	X	X
4. Train personnel	X	X
5. Assess performance		
6. Random observer allocation		X
7. Blinded		X
8. Report standardised fashion		X

Contrasting distributions of cholesterol, Japan & Finland



BP distributions in populations in 5 countries



Summary

- Measurement is fundamental to medical practice & research
- Accuracy has far reaching implications
- Variability arises from numerous sources
  - expected & unexpected
- Awareness offers strategies to account for variability

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9th January 2012

Types of error (1)

Random error

Results in lack of power and chance of finding a true relationship

Reduce by

1. Increasing measurements per subject
2. Increasing sample size

Can estimate size and correct for it

“Clean dirt”

Types of error (2)

BIAS: Systematic error

Can lead to spurious inferences

Study design critical; standardise; randomise

“Dirty dirt”