



*The Role of Experience in the  
Development of Medical Diagnostic  
Expertise*

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McMaster University**



## *Why study diagnostic expertise?*

- ◆ If we can understand how experts do it, perhaps we can arrange learning to increase efficiency of becoming an expert.....

More on this later....



## *Early History of Clinical Reasoning (1973-79)*

- Search for general problem - solving skills
- Content Specificity (Elstein, Shulman)
- Central Role of Knowledge

# *The Paradigm Shift (1979 - 99)*

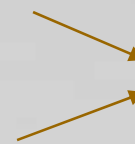
- ◆ Expertise as Acquisition of Knowledge

- ◆ Mechanisms (basic science)

- ◆ Rules (signs --> diagnosis)

- ◆ Exemplars (Experience)

- +/- Metacognition / Reflection



Analytical



Pattern  
Recognition



# *Mechanisms*

Explanations of how phenomena arise:

- ◆ Starling Law
- ◆ Krebs Cycle
- ◆ Adaptation
- ◆ Berkson Bias

(All the stuff of the preclinical curriculum)



## *Rules*

- ◆ The relationship between signs, symptoms and diagnoses.
  - ◆ Base rates
  - ◆ Conditional probabilities
  - ◆ Lists of features
  - ◆ “Causes of....”



## *Examples*

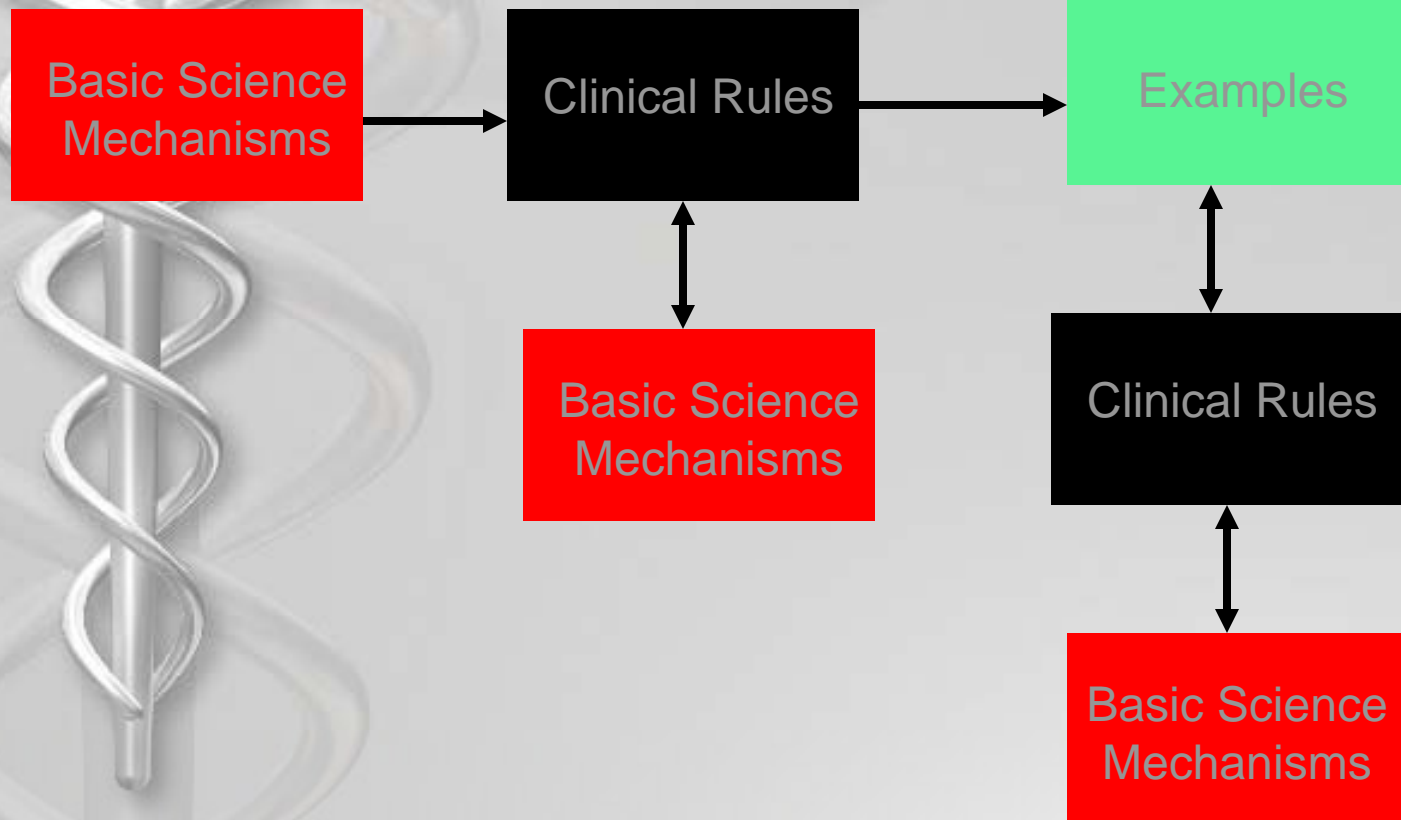
- ◆ Memory of individual patient experiences

# *Schmidt & Norman, 1991*

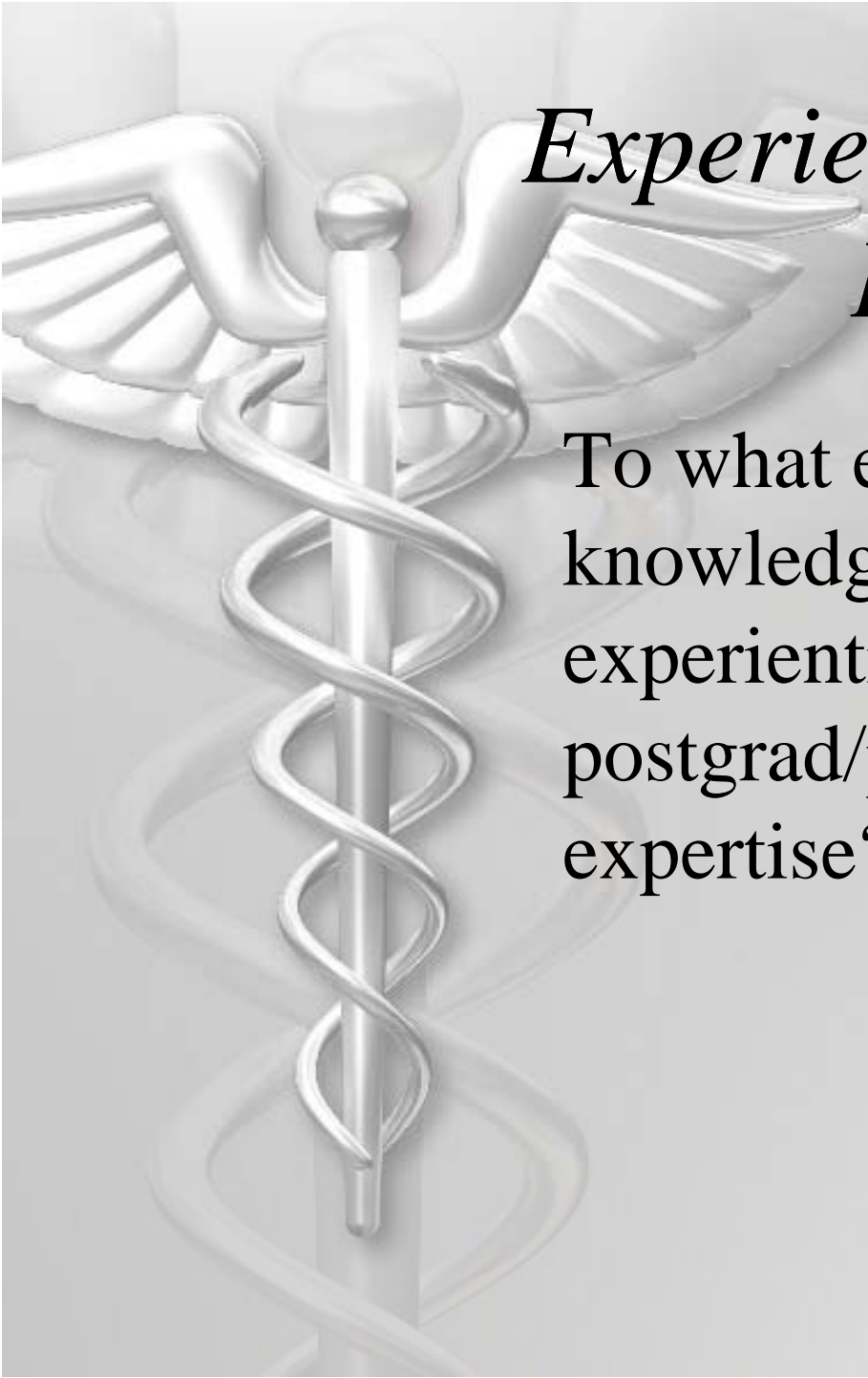
Novice

Intermediate

Expert







# *Experiential vs. Analytical Knowledge*

To what extent does the formal knowledge of med school vs. the experiential knowledge of postgrad/practice contribute to expertise?



# *What's Happened since 1991?*

Mechanisms:

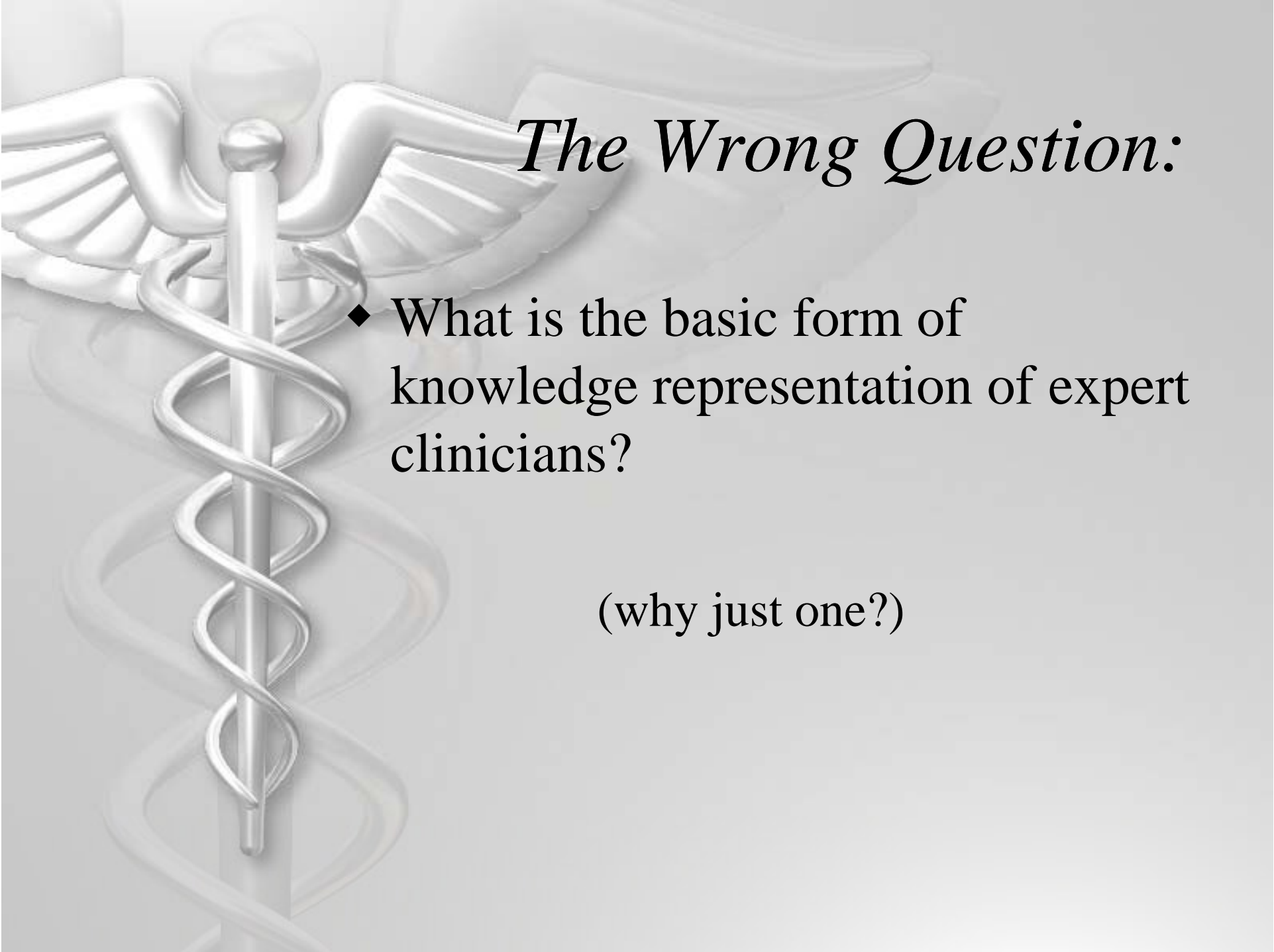
not much

Rules:

proliferation of “basic” rules

Examples:

lots of evidence in diff  
domains



## *The Wrong Question:*

- ◆ What is the basic form of knowledge representation of expert clinicians?

(why just one?)



## *The Right Questions:*

- ◆ How is knowledge of mechanisms , rules and examples coordinated?
- ◆ How does the reliance on different kinds of knowledge change with experience?
- ◆ Can we adopt some instructional strategies to improve effectiveness?



# *Agenda*

- ◆ **MECHANISM**

- ◆ When does an expert need/use basic science?
- ◆ What does a novice gain from basic science?

- ◆ **RULES**

- ◆ Methodological problems in distinguishing types of rule knowledge

- ◆ **EXAMPLES**

- ◆ Why exemplar knowledge is different

- ◆ **COORDINATION OF KNOWLEDGE**

- ◆ How do we coordinate examples and rules?



# *Rules -- Analytical Knowledge*

What is the basic representation?

- ◆ Bayesian probabilities (Papa, Wolf)
- ◆ “If-then” rules (expert system) (Shortliffe)
- ◆ Illness scripts (Feltovich, Charlin)
- ◆ Propositional networks (Patel)
- ◆ Semantic axes (Bordage)
- ◆ Prototypes (Bordage)
- ◆ Schema (Mandin, Coderre)
- ◆ Concept map (McLaughlin, Mcgaghie, West)

Surely they can't all be right?

Or can they?



# *The methodological problems*

- ◆ Problem 1:

Verbal reports as data

People may have access to, or can generate, all kinds of knowledge to satisfy researchers

People are unlikely to have insight into where their knowledge came from

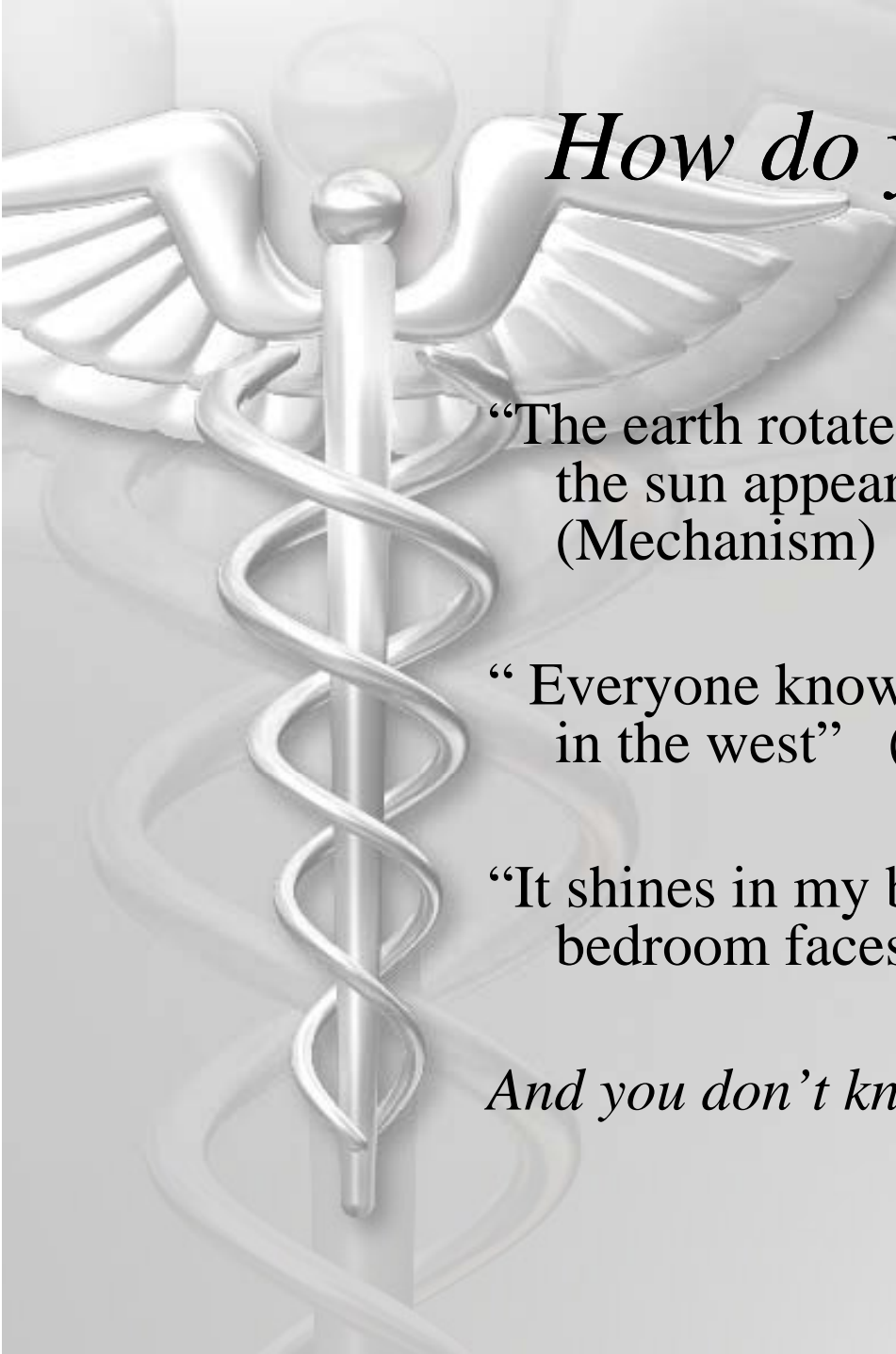




Where does the sun rise?

- a) North
- b) South
- c) East
- d) West
- e) It depends





*How do you know where the  
sun rises?*

“The earth rotates from west to east so this makes the sun appear to rise in the east”  
(Mechanism)

“Everyone knows that it rises in the east and sets in the west” (Rule)

“It shines in my bedroom window, and my bedroom faces east” (Example)

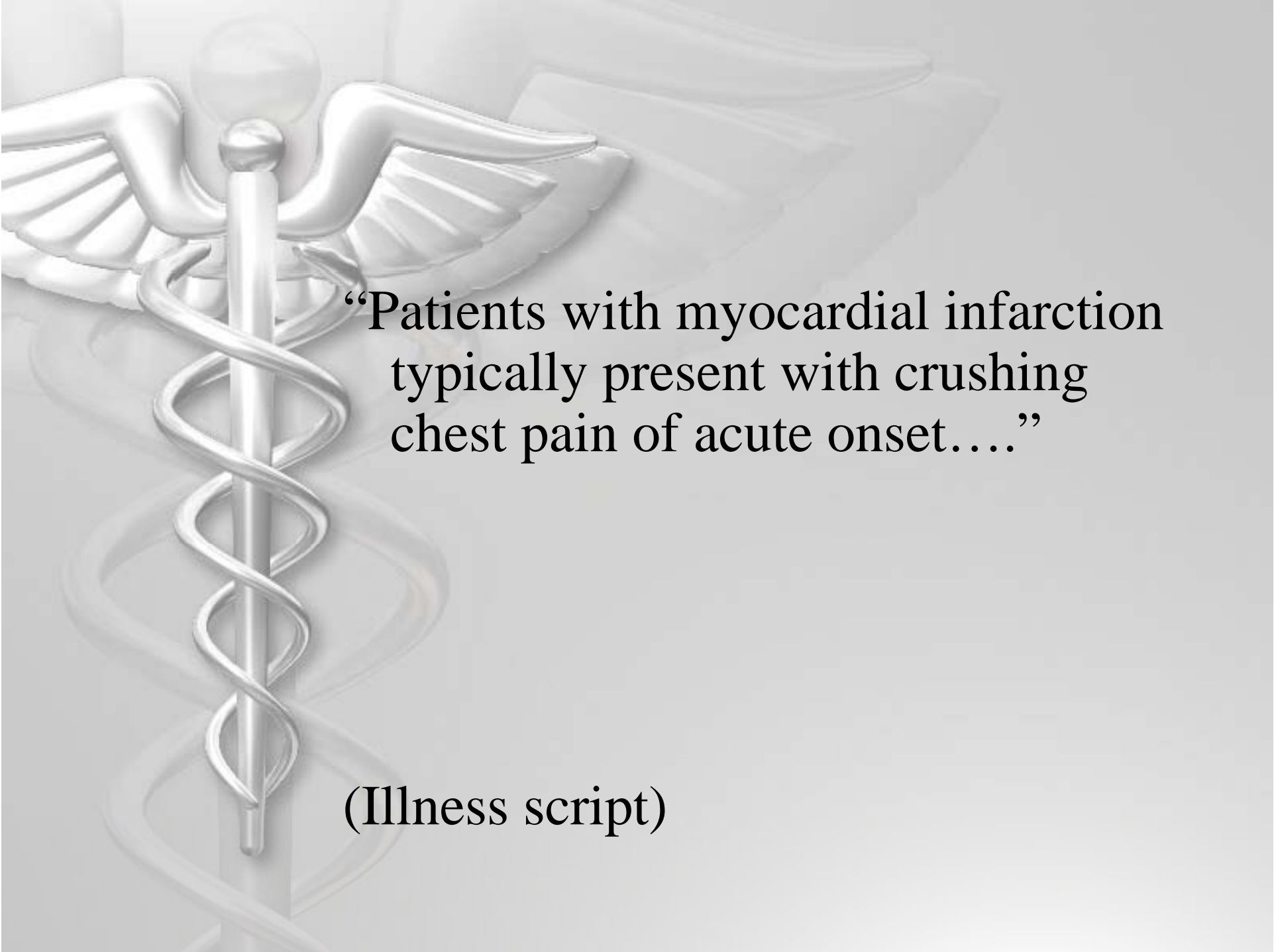
*And you don't know how you know.....*



How do you approach the patient with jaundice?

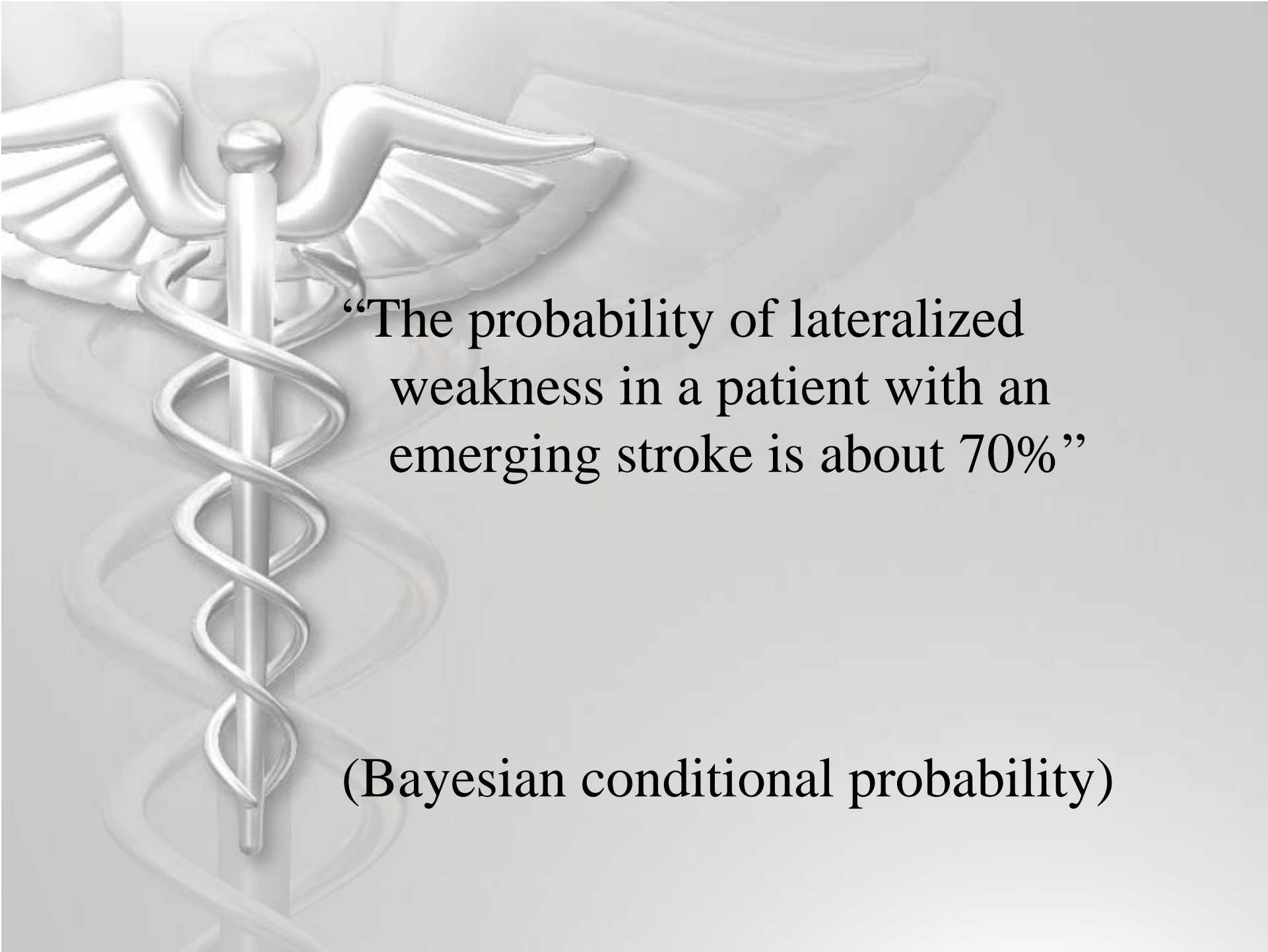
- ◆ Prehepatic
- ◆ Hepatic
- ◆ Post-hepatic

(Schema induction)



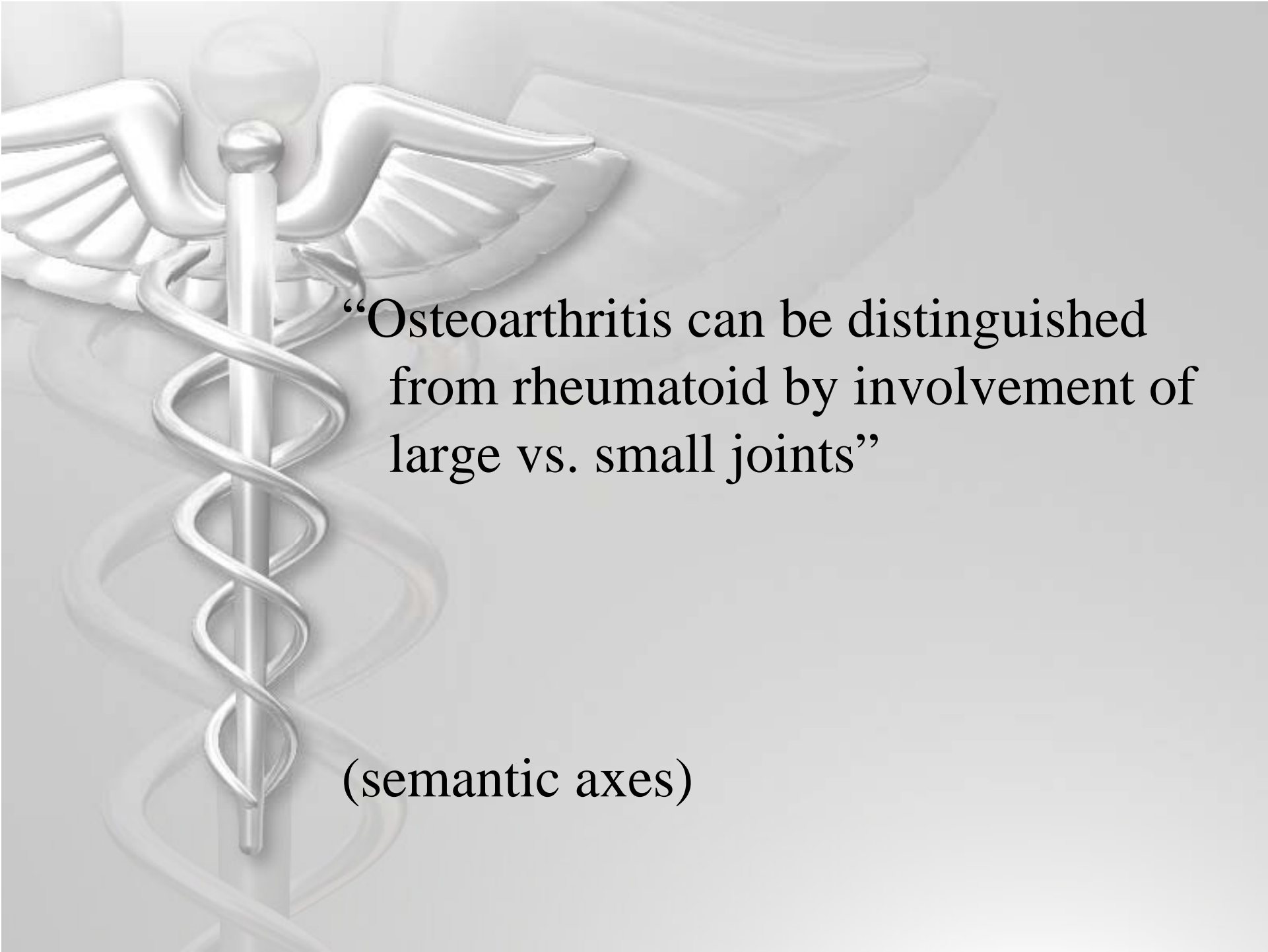
“Patients with myocardial infarction typically present with crushing chest pain of acute onset....”

(Illness script)



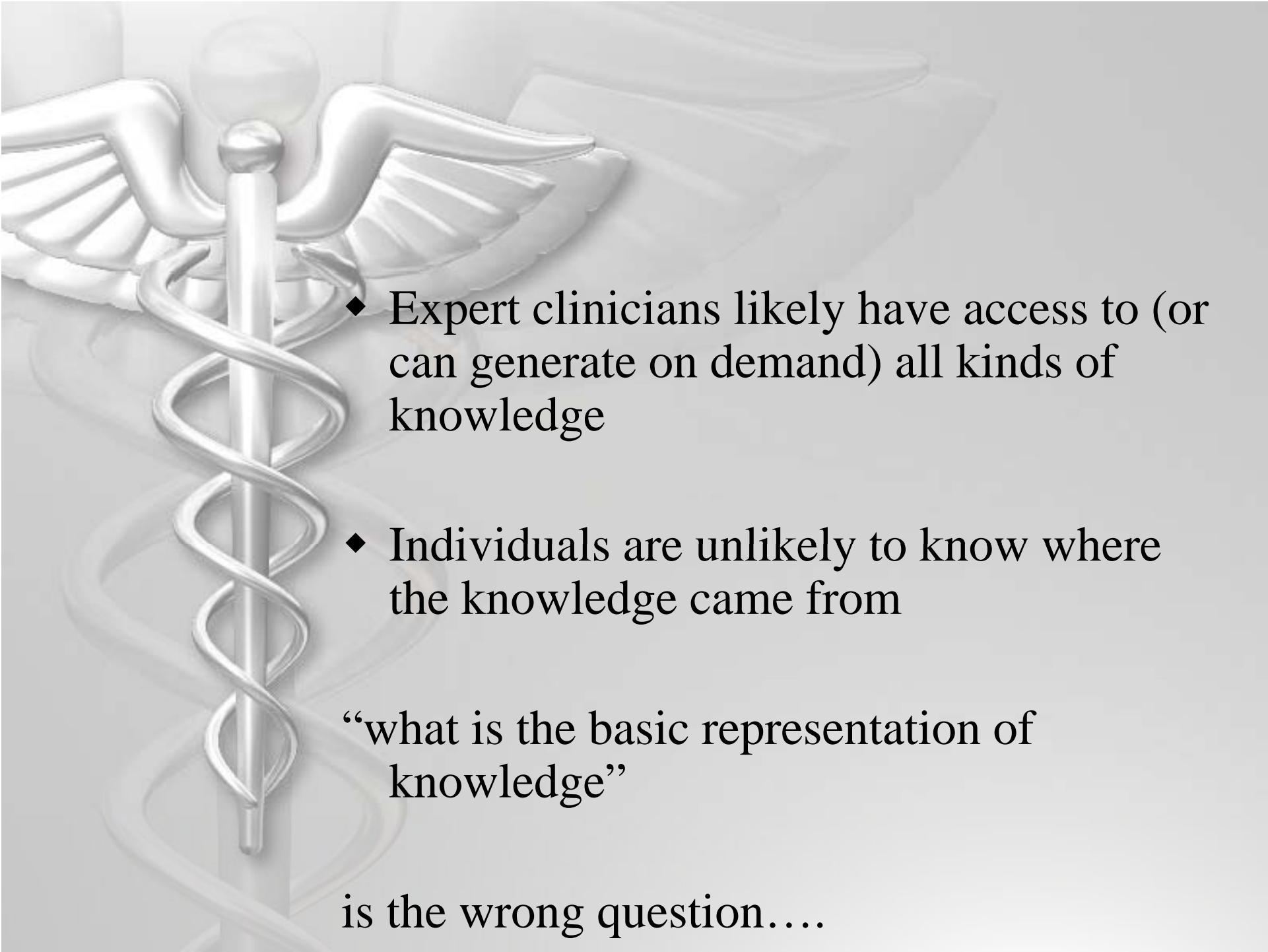
“The probability of lateralized weakness in a patient with an emerging stroke is about 70%”

(Bayesian conditional probability)



“Osteoarthritis can be distinguished from rheumatoid by involvement of large vs. small joints”

(semantic axes)

- 
- ◆ Expert clinicians likely have access to (or can generate on demand) all kinds of knowledge
  - ◆ Individuals are unlikely to know where the knowledge came from

“what is the basic representation of knowledge”

is the wrong question....



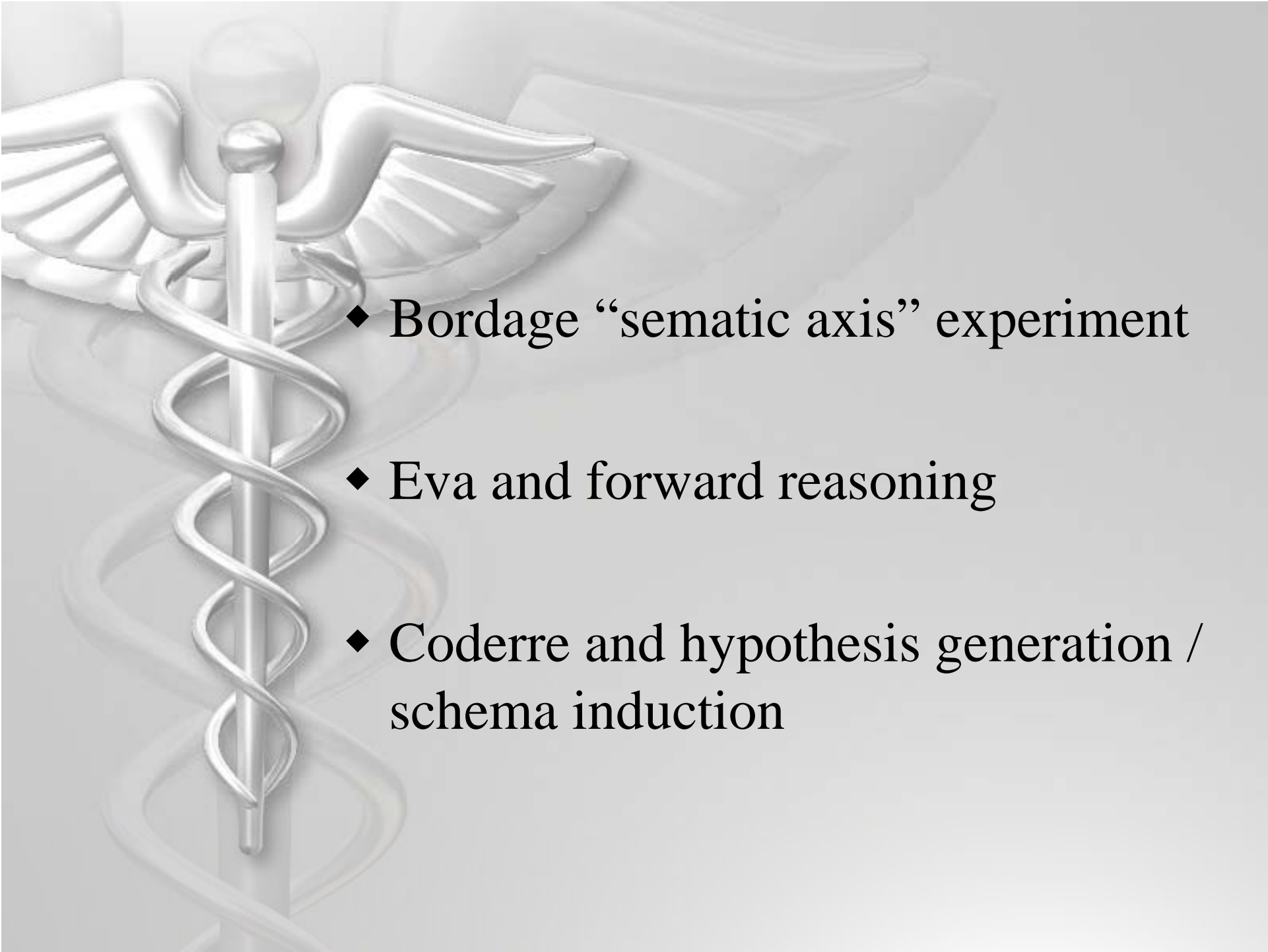
◆ Problem 2:

The chicken and the egg:

Does (schema induction, forward reasoning, compiled knowledge, semantic axes, etc.) lead to better solutions...

OR

Do people who get the right answer tend to talk about it in a coherent fashion?

- 
- ◆ Bordage “sematic axis” experiment
  - ◆ Eva and forward reasoning
  - ◆ Coderre and hypothesis generation / schema induction




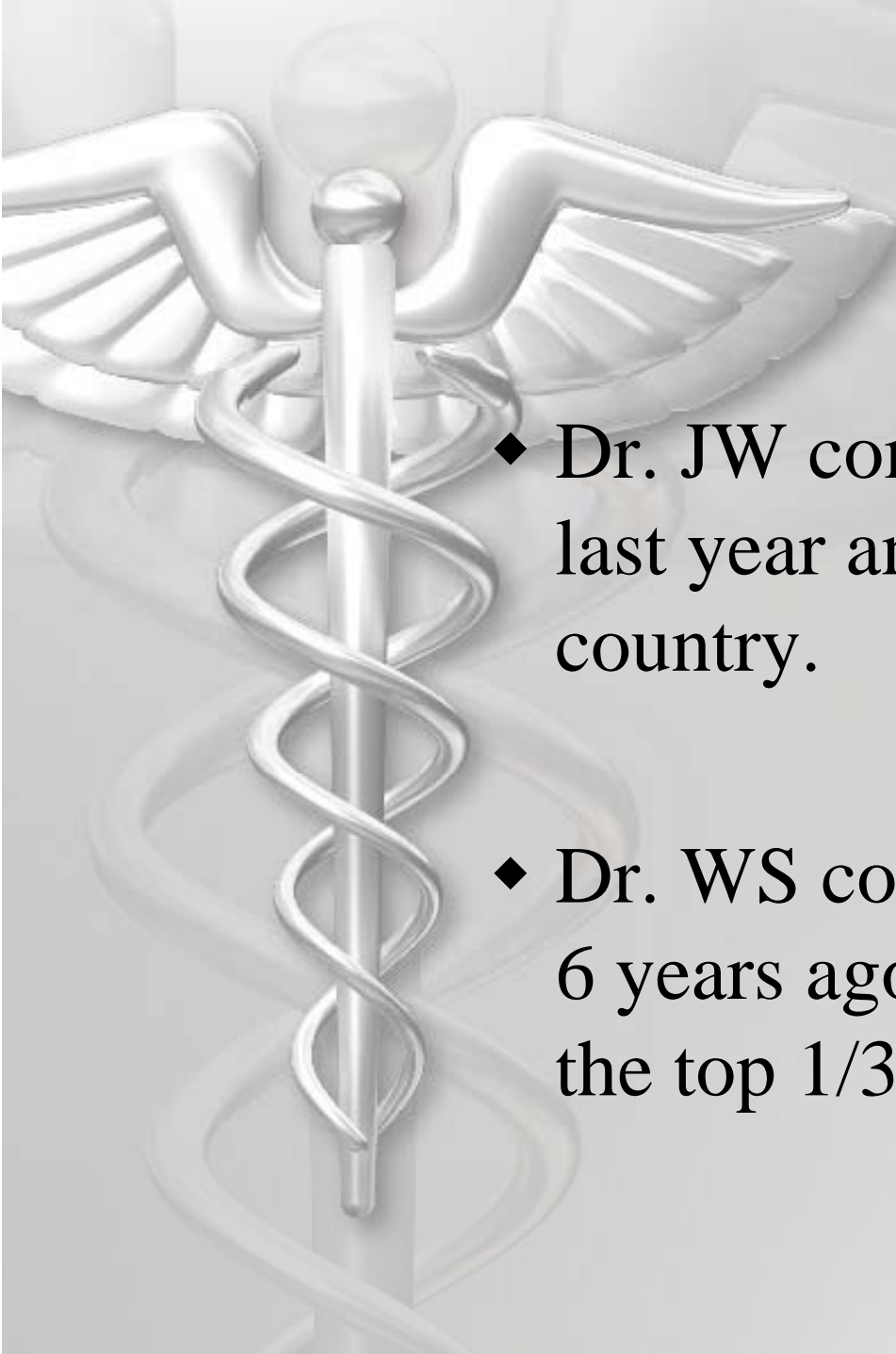


## *Conclusions -- Rules*

- ◆ Analytical knowledge is likely represented in many forms
- ◆ Experts have access to all kinds of knowledge
- ◆ Experts are able to “create” knowledge “on the fly”

Quest for the basic knowledge representation is Quixotic

- 
- ◆ How long *after* you completed training in your specialty before you felt you were competent?



## *Who do you pick?*

- ◆ Dr. JW completed the ABIM exam last year and stood 14th in the country.
- ◆ Dr. WS completed the ABIM exam 6 years ago. At the time, she was in the top 1/3 of all candidates.



## *The Conundrum*

Why do we prefer the candidate with apparently less “competence” but much more experience?

What did she get from 10 years of experience?

*10 years of experiences*

# *How do you get to play grand master chess?*

Is it:

- learning the rules?
- learning to think of more moves and deeper strategy?  
(process)
- learning to think *better* moves?  
(knowledge)





How do they get to think of *better* moves?

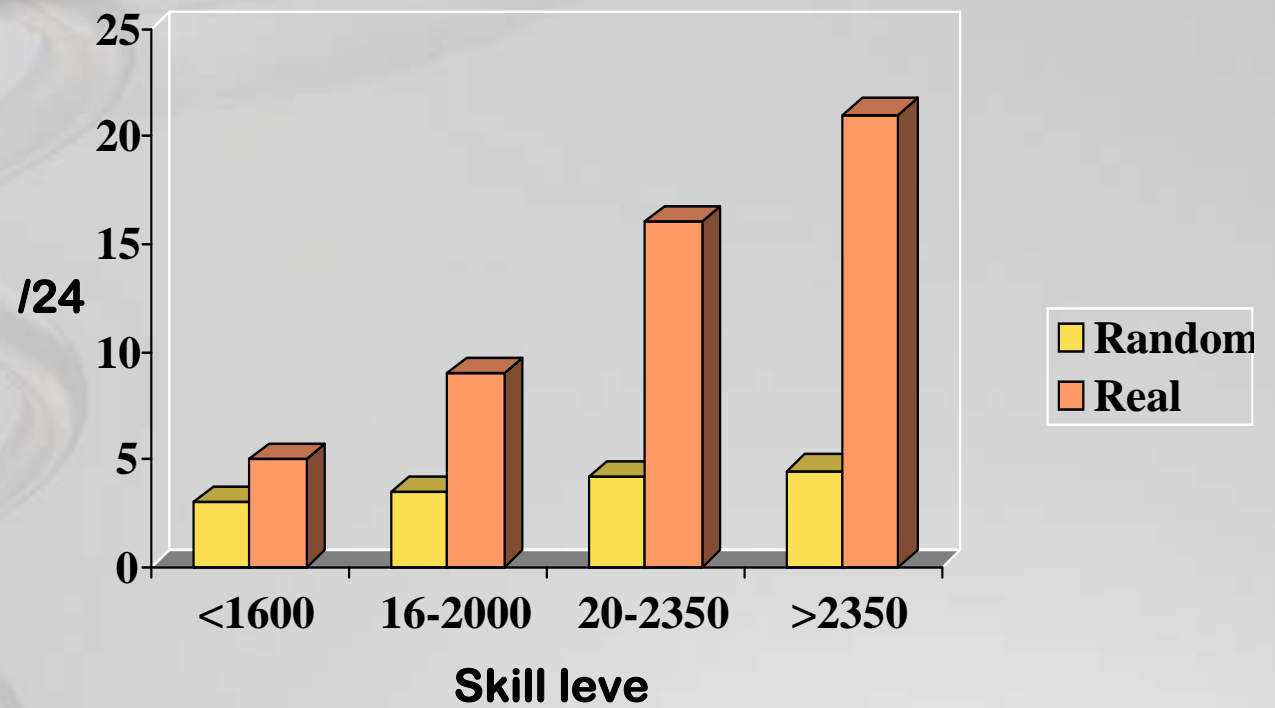
It takes time:

A chess grand master has learned about 50,000 strategies



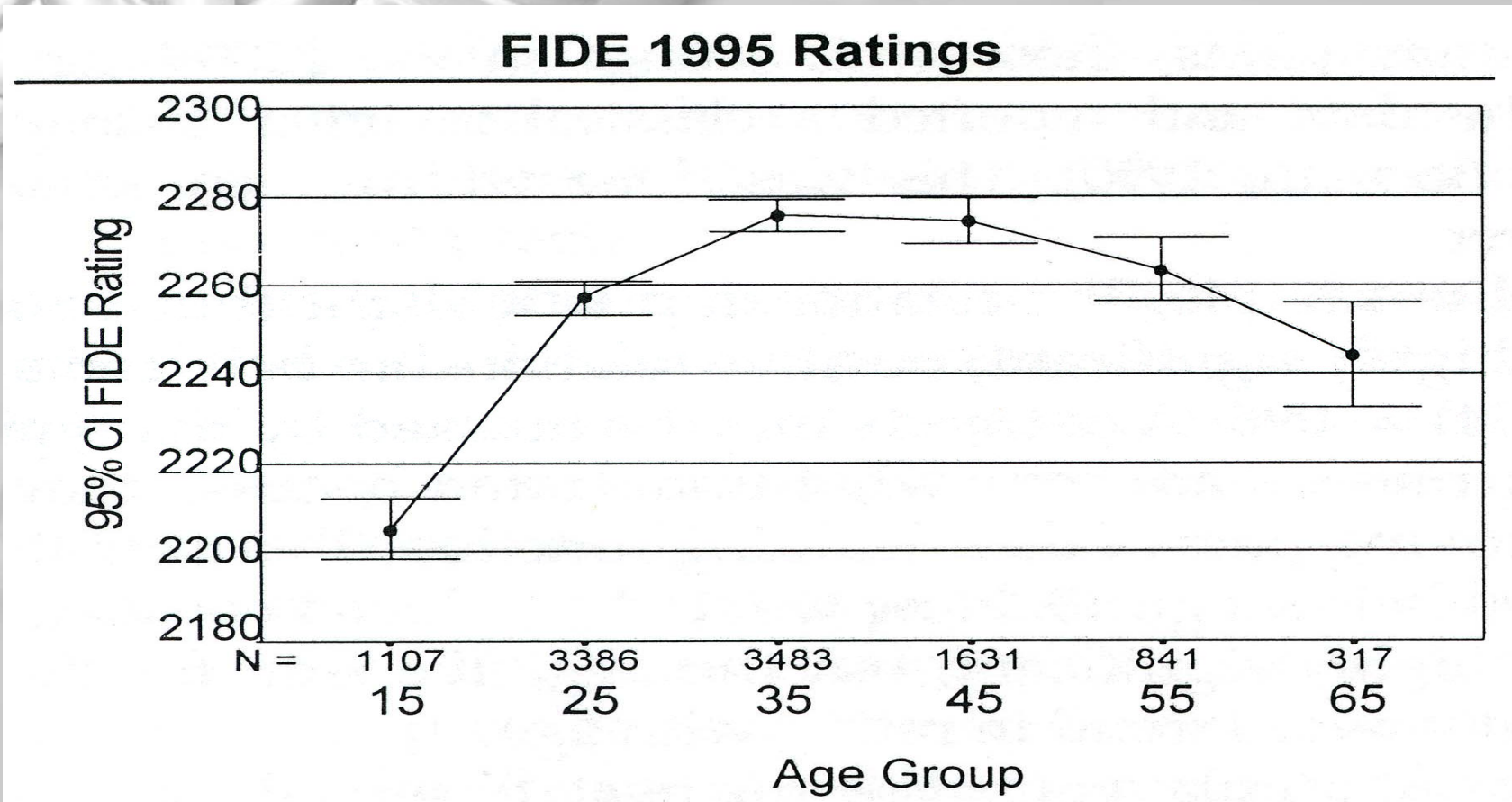


*Recall after 5 sec.  
exposure*





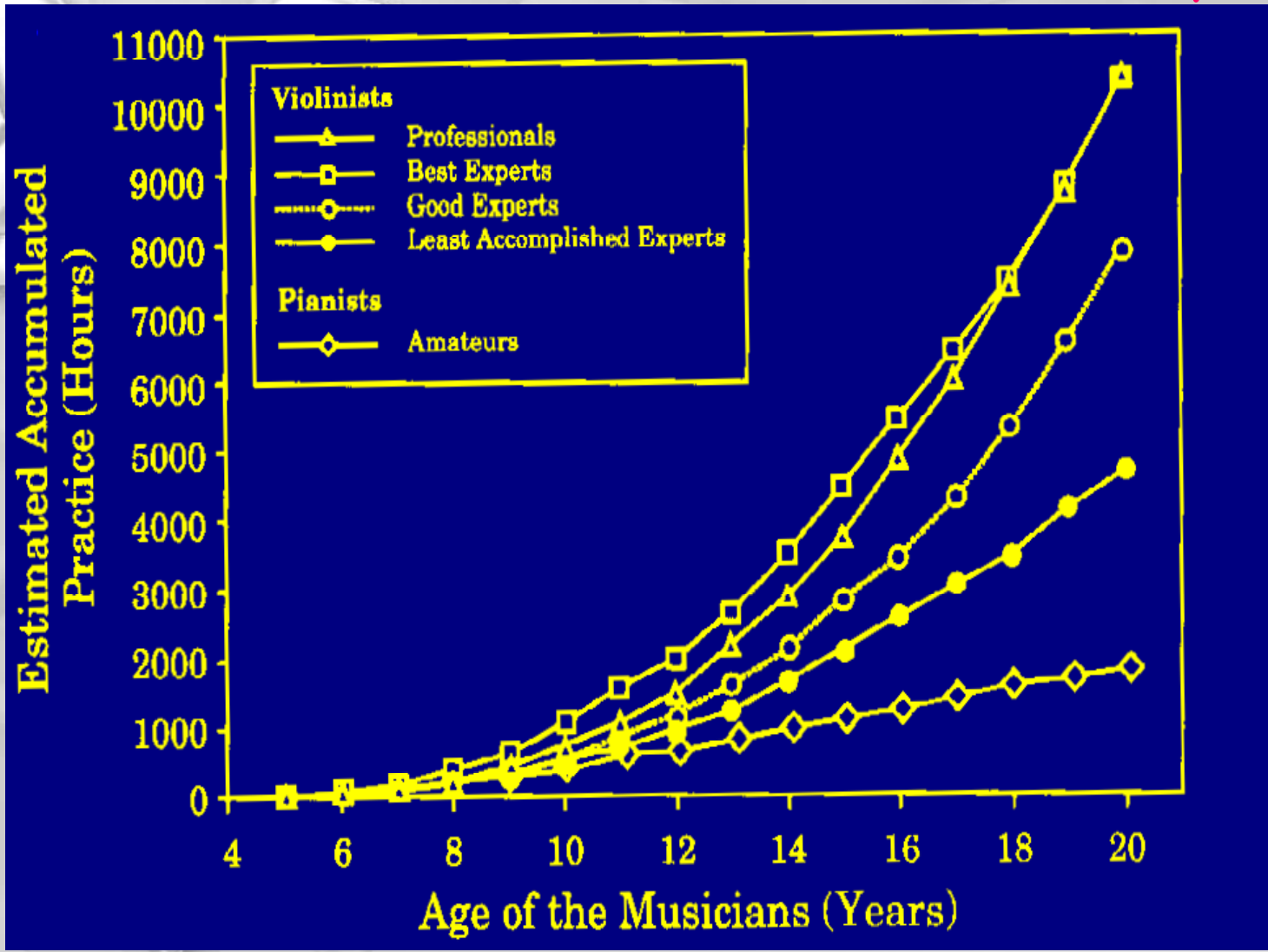
# Age and Skilled Chess Performance



**Ericsson and Charness, 1998**



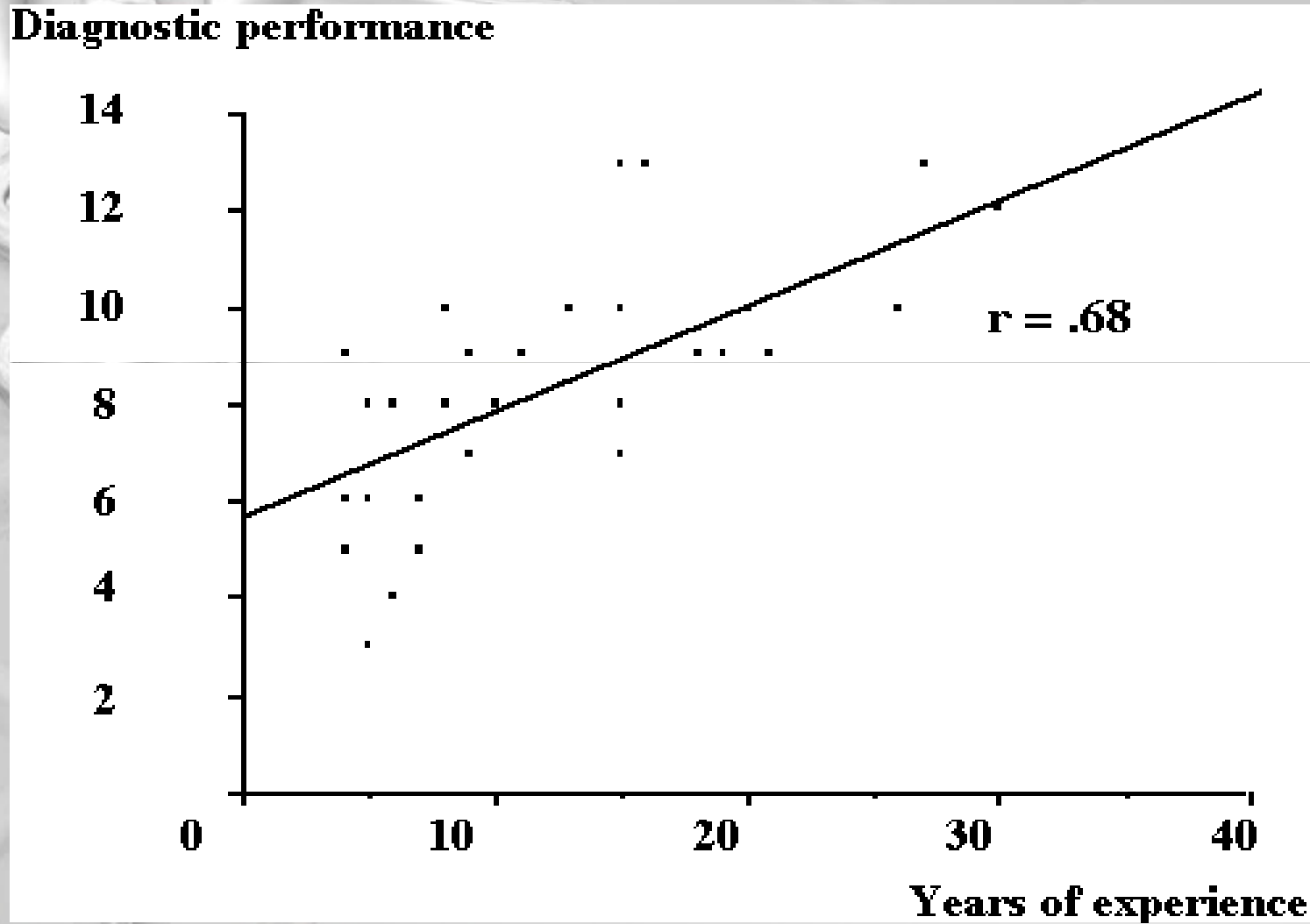
*How do you get to play violin?*



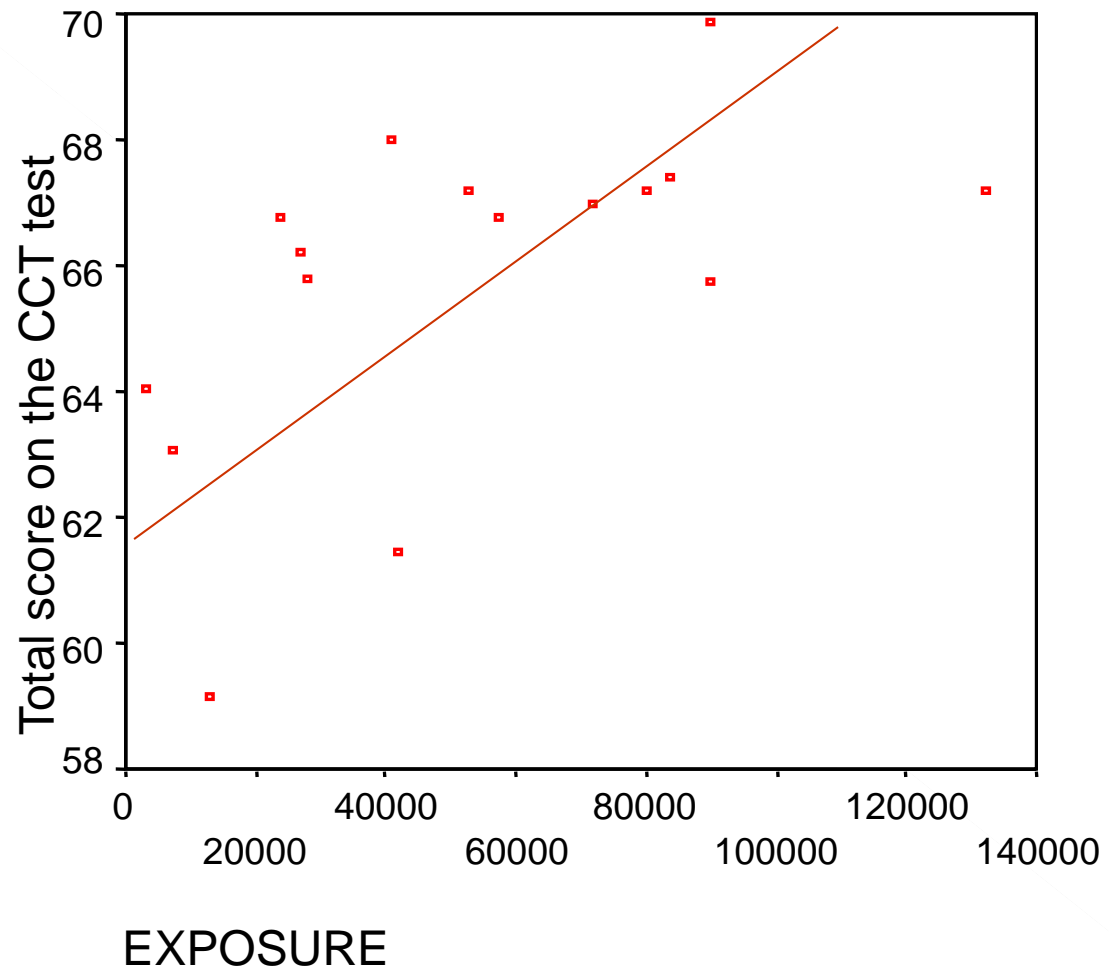


*How do you get to play doctor?*

# Age and Diagnostic Accuracy



Hobus & Schmidt, 1993



Schuwirth et al., 2004



*Conclusion:*

It takes 10 years / 10,000 hours to acquire sufficient experience to be a “master”

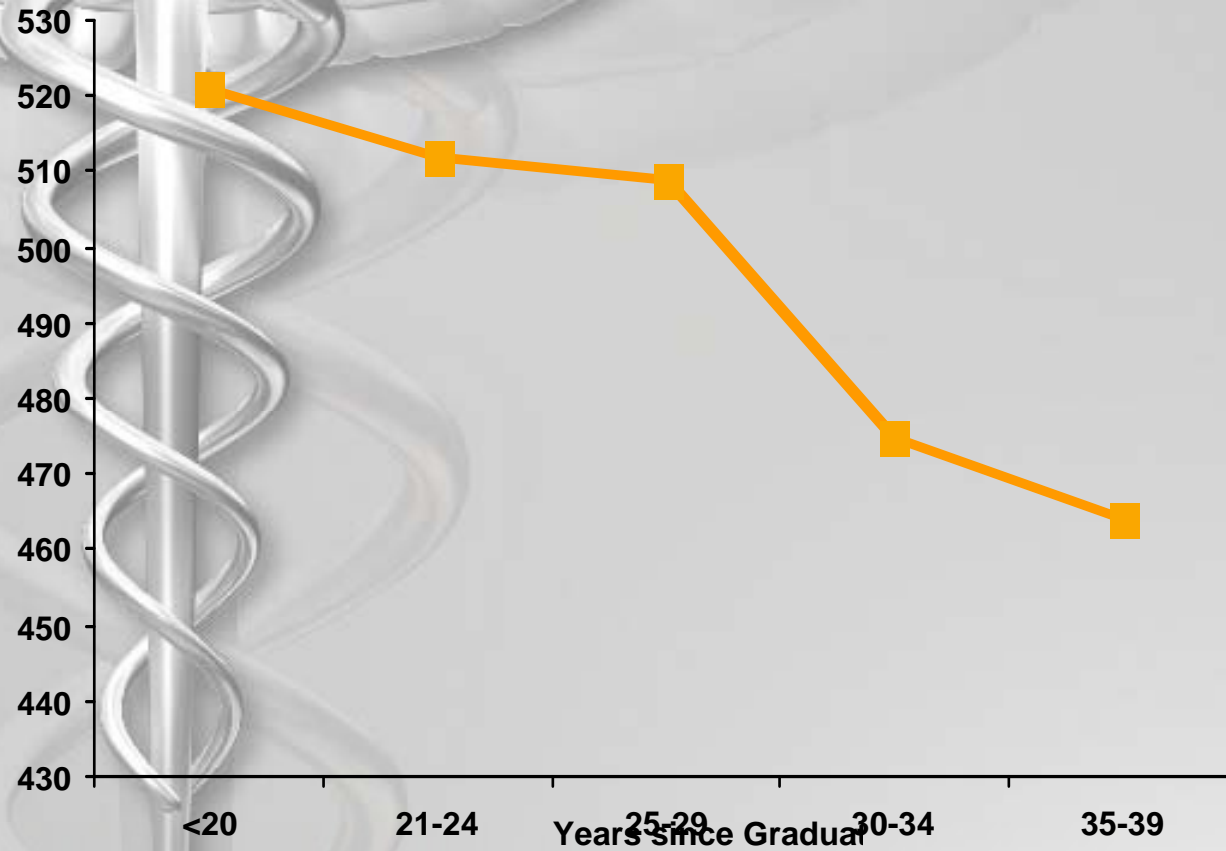


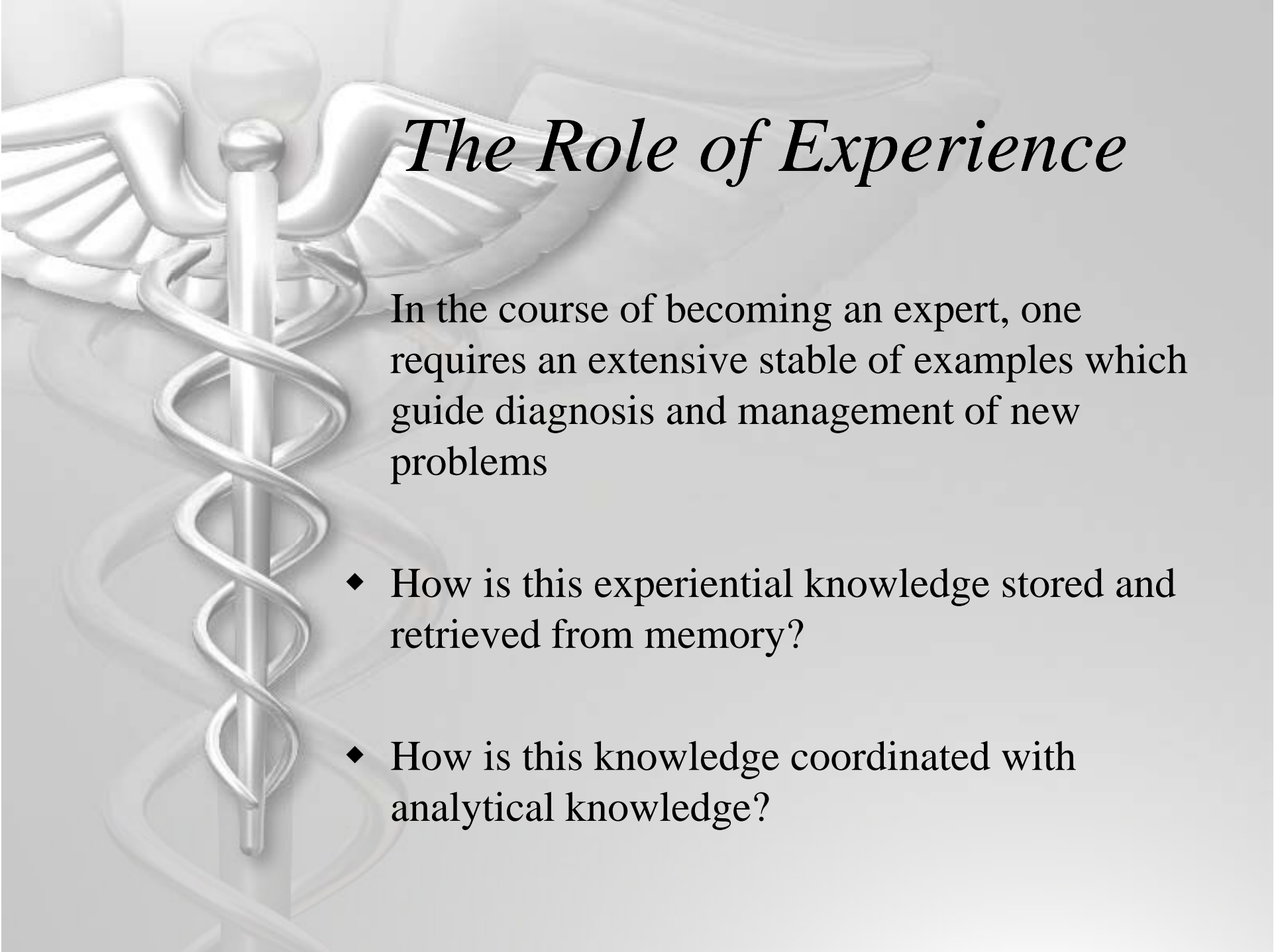


*BUT*

Every measure of knowledge  
decays right after graduation

# *Day and Norcini, 1988*





# *The Role of Experience*

In the course of becoming an expert, one requires an extensive stable of examples which guide diagnosis and management of new problems

- ◆ How is this experiential knowledge stored and retrieved from memory?
- ◆ How is this knowledge coordinated with analytical knowledge?



*What does experiential  
knowledge look like?*

Experiential knowledge is different  
from formal knowledge

- “unconscious” vs. conscious
- not easily assessed
- not easily verbalized

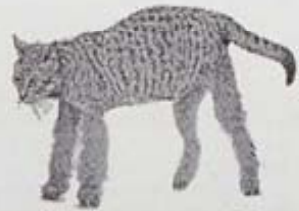
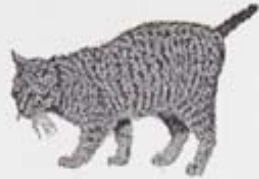


## *Exemplar Theory - Medin, Brooks*

- ◆ Categories consist of a collection of prior instances
  - ◆ identification of category membership based on availability of similar instances
  - ◆ Retrieval process is “non-analytic (unaware), hence can result from objectively irrelevant features
  - ◆ Retrieval process is not deliberate, not available to introspection











I can explain...

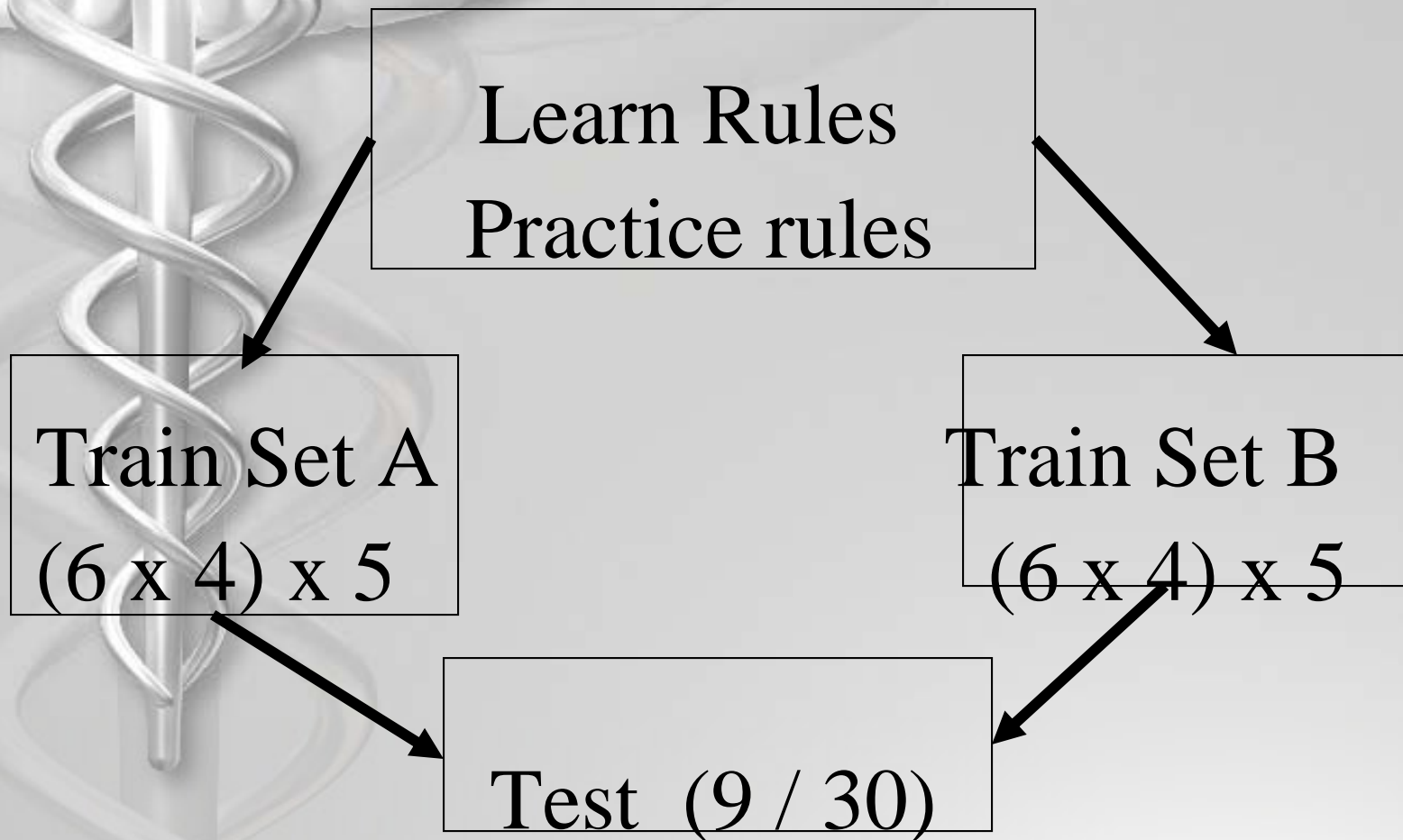
www.lollie.com



# *Effect of Similarity*

*(Allen, Brooks, Norman, 1992)*

- ◆ 24 medical students, 6 conditions







CONTACT D.

LICHEN P.L.

SET

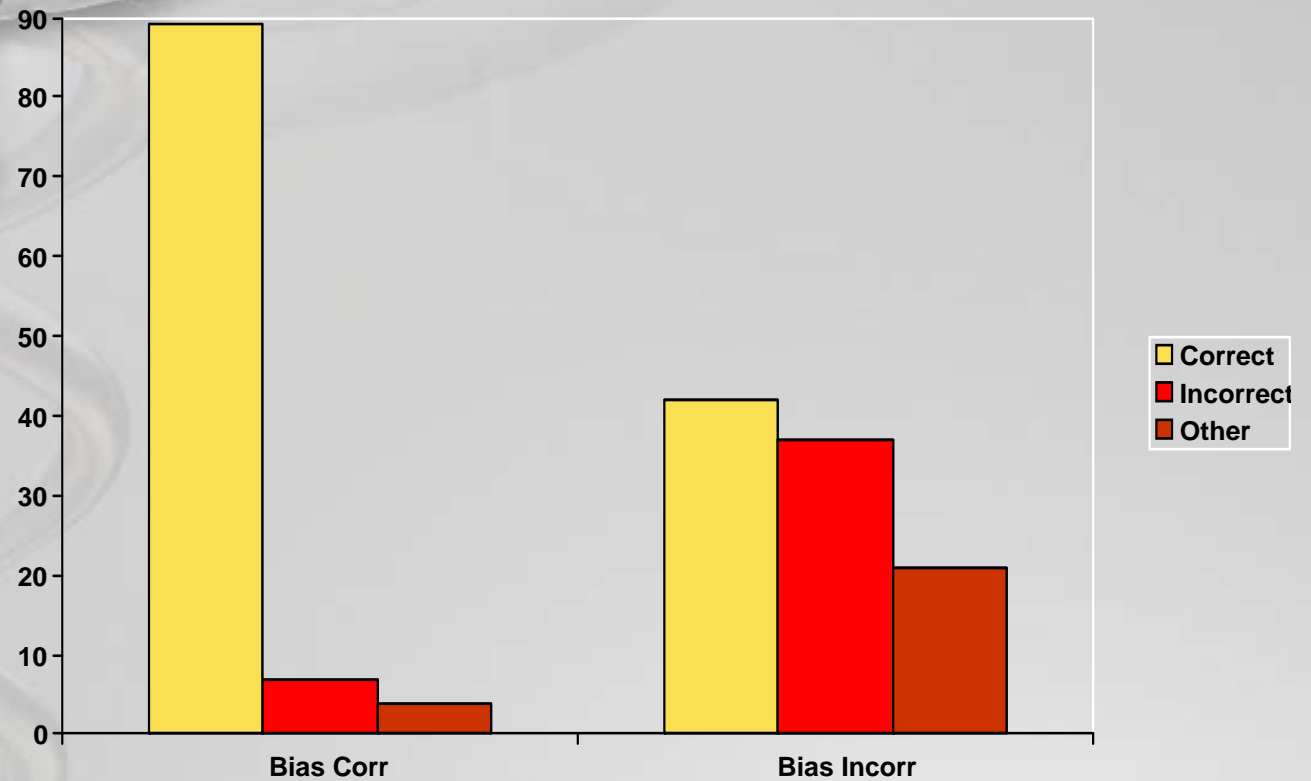
A

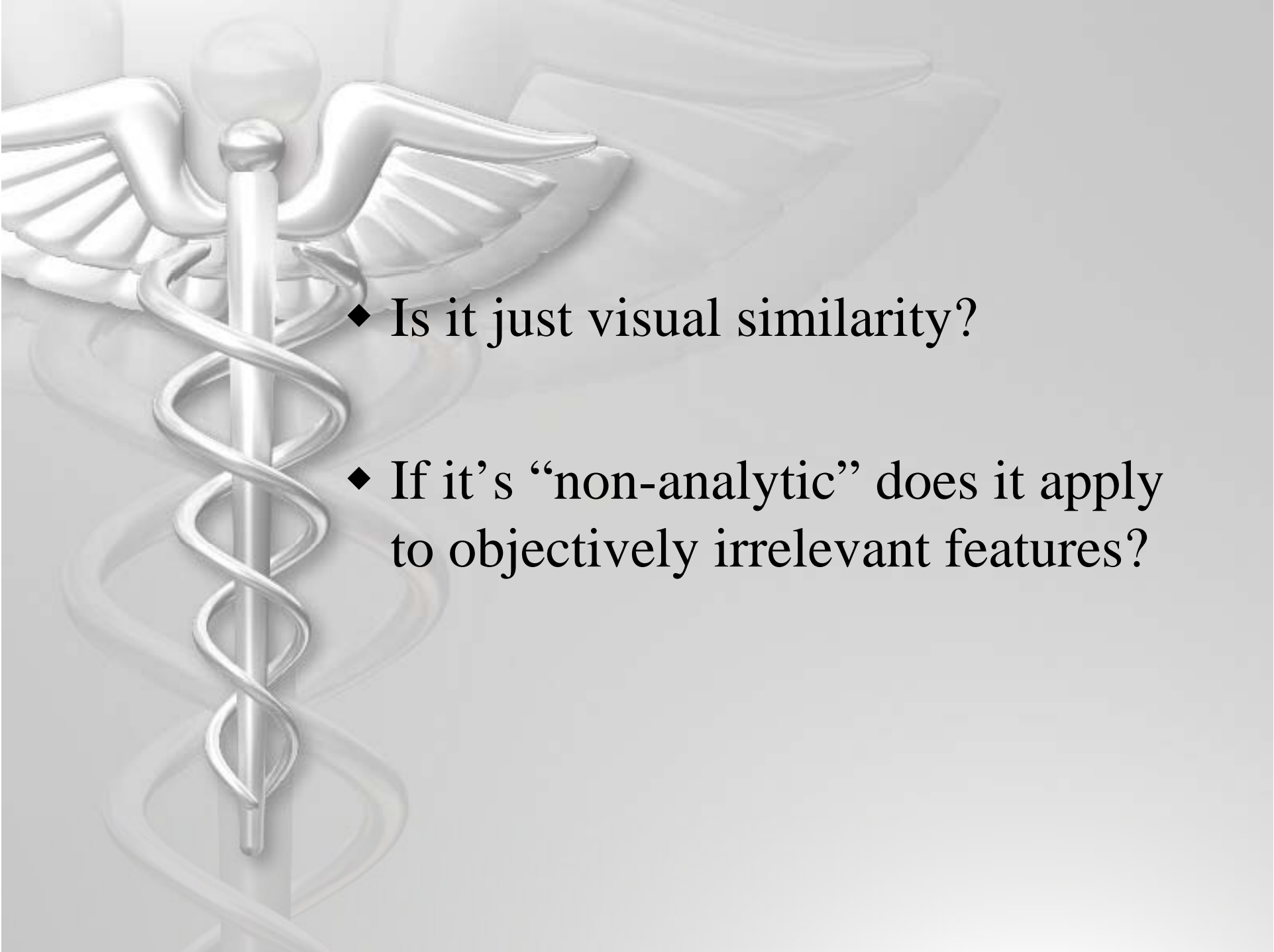
B

**TEST  
CHAMELEON**



# *Accuracy by Bias Condition*



- 
- ◆ Is it just visual similarity?
  - ◆ If it's “non-analytic” does it apply to objectively irrelevant features?





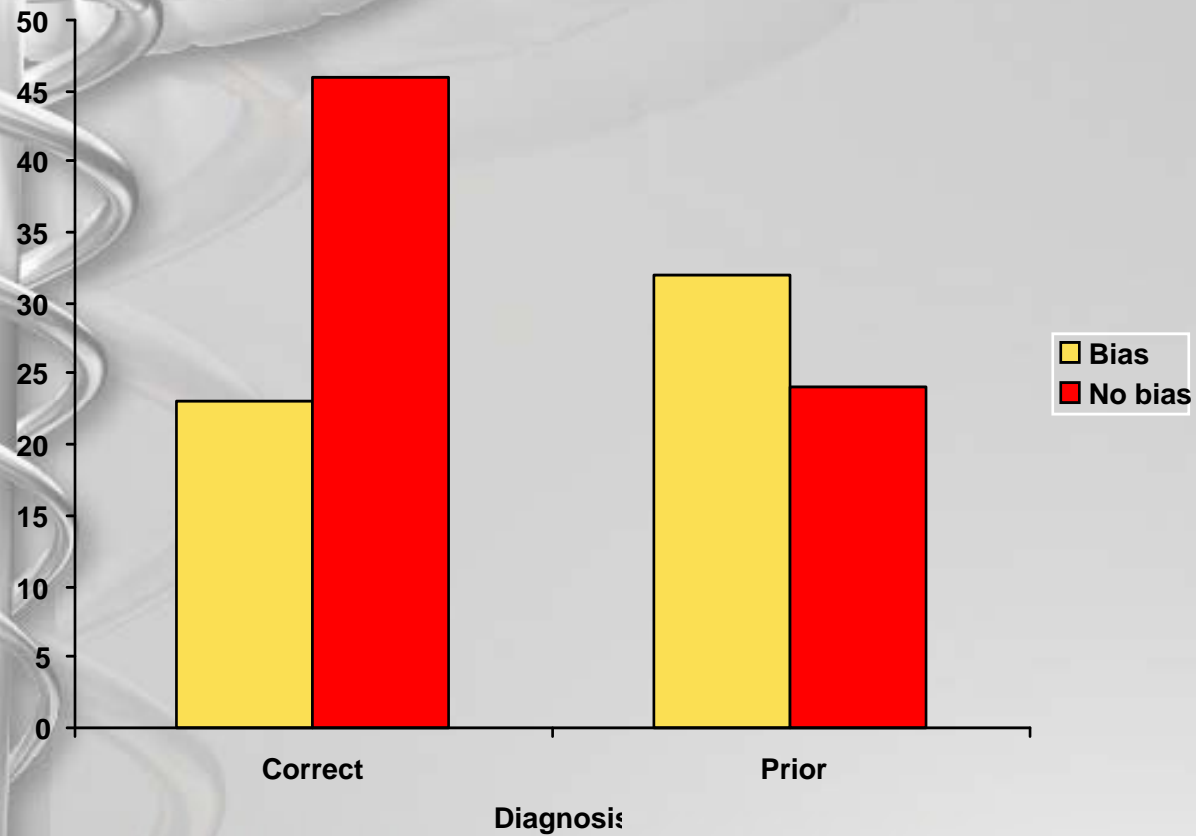
# *ECG Interpretation*

## *Hatala et al, 1999*

- ◆ Medical students/ Fam Med residents
- ◆ **PRACTICE** (4/4 + 7 filler)
  - ◆ middle aged banker with chest pain
- OR
- ◆ elderly woman with chest pain
  - ◆ **Anterior M I**
- ◆ **TEST** ( 4 critical + 3 filler)
  - ◆ Middle aged banker with chest pain
    - ◆ **Left Bundle Branch Block**

# RESULTS

## *Percent of Diagnoses by Condition*





## *Is that the only role of experience?*

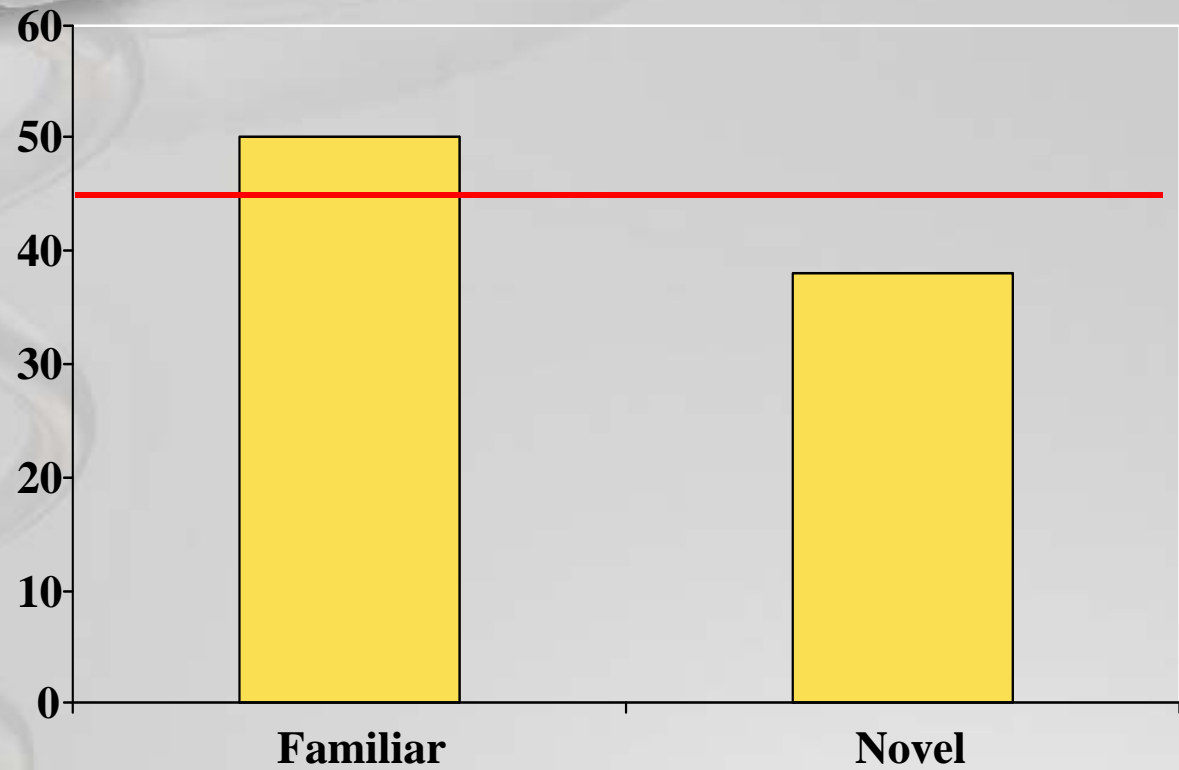
- ◆ Experts learn:
  - ◆ The features in a rule
    - ◆ “informational” - dyspnea, crushing chest pain
  - ◆ The ways that the features can present
    - ◆ “instantiated” -- “can’t catch my breath”, “like a vise”
- ◆ Experience helps in interpretation of features?



*Dore, Brooks & Norman, 2005*

- ◆ 23 Undergrad Psychology students
- ◆ 4 “pseudopsychiatry” disorders
- ◆ Practice with one version of features (e.g ‘tired’, ‘anxious’, ) - 4 cases
  
- ◆ Test with 50/50 cases
  - ◆ 2 familiar, Dx A (‘tired’, ‘anxious’),
  - ◆ 2 novel Dx B (‘weary’, ‘nervous’)

# *Dx Probability assigned*

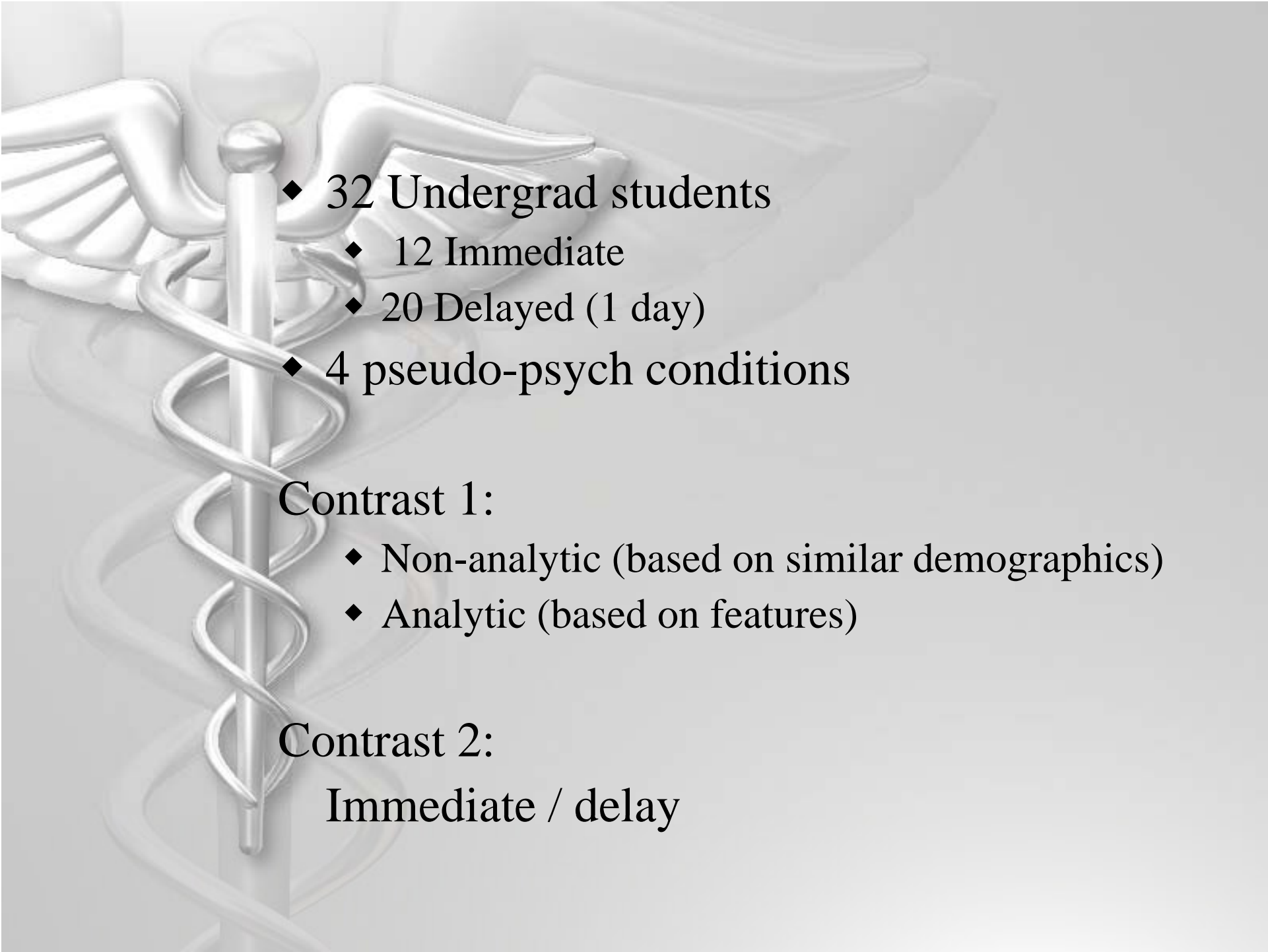




# *Exploring the Nature of “Non-Analytic” Similarity*

Young & Norman, 2006

1. Is similarity a visual phenomenon?
2. How similar is similar enough?
3. Effect of time delay

- 
- ◆ 32 Undergrad students
    - ◆ 12 Immediate
    - ◆ 20 Delayed (1 day)
  - ◆ 4 pseudo-psych conditions

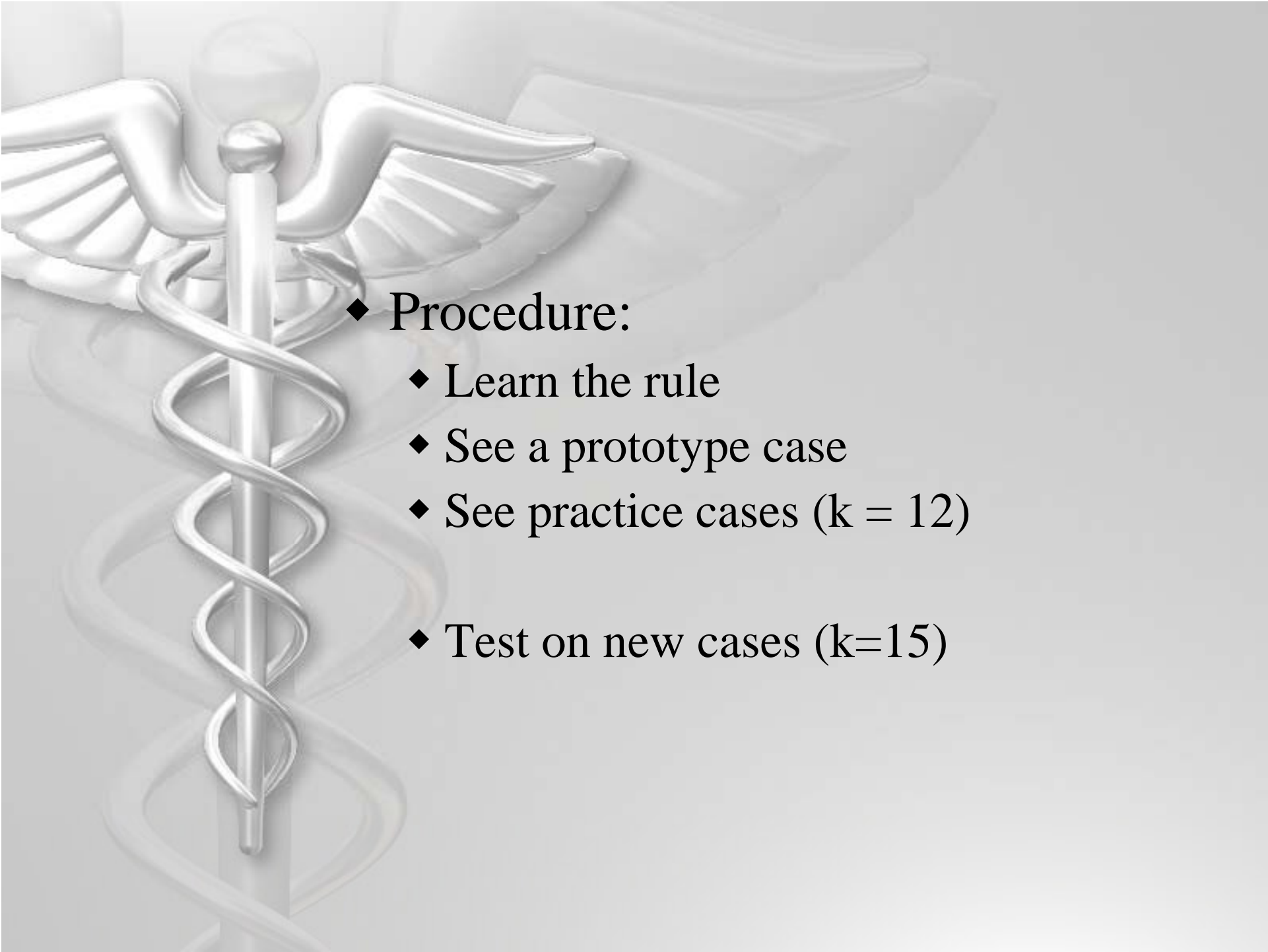
#### Contrast 1:

- ◆ Non-analytic (based on similar demographics)
- ◆ Analytic (based on features)

#### Contrast 2:

Immediate / delay



- 
- ◆ Procedure:
    - ◆ Learn the rule
    - ◆ See a prototype case
    - ◆ See practice cases ( $k = 12$ )
    - ◆ Test on new cases ( $k=15$ )



## Familiarity:

- ◆ Demographics

- ◆ John McKay, 35 year old public school teacher, married, 2 young daughters
- ◆ James McNaughton, 37 year old elementary school teacher, married, a son and daughter

- ◆ Features

- ◆ Thought his wife was having an affair with the neighbour
- ◆ Thought his wife was messing around with a colleague



TEST:

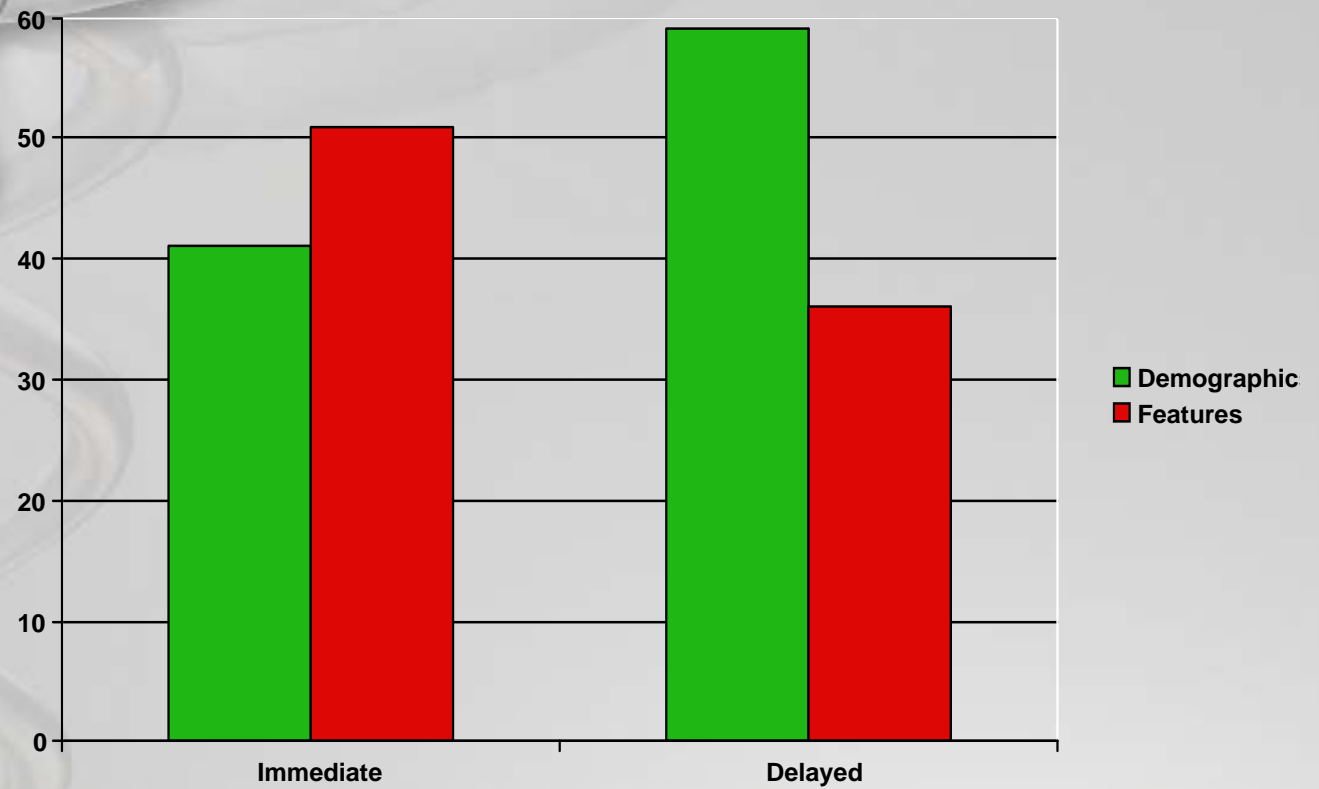
15 cases, 50/50 (2 features for each of 2 conditions)

Match on: demographic similarity  
vs.  
feature similarity

# *Mean Probability*



# *Mean Probability*





## *CONCLUSIONS - The Role of Examples*

- ◆ Experiential knowledge is a major contributor to diagnostic expertise
- ◆ Categories and concepts are based on our **specific** experience with the world
- ◆ These specific experiences are accessed and used without awareness



## *Where Do Clinicians Use Basic Science?*

- ◆ Most use basic science rarely?
  - ◆ Observational studies (Schmidt, Patel)
- ◆ Some use basic science some of the time
  - ◆ Difficult problems in nephrology
- ◆ Some use physiology ALL the time
  - ◆ Intensivists, anesthesiology





*Most use it rarely*  
*(Patel, Schmidt)*

- ◆ Clinicians rarely use basic science explanation in routine practice.
- ◆ While they may possess the knowledge, it remains “encapsulated” until mobilized for specific goals (to solve specific problems) (Schmidt, HG)

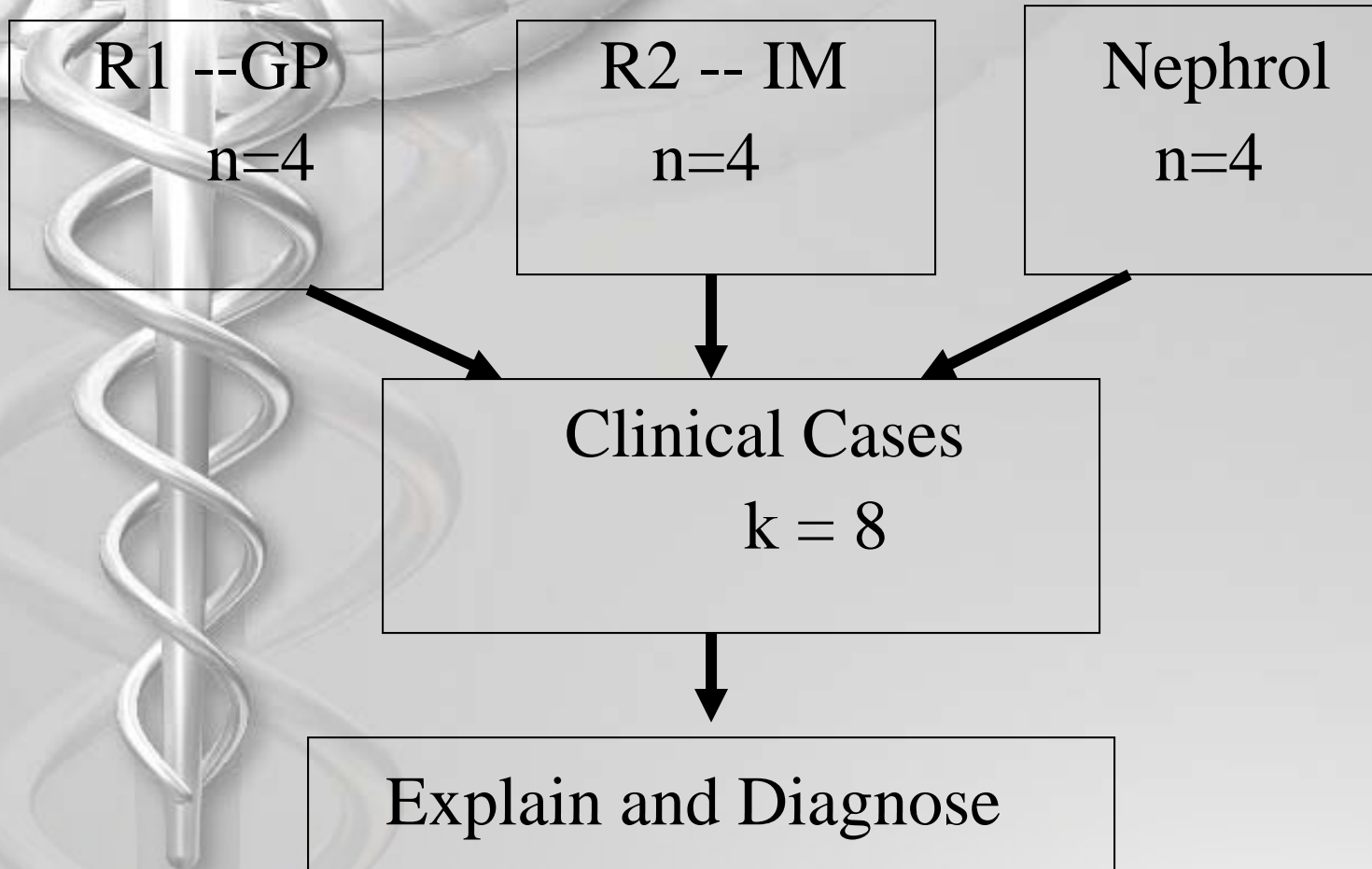


# *Some Use it with Difficult Cases*

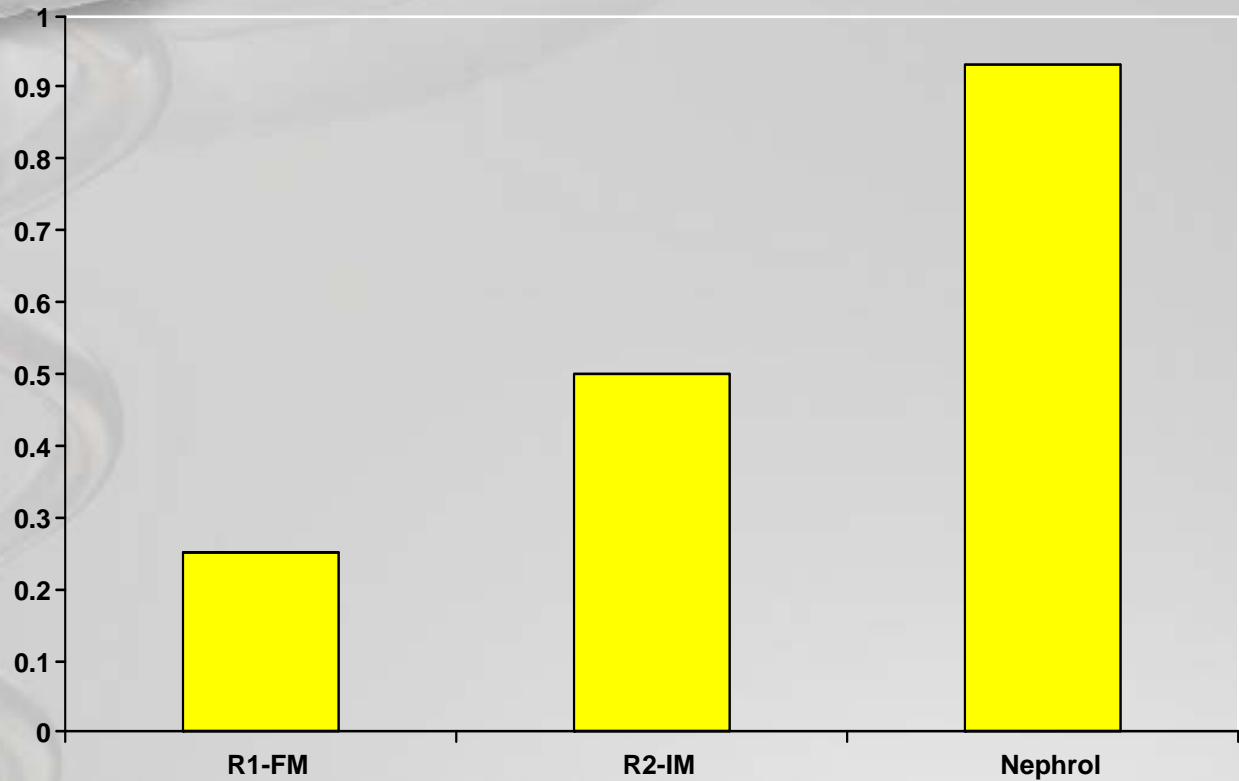
*(Norman, Brooks, Trott, Smith)*

- ◆ When experts are confronted with difficult cases, do they revert to causal reasoning?

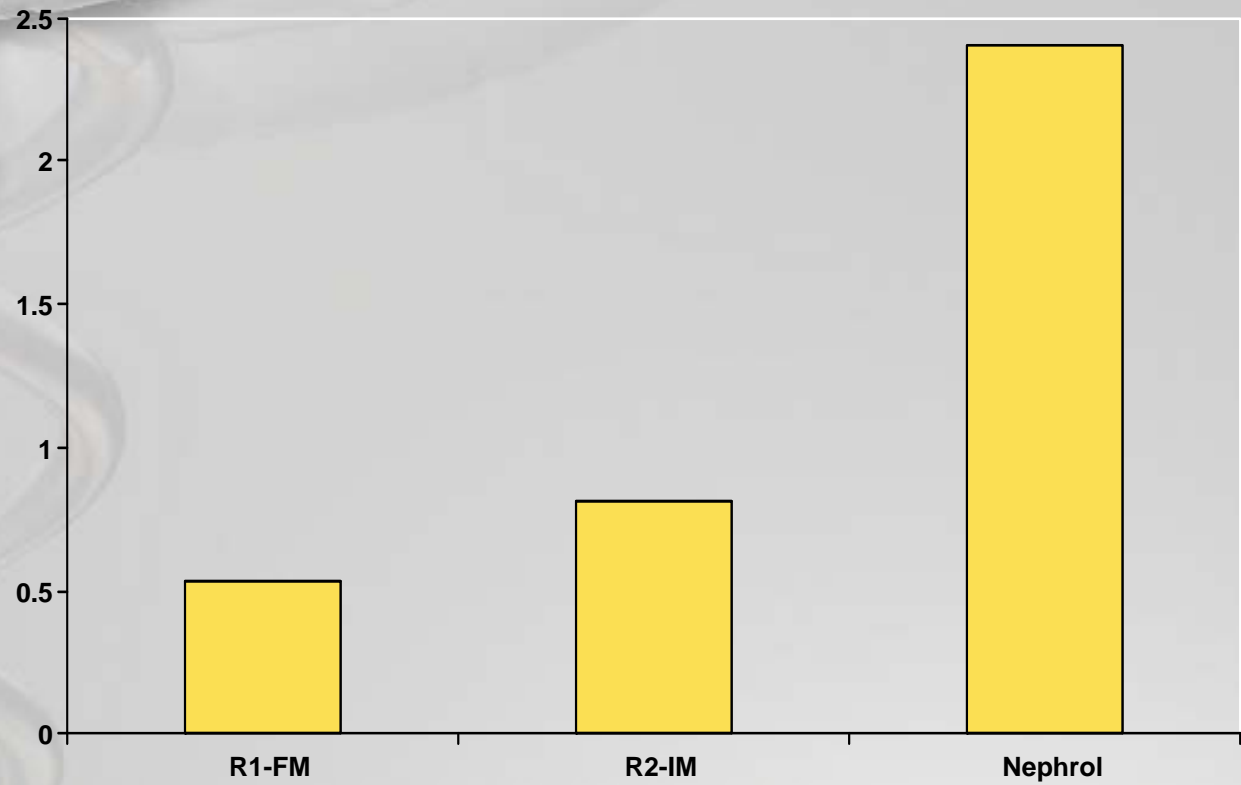
# *Experimental Design*



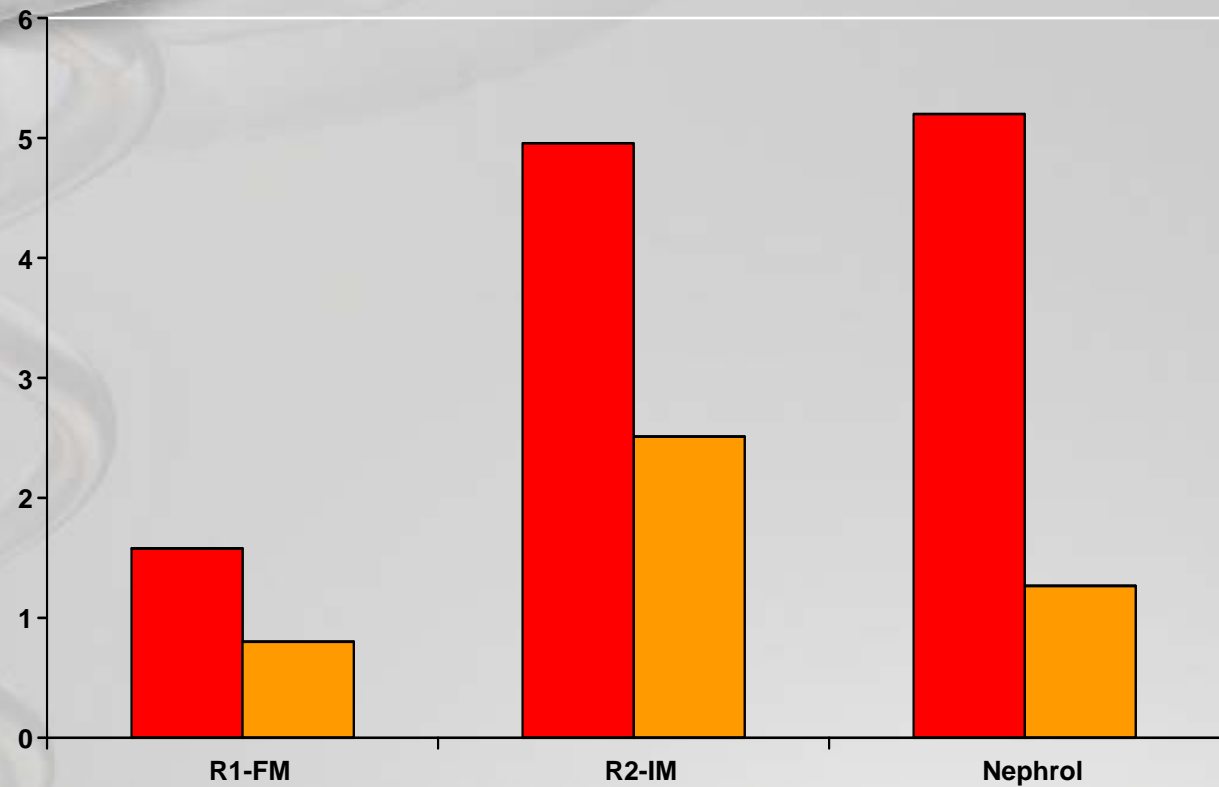
# *Diagnostic Accuracy*



# *Causal Explanations*



# *No of Diagnoses / Investigations*

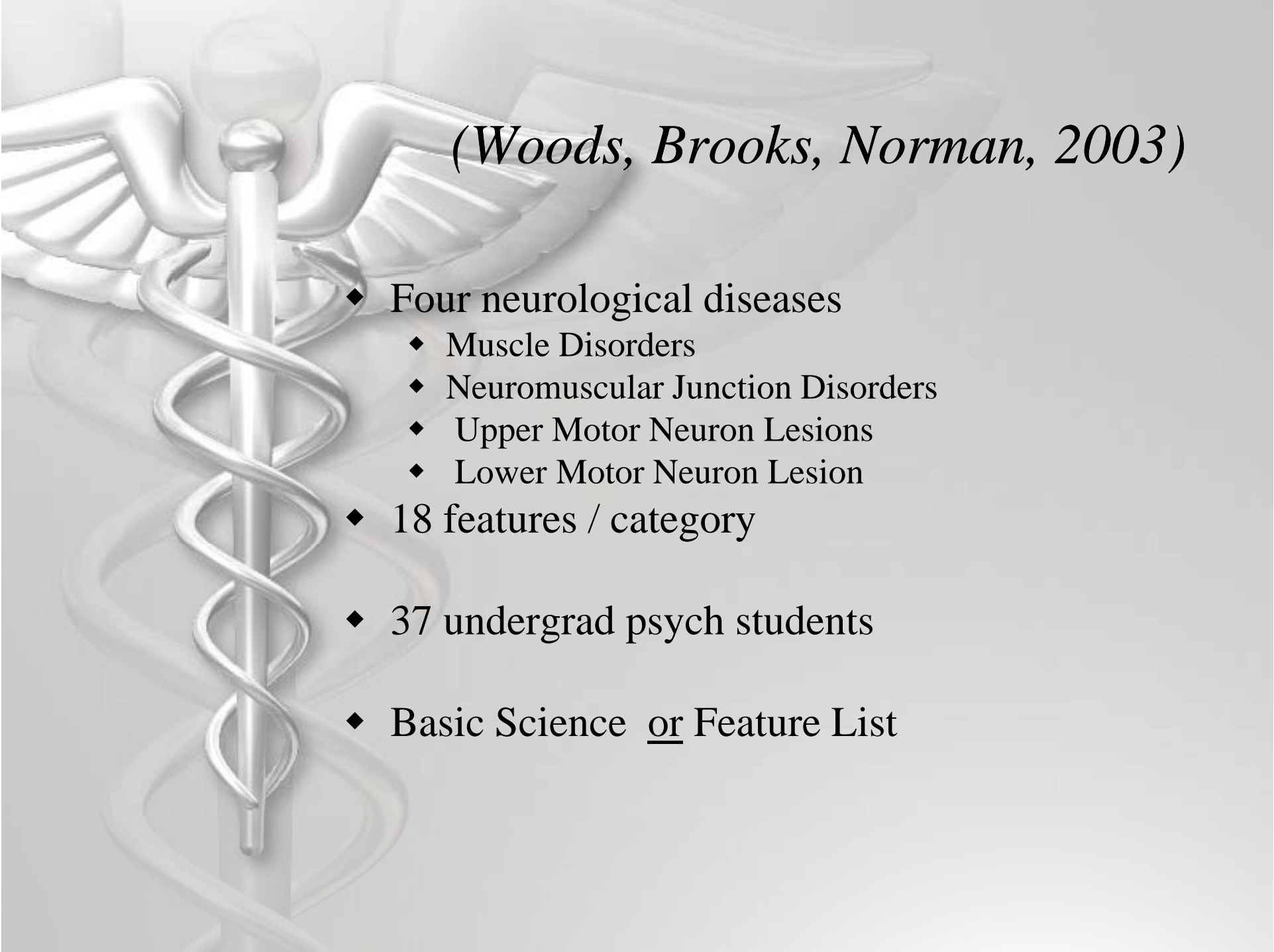




*If experts rarely use it, why do students need basic science?*


Perhaps to improve memorability / coherence of diagnostic rules?





*(Woods, Brooks, Norman, 2003)*

- ◆ Four neurological diseases
  - ◆ Muscle Disorders
  - ◆ Neuromuscular Junction Disorders
  - ◆ Upper Motor Neuron Lesions
  - ◆ Lower Motor Neuron Lesion
- ◆ 18 features / category
- ◆ 37 undergrad psych students
- ◆ Basic Science or Feature List

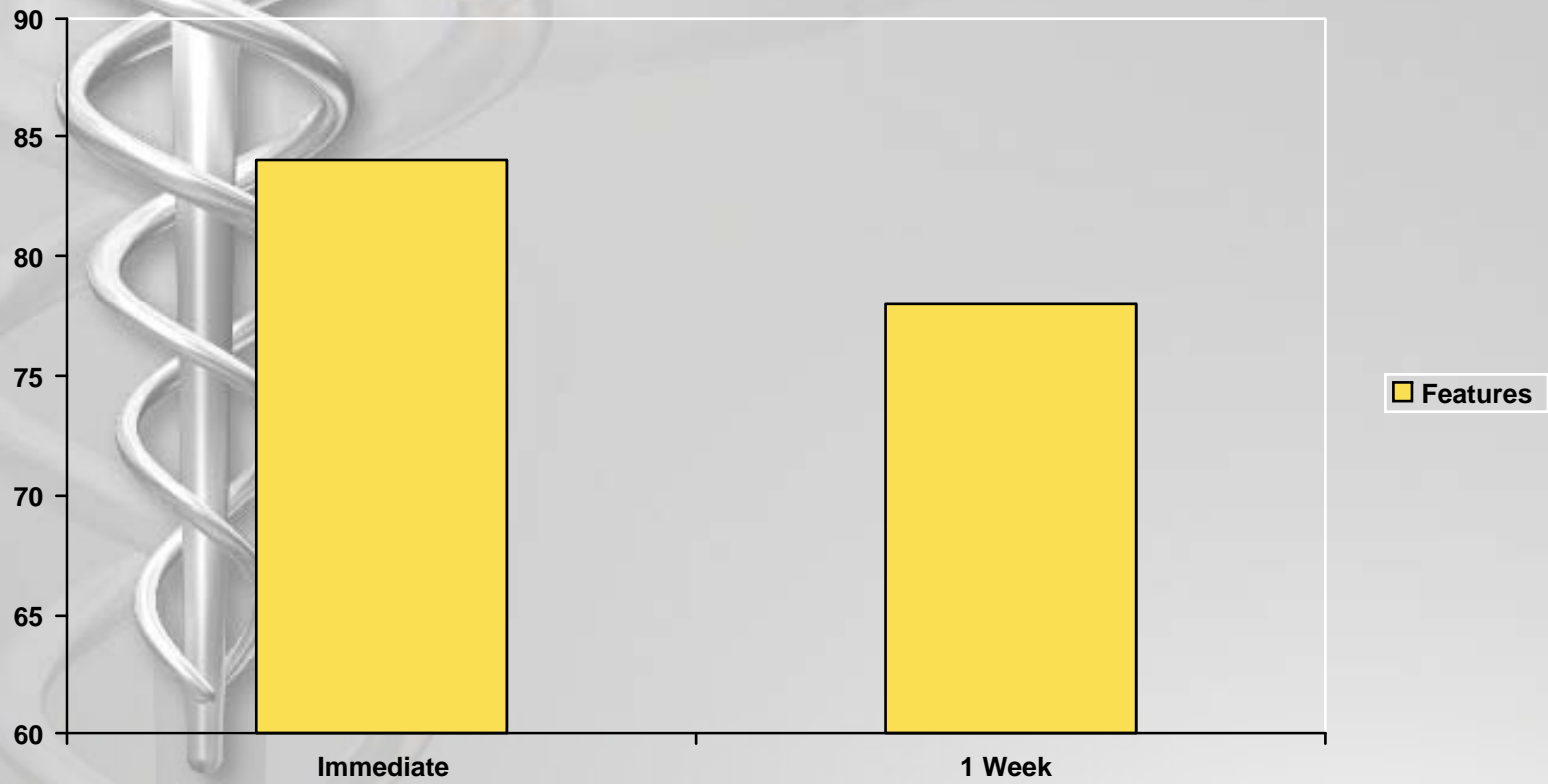
- 
- ◆ Basic Science condition
    - ◆ Overview of neuroanatomy
    - ◆ Specific disease process description
    - ◆ Features “always” or “sometimes” associated with disease
  
  - ◆ Feature List
    - ◆ Symptoms associated with each condition



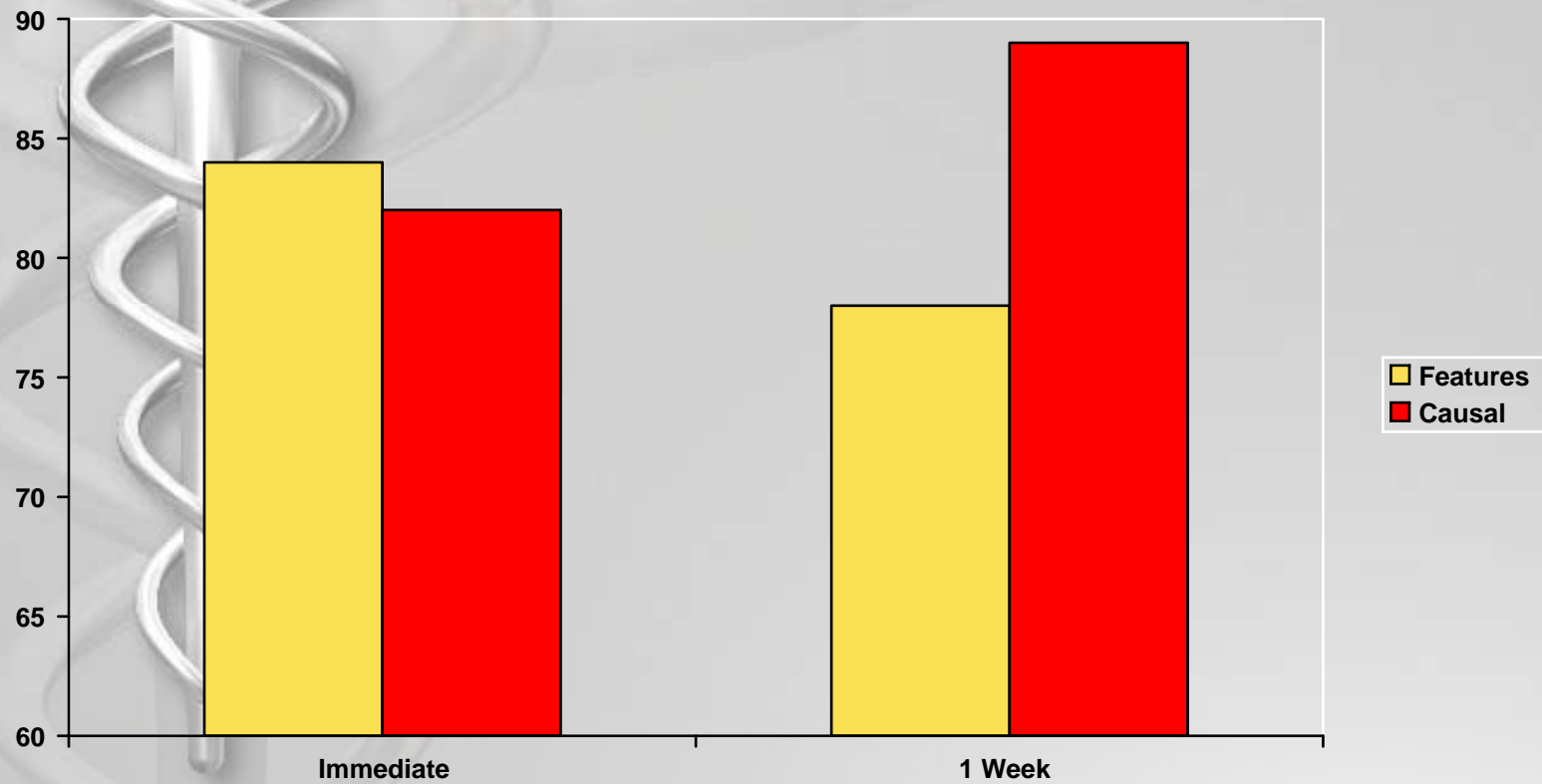
- ◆ Measures

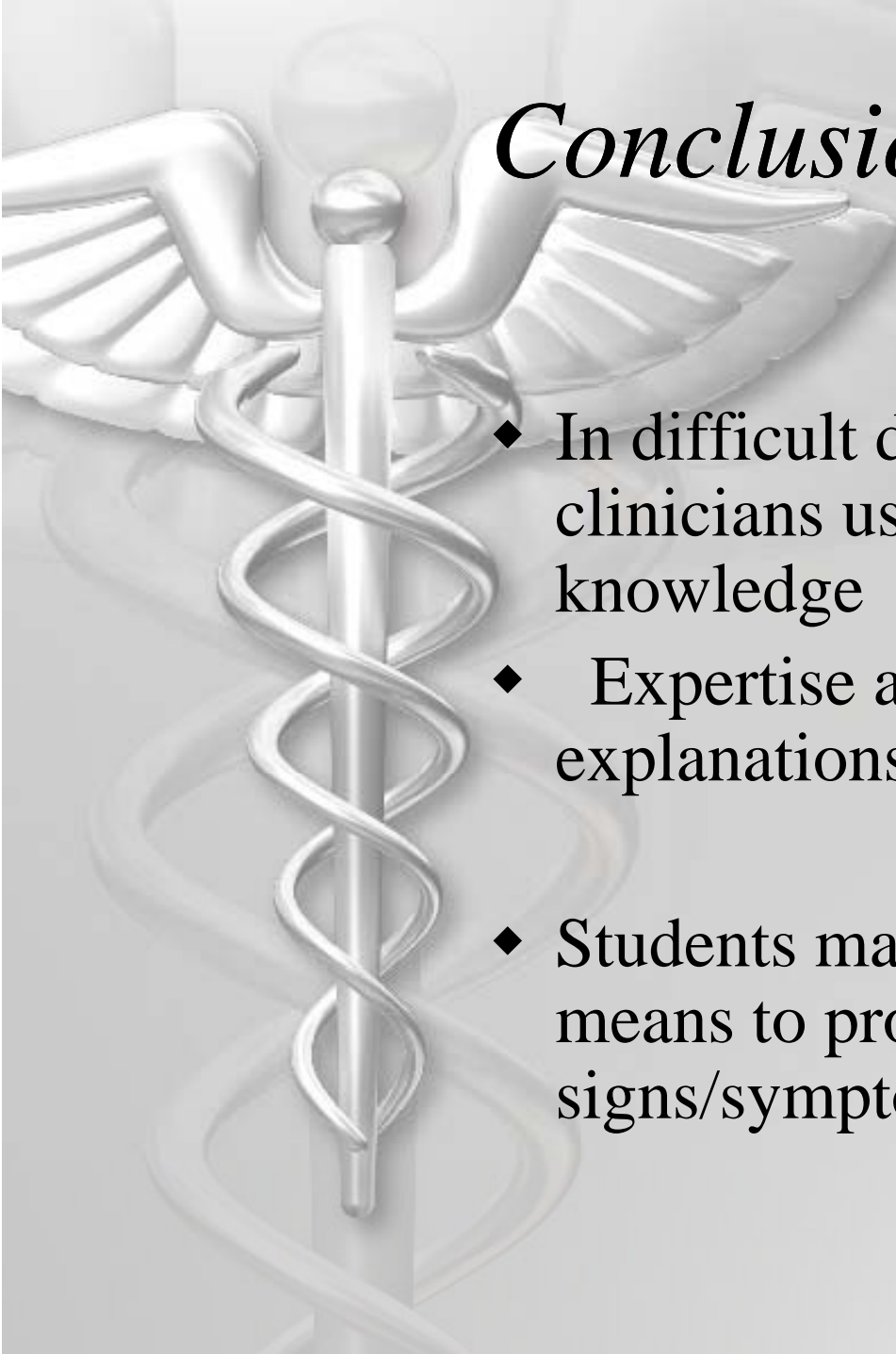
- ◆ Test of knowledge (0, 1 week)
- ◆ Diagnostic test (0, 1 week)
  - ◆ 15 cases
  - ◆ Name, age, >4 features
  - ◆ Form A, Form B

# *Score on Dx Test*



# *Score on Dx Test*





## *Conclusions - Use of Basic Science*

- ◆ In difficult diagnostic situations, clinicians use causal physiological knowledge
- ◆ Expertise associated with more coherent explanations, better diagnosis
- ◆ Students may use basic science as a means to provide coherence to signs/symptoms



## *Coordinating Analytical and Non-analytic Processing*

- ◆ Do students /physicians use both processes?
- ◆ Is one more effective than the other?
- ◆ Are the processes amenable to instruction?
- ◆ Are there circumstances where one is more effective?
- ◆ Does a combined strategy work better?





# *Observational Studies*

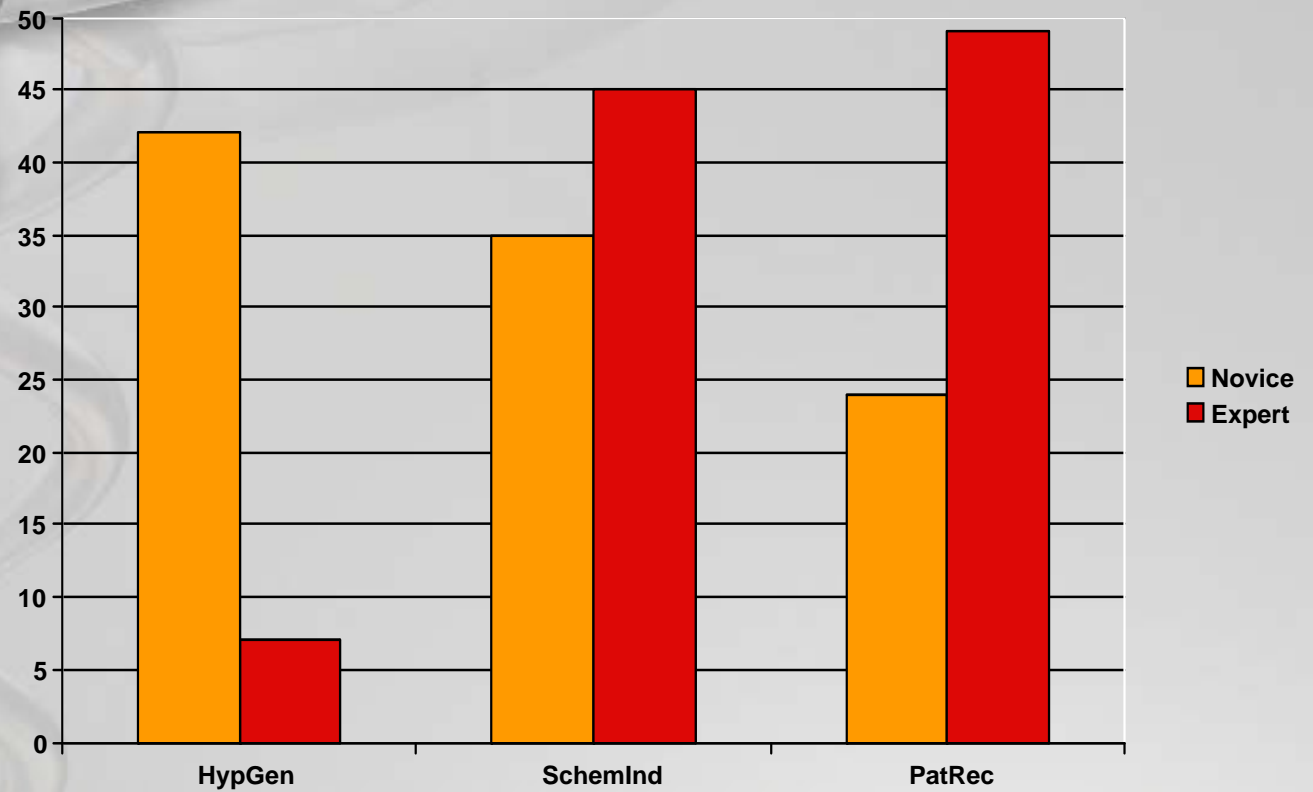
- ◆ Coderre & Mandin (Gastro)
  - ◆ Students and Experts
- ◆ Groves, O'Rourke & Alexander (GP)
  - ◆ Student 2, Student 4, GP
- ◆ Moruzi Brooks Norman (Derm)
  - ◆ Students GPs Dermatologists
- ◆ Hatala & Norman (ECG)
  - ◆ Students, residents



*Coderre, Mandin, Harasym & Fick, 2003*

- ◆ 20 clinical clerks, 20 gastroenterologists
- ◆ 12 questions, (MCQ, EMQ) case-based
- ◆ Hyp Deduct vs. Schema Induct vs. Pattern Recog based on protocol analysis

# *Proportion using Strategy*





## *Likelihood of success (Against Hyp Gen)*

- ◆ Pattern Recognition - 10.3
- ◆ Schema Induction - 5.1

But is Hyp Gen a weak strategy

or

Do you use Hyp Gen (multiple solutions) when you're not sure what's going on?

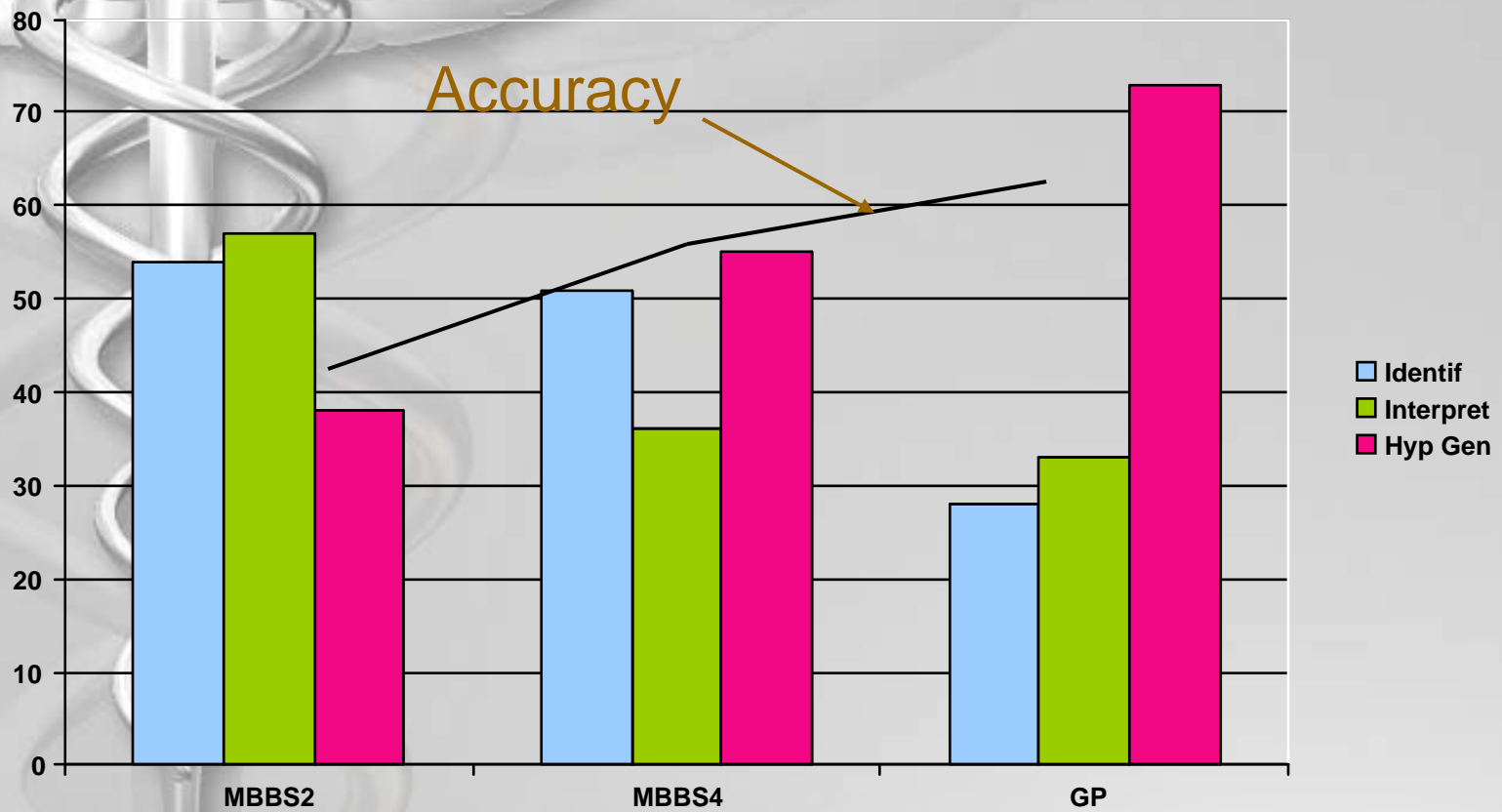
And pattern recognition when you've seen it all before?



*Groves, O'Rourke & Alexander, 2003*

- ◆ 21 GP, 35 Year 2 MBBS, 43 Year 4 MBBS
- ◆ 10 written CRP's, graded difficulty
- ◆ Errors in:
  - ◆ Identification of critical features
  - ◆ Interpretation of critical features
  - ◆ Generation of hypotheses

# *Proportion Correct Actions*





# *Studies of Relative Experts*

*(Moruzi, Brooks, Norman, 2003)*

- ◆ Dermatologists/ GPs / residents
- ◆ 36 slides (typical / atypical)

## Condition A

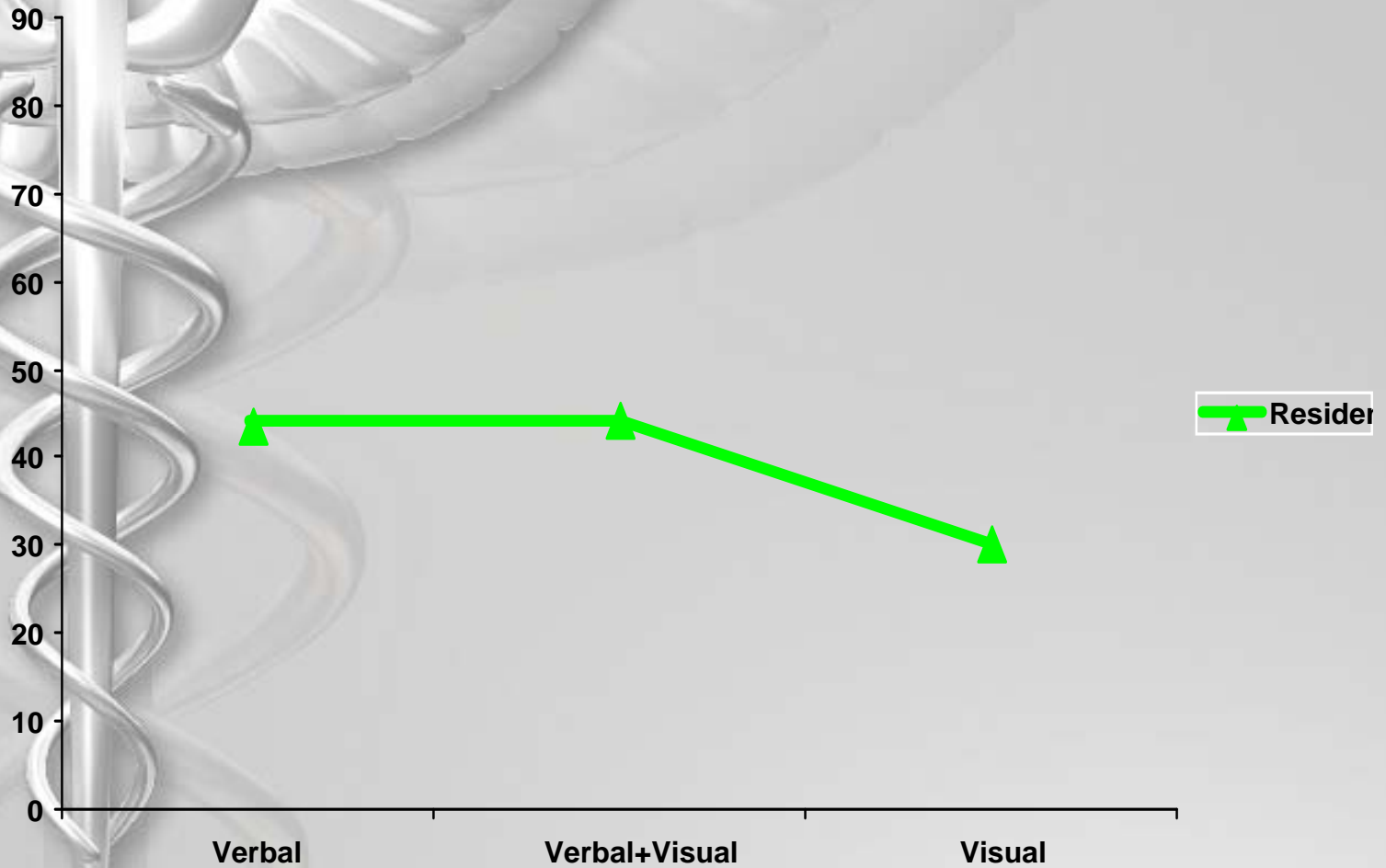
- ◆ Verbal description of slide (verbal)  
then photo (visual + verbal)

## Condition B

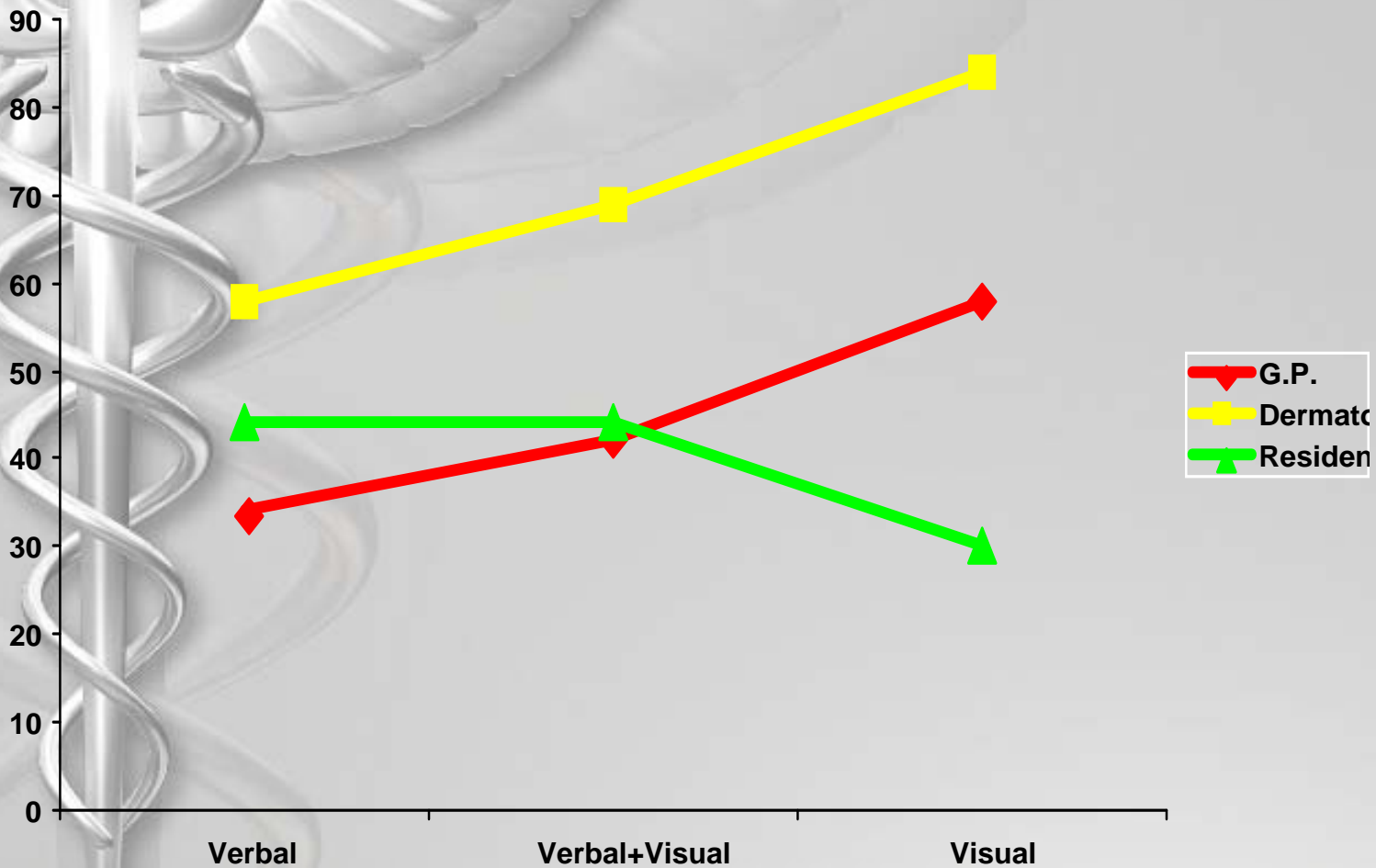
- ◆ Photo only (visual)



# *Diagnostic Accuracy*



# *Diagnostic Accuracy*





# *ECG Interpretation*

*Hatala et al., 1999*

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- ◆ **PRACTICE** (4/4 + 7 filler)
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    - ◆ **Left Bundle Branch Block**

# RESULTS

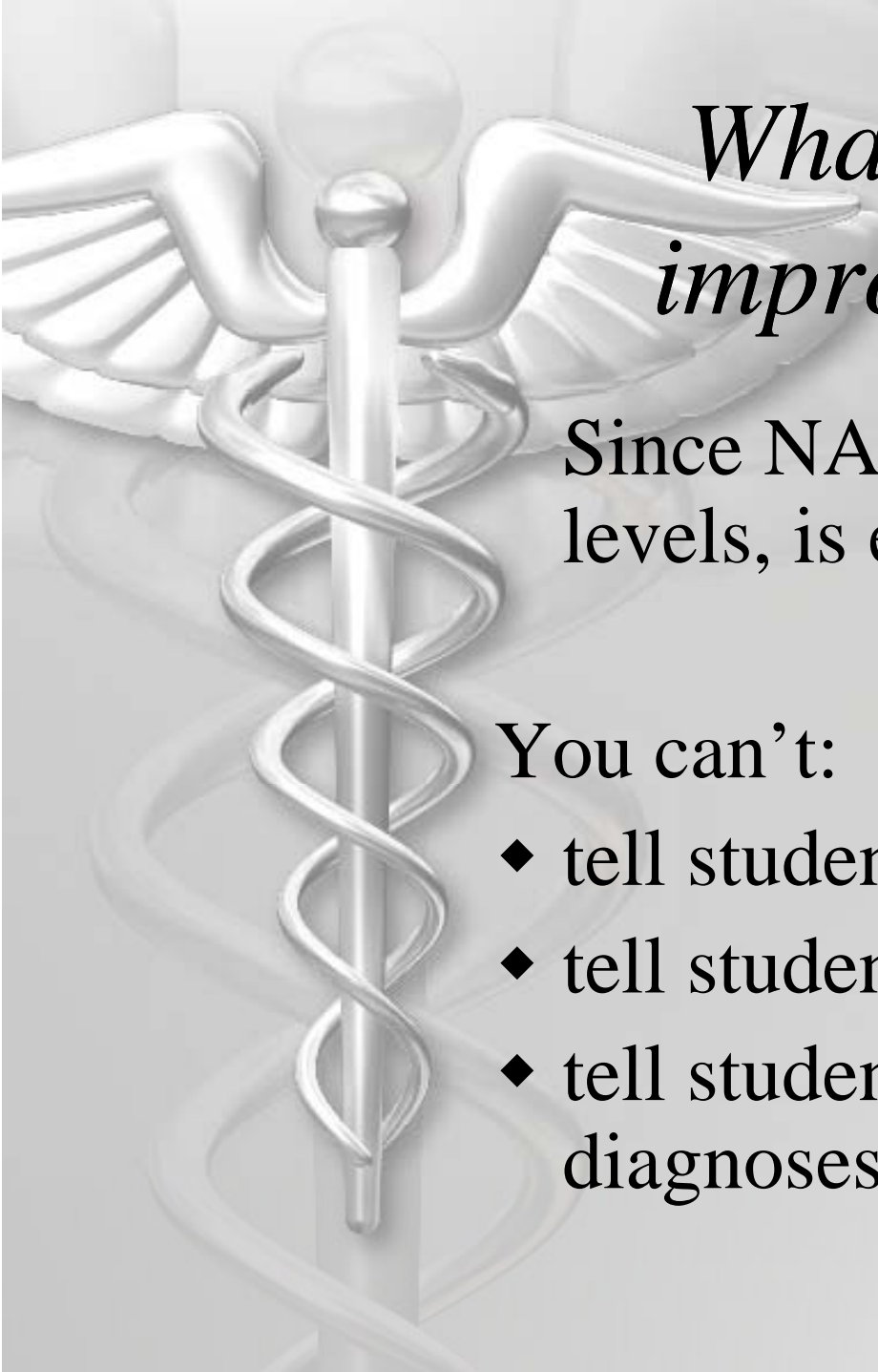
## *Percent of Diagnoses by Condition*





## *Conclusions*

- ◆ Diagnosis at all levels of expertise can and does use both analytic and experience-based reasoning
- ◆ Some evidence of increased reliance on prior experience with age/expertise



*What can we do to  
improve reasoning?*

Since NA reasoning occurs at all levels, is effective, is “automatic”

You can't:

- ◆ tell student to not do it
- ◆ tell student to beware of biases
- ◆ tell student to think of better diagnoses



*Does a coordinated strategy  
(exemplar --> rules) improve  
accuracy?*

- ◆ Norman, Brooks, Colle (ECG)
- ◆ Schmidt and Mamede (Gen Medicine)
- ◆ Moruzi, Norman Brooks (Derm)





*Norman, Brooks Colle, 2000*

- ◆ Contrast instructions to:
  - ◆ Think of the first thing that comes to mind, then consider features
- vs.
- ◆ Gather all the data then arrive at diagnosis
- ◆ 32 Undergrad Psychology students
- ◆ 11 disorders, rules + examples
- ◆ Test -- 10 new ECG's

# *Diagnostic Accuracy*



# *Diagnostic Accuracy*





## *Schmidt & Mamede, 2005*

- ◆ 42 I.M. residents
- ◆ 16 written cases --- simple / complex
- ◆ Within subject/case design
- ◆ Instructions:

“First thing that comes to mind”

vs.

“Hypotheses, findings for/against,  
differential, ....”

# *Diagnostic Accuracy*





# Moruzi, Norman, Brooks, 2005

## Subjects:

39 medical students

## Materials

Dermatology

10 learning cases / 20 test cases

## Instructions

Pass 1 Similarity

Group 1 “First thing that comes to mind”

Pass 2 Similarity then Analytic

“Now carefully consider features”

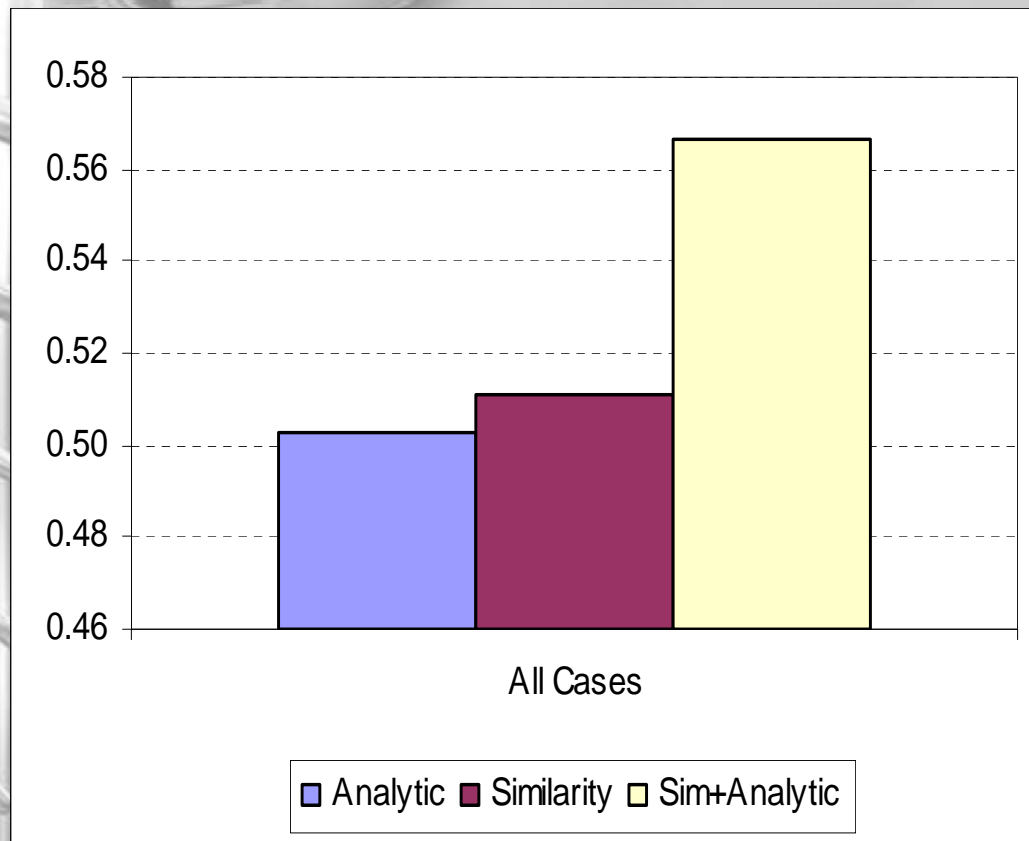
vs.

Group 2

Analytic

“Carefully list features and diagnose”

# Combined vs. Individual Strategies







# *ECG Diagnosis - Ark & Eva*

- ◆ 48 undergrad psychology students
- ◆ 8 ECG diagnoses (A/A', B/B', C/C', D/D')

## Instructions

- Compare and contrast vs. Sequential
- Combined Analytical/Non-analytical vs. usual approach

## Test

20 ECG's (10 old, 10 new)

Immediate / 1 week later

# *Effect of Examples and Instructions on New Cases after One Week*



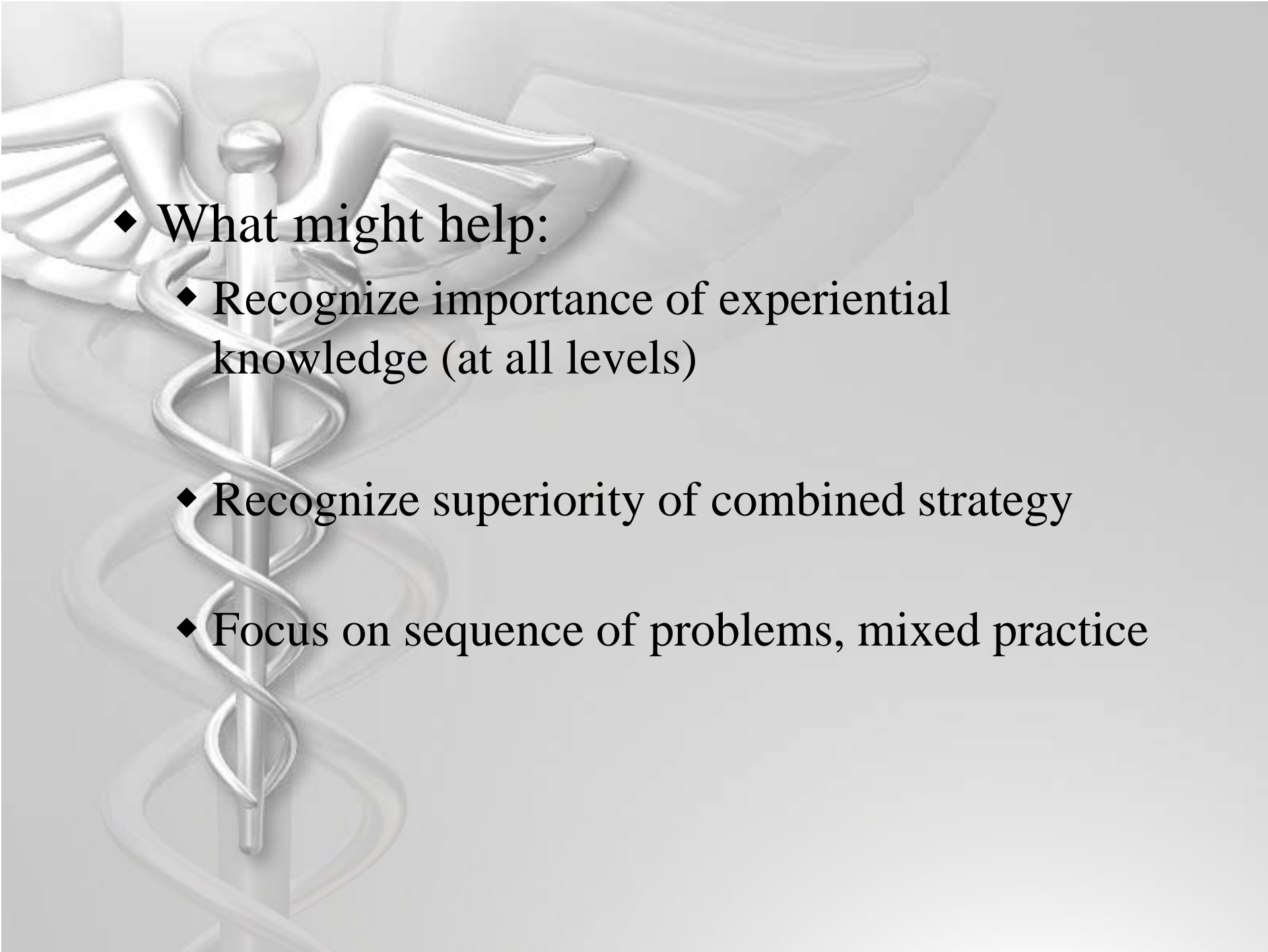
Ark & Eva, 2005

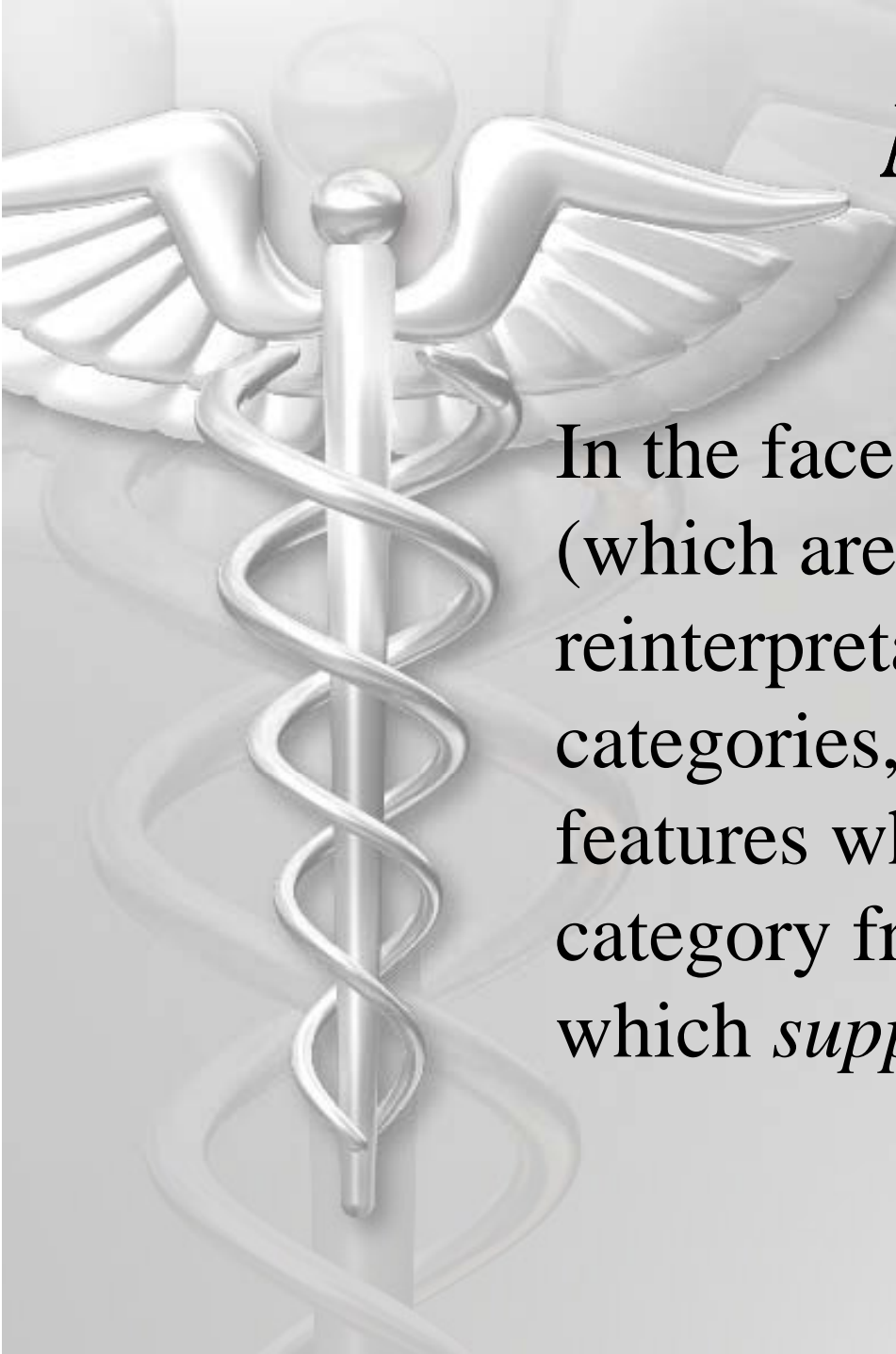


# *Implications for Education:*

What NOT to do to improve learning:

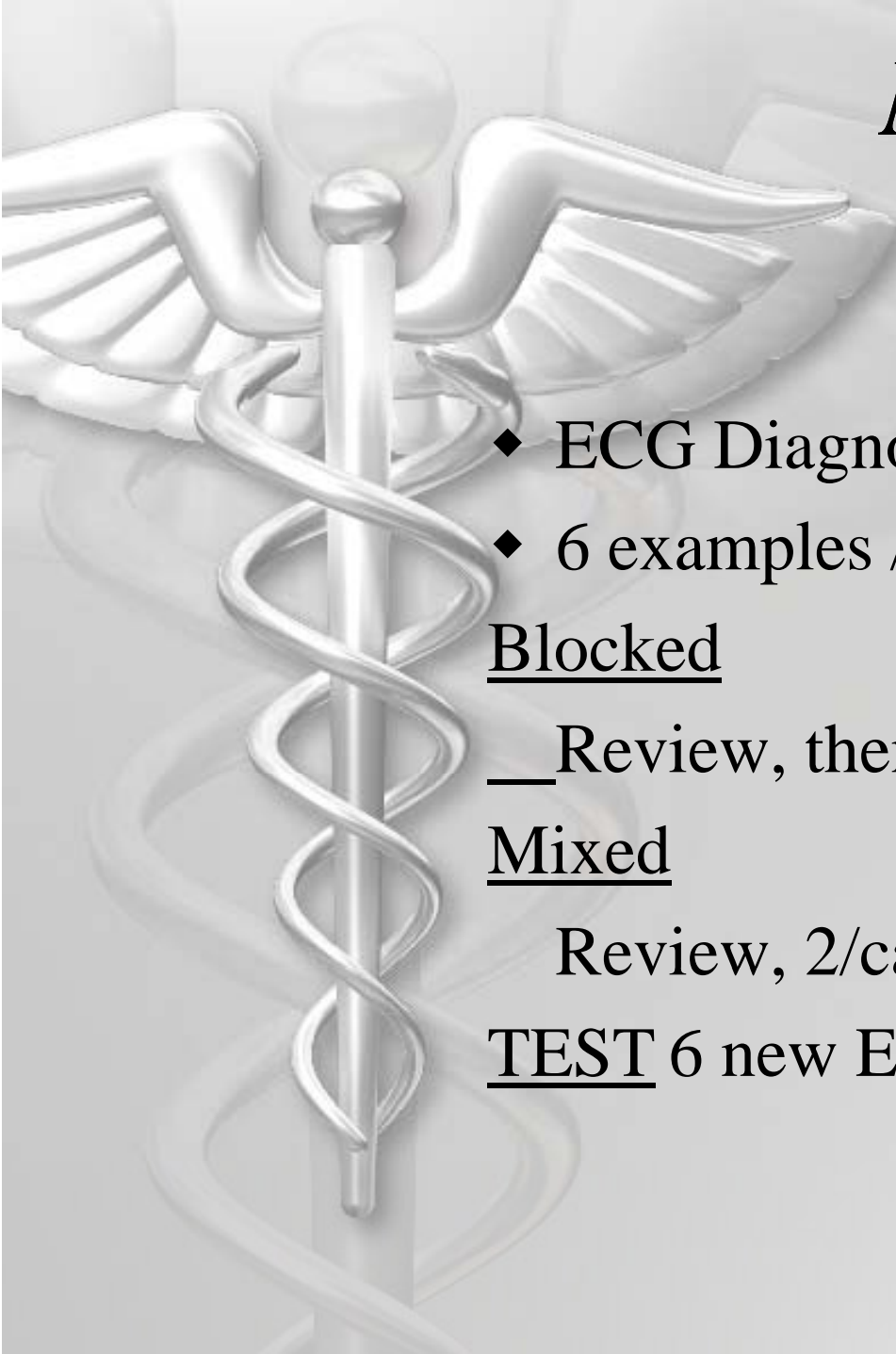
- ◆ Focus on one kind of knowledge
  - ◆ Schemas, semantic qualifiers, etc.
- ◆ Insist on Complete and Objective data gathering
  - ◆ Reward thoroughness (e.g. checklist OSCE)
- ◆ Denigrate “just pattern recognition”

- 
- ◆ What might help:
    - ◆ Recognize importance of experiential knowledge (at all levels)
    - ◆ Recognize superiority of combined strategy
    - ◆ Focus on sequence of problems, mixed practice



## *Mixed vs. Blocked Practice*

In the face of ambiguous features (which are subject to reinterpretation), and multiple categories, students must learn the features which *discriminate* one category from another, not those which *support* a particular category



# *Mixed vs. Blocked Practice*

*Hatala, 2000*

- ◆ ECG Diagnosis -- 3 categories
- ◆ 6 examples / category

## Blocked

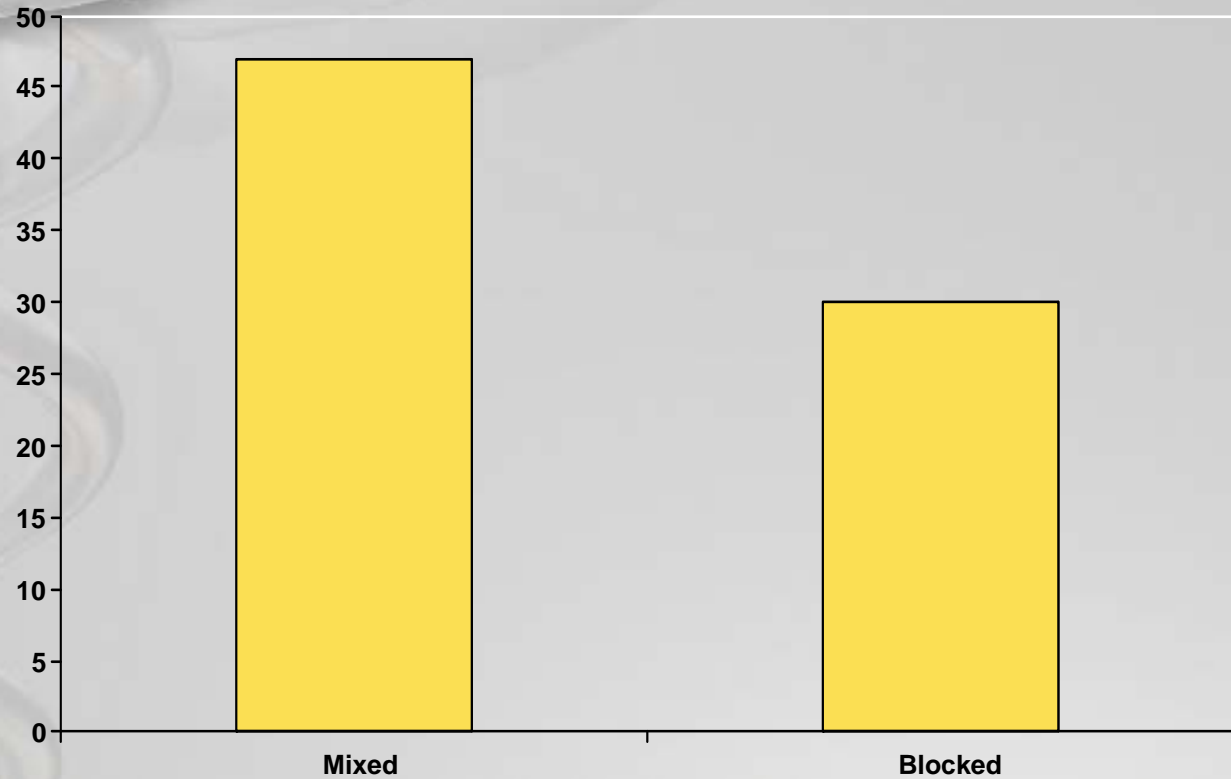
\_\_Review, then 6 examples/category

## Mixed

Review, 2/category, 12 (4 x 3) practice

TEST 6 new ECGs

# *Diagnostic Accuracy*





# *The Revised Theory of Expertise*

Novice

Intermediate

Expert

Basic Science  
Mechanisms

Clinical Rules

Examples

Rules

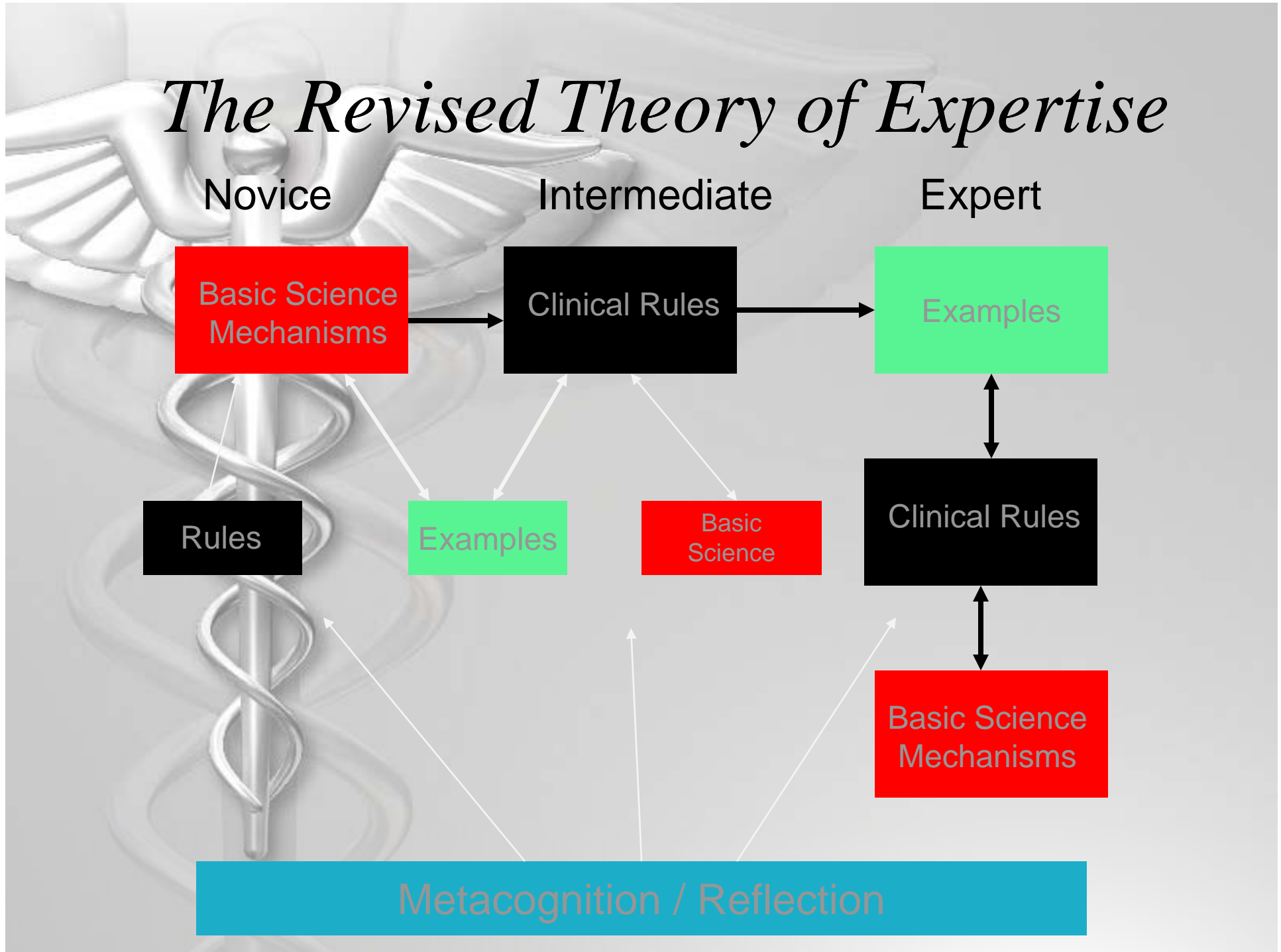
Examples

Basic  
Science

Clinical Rules

Basic Science  
Mechanisms

Metacognition / Reflection





## *OVERALL CONCLUSIONS*

- ◆ Clinical reasoning is based on both analytical facts and relationships and an accumulation of examples
- ◆ As one move from novice to expert, greater reliance on examples
- ◆ Instruction to explicitly use both is more effective than either alone