

# What does it take to make an “outlier”: Deliberate Practice and the Development of Elite Sport Performance

K. Anders Ericsson

Department of Psychology  
Florida State University

Trainertagung 2011  
«Vom Talent zum Überflieger –  
Learn from the best»

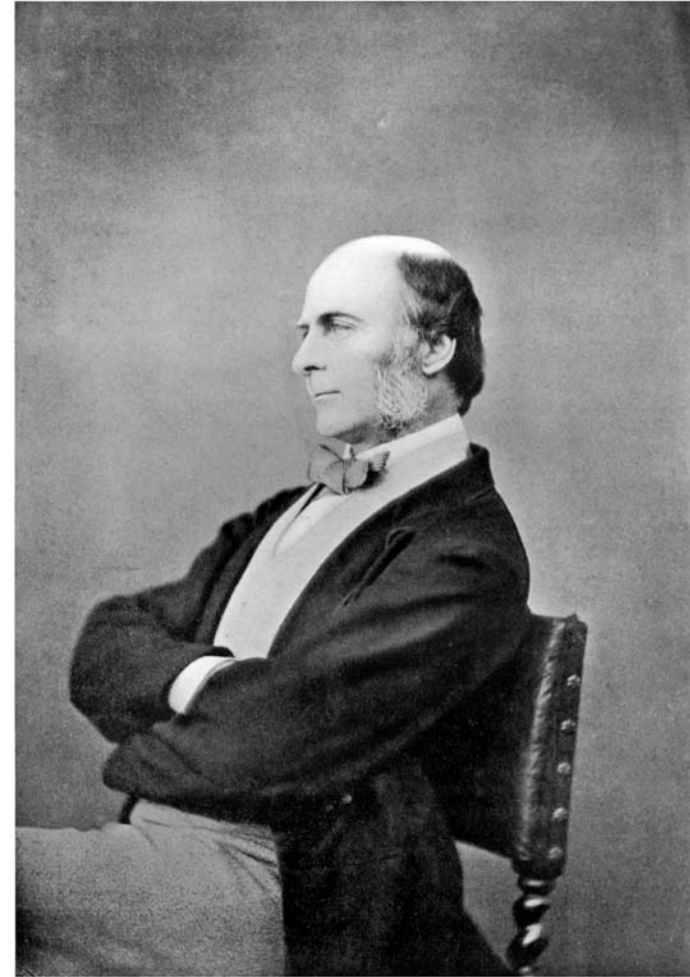
*Swiss Federal Institute of Sports*

Magglingen, Switzerland, November 3<sup>rd</sup> , 2011

# Galton (1869) on Limits on Modifiability of Performance

“So long as he is a novice, he perhaps flatters himself there is hardly an assignable limit to the education of muscles; but the daily gain is soon discovered to diminish, and at last it vanishes altogether. ... There is a definite limit to the muscular powers of every man, which he cannot by any education or exertion overpass.

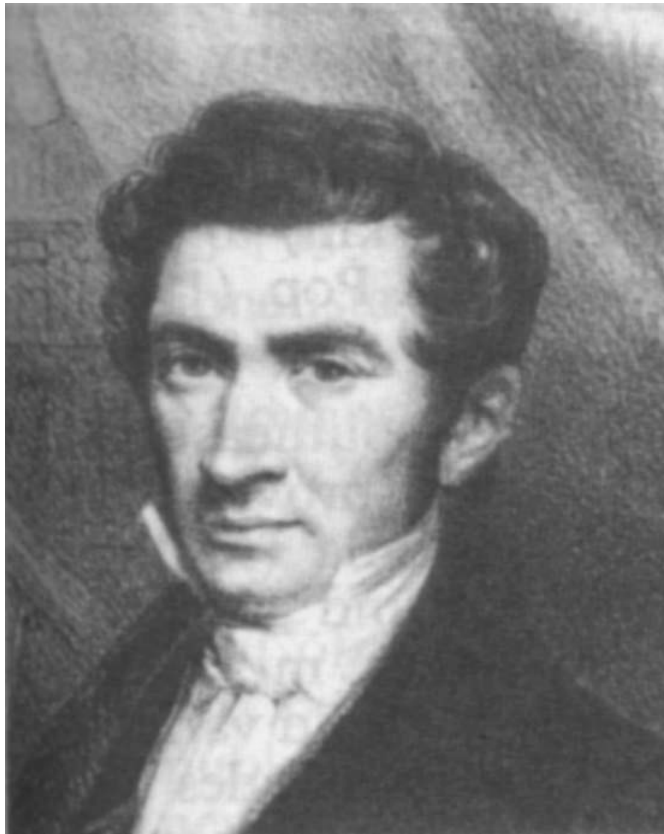
(pp. 15-16, Hereditary Genius)



Francis Galton when about fifty years of age.

# Individual Differences in Physical and Mental Characteristics

Quetelet



The Approximately  
Normal Distribution of  
Body Size

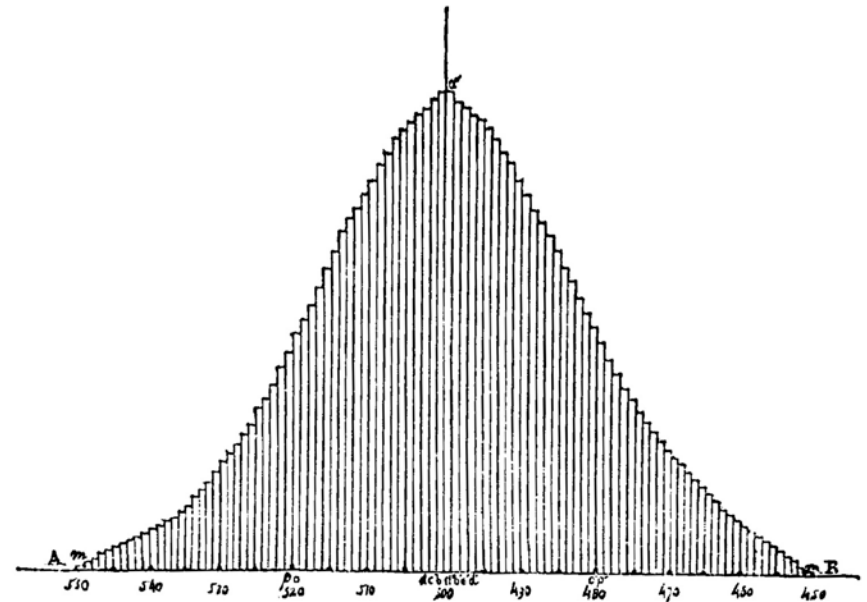
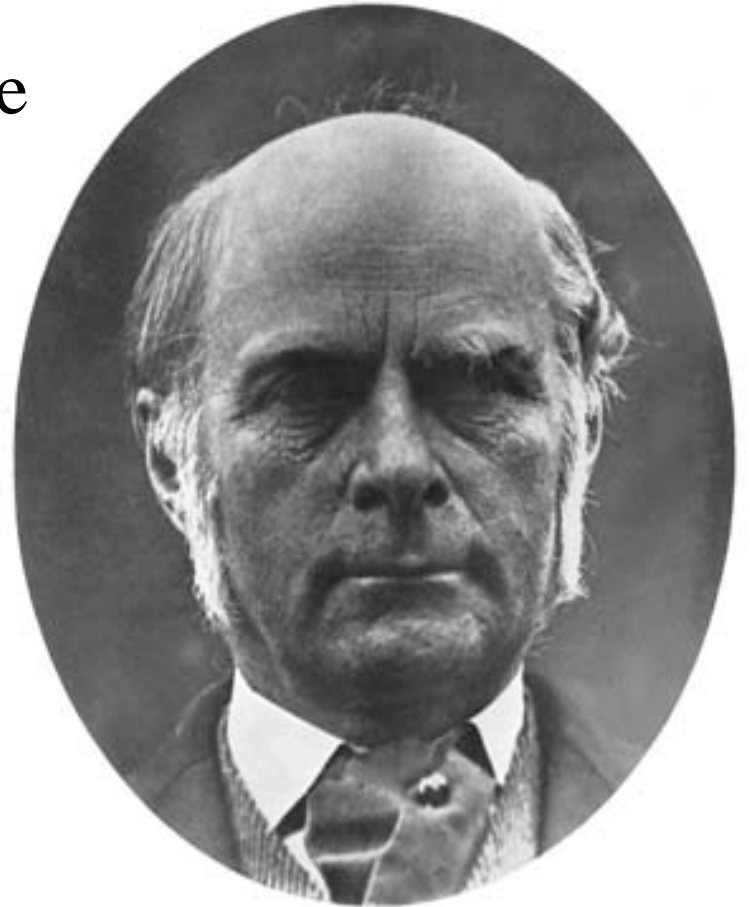


Figure 5.4. Quetelet's 1846 rendition of a symmetric binomial distribution with 999 trials, based upon the table in Figure 5.5. (From Quetelet, 1846, p. 396.)

“... if this be the case  
with stature [height], then it will be  
true as regard to every other  
physical feature—as  
circumference of head,  
size of brain,  
weight of grey matter,  
number of brain fibres, & c. ;  
and thence, by a step  
on which no physiologist  
will hesitate,  
as regards mental capacity.”

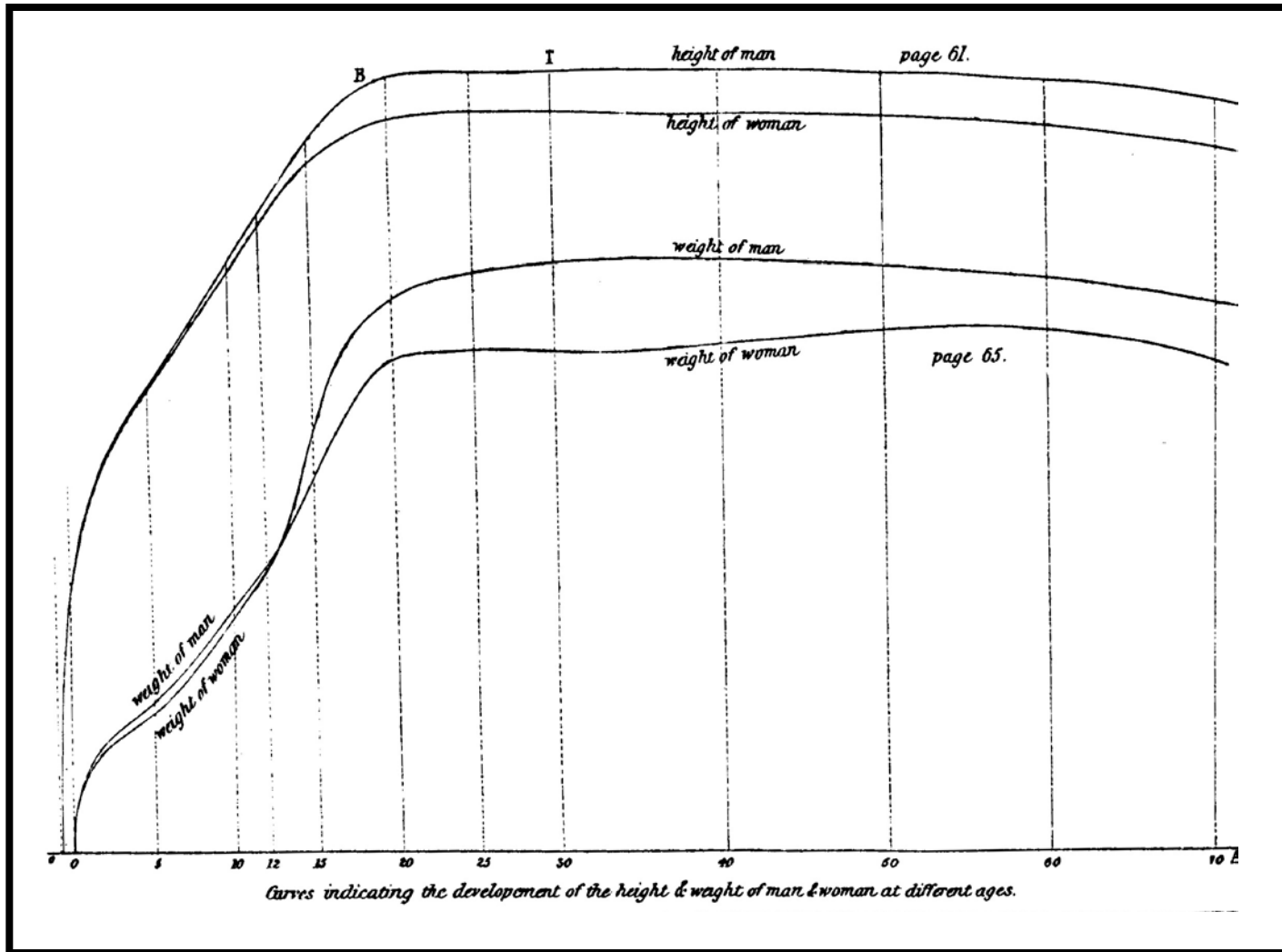
*(Hereditary Genius, 1869,  
pp. 31-32)*



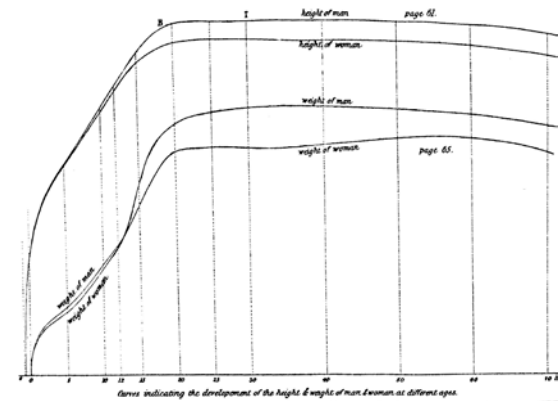
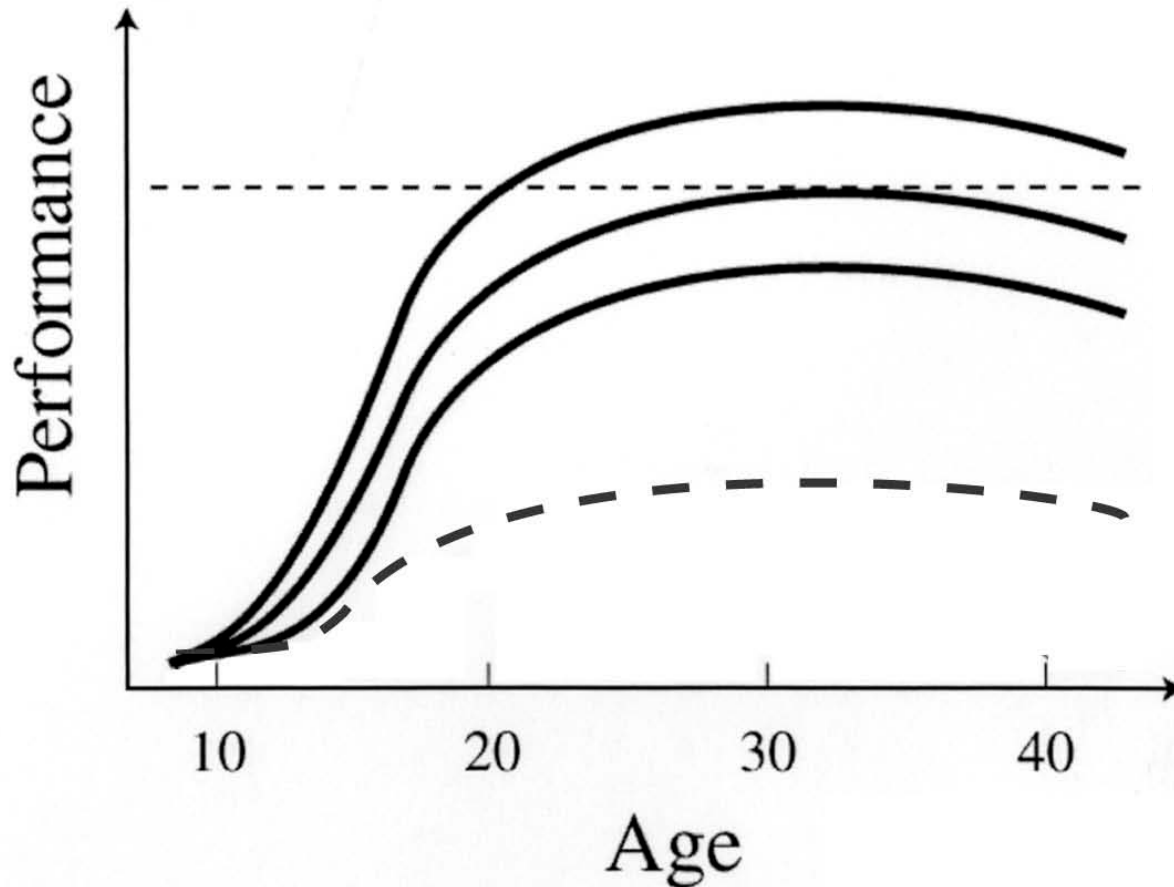
Francis Galton  
(1822-1911)



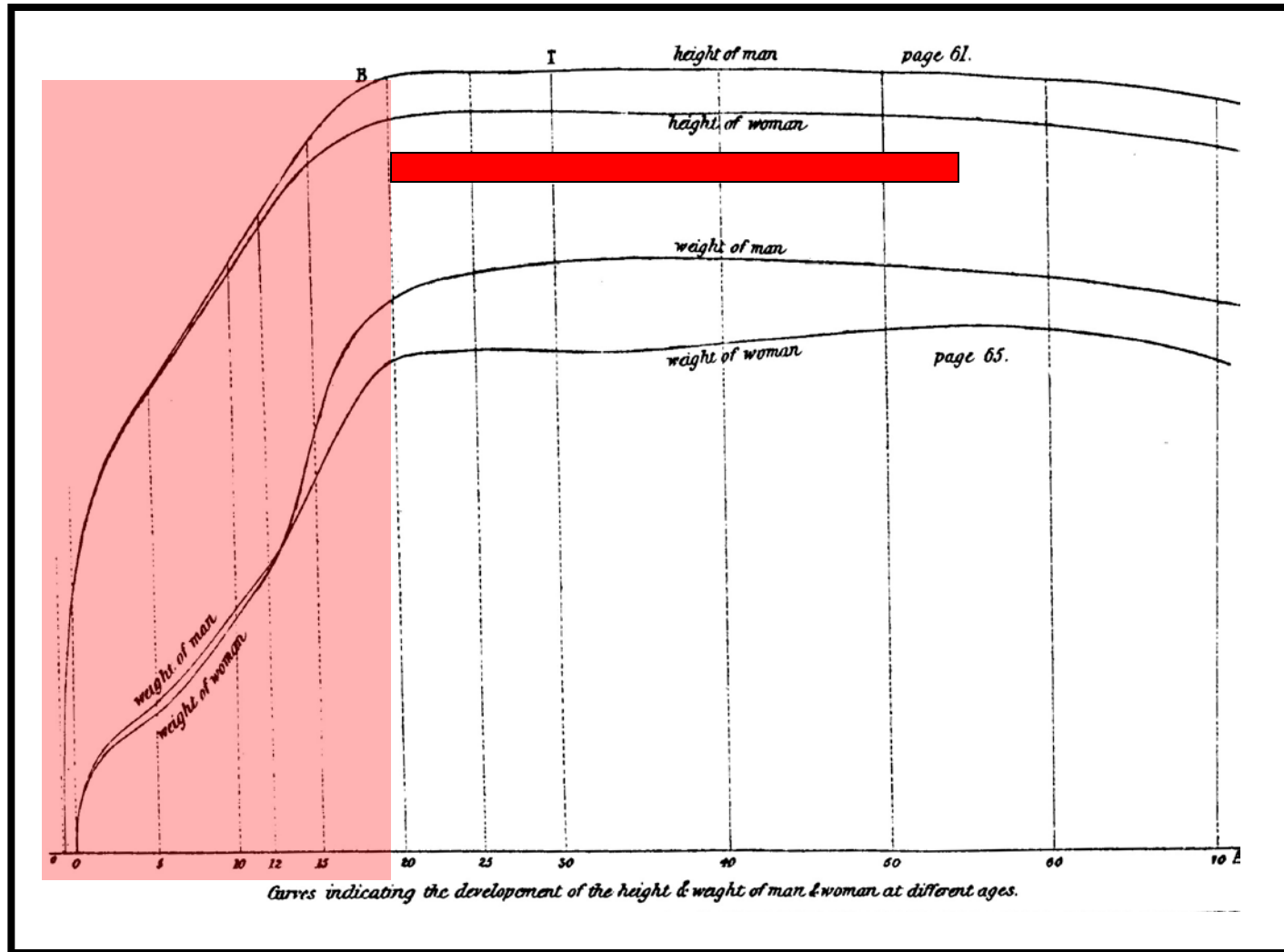
# The Development of Height and Weight



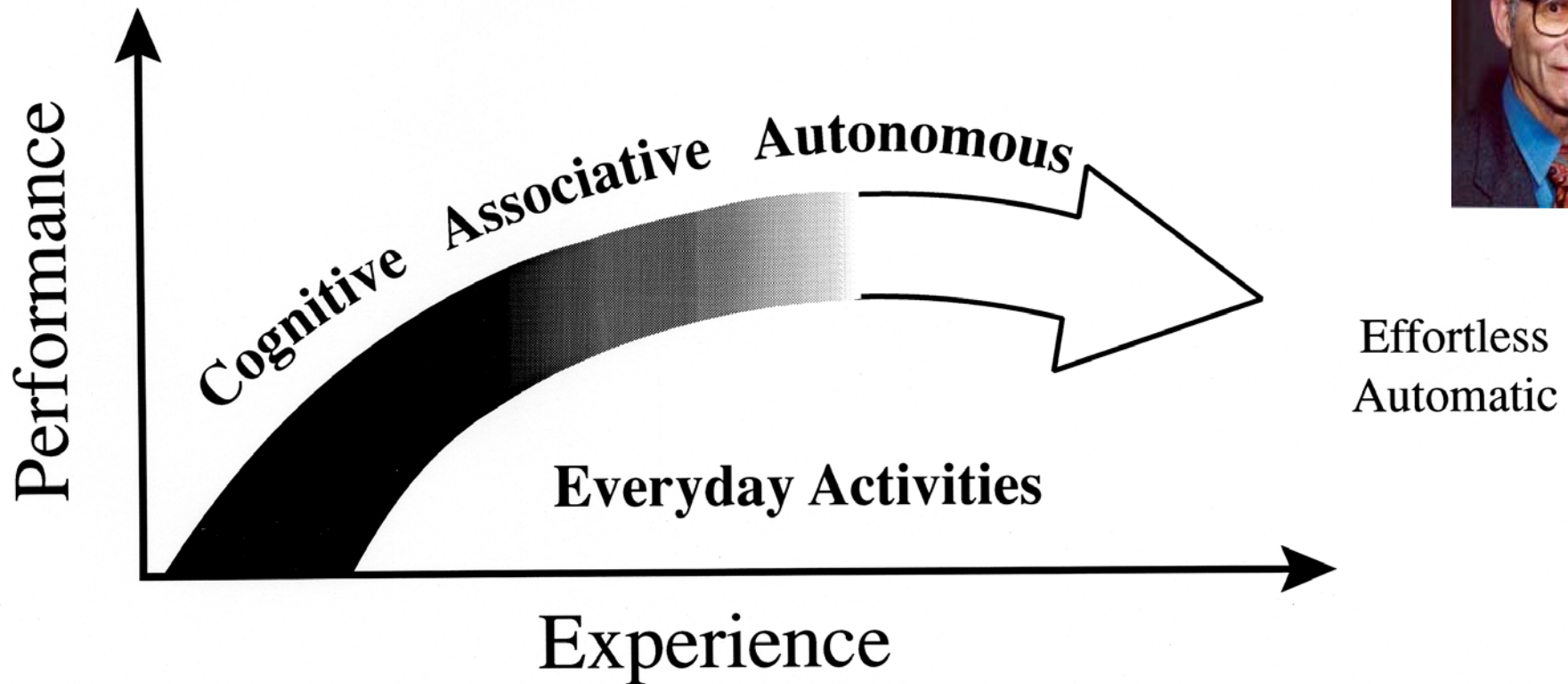
# Individual Differences in Attained Performance



# The Development of Height and Weight



# Acquisition of Everyday Skills, like typing, driving, and playing tennis (Fitts & Posner, 1967)



## Stages of skill acquisition

Autonomous

Practice  
fixation

Cognitive

*Rules*

*Intuition*

Novice    Advanced beginner    Competent    Proficient    Expert

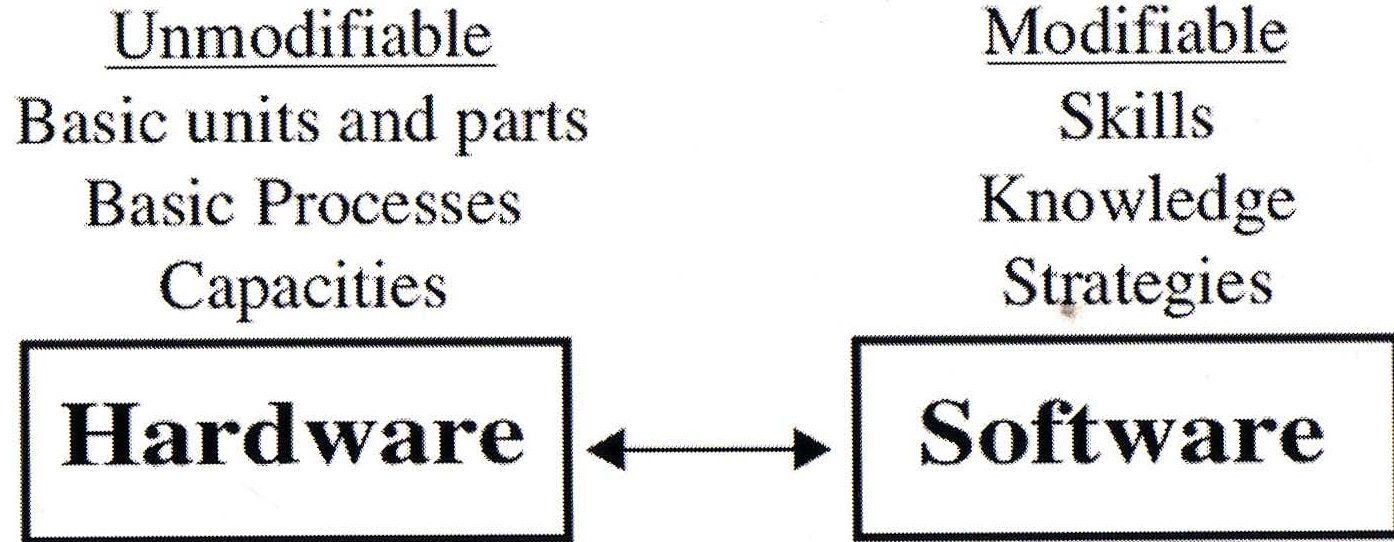
Hubert Dreyfus



Hubert Dreyfus, 2003

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# *Machines and Computers*

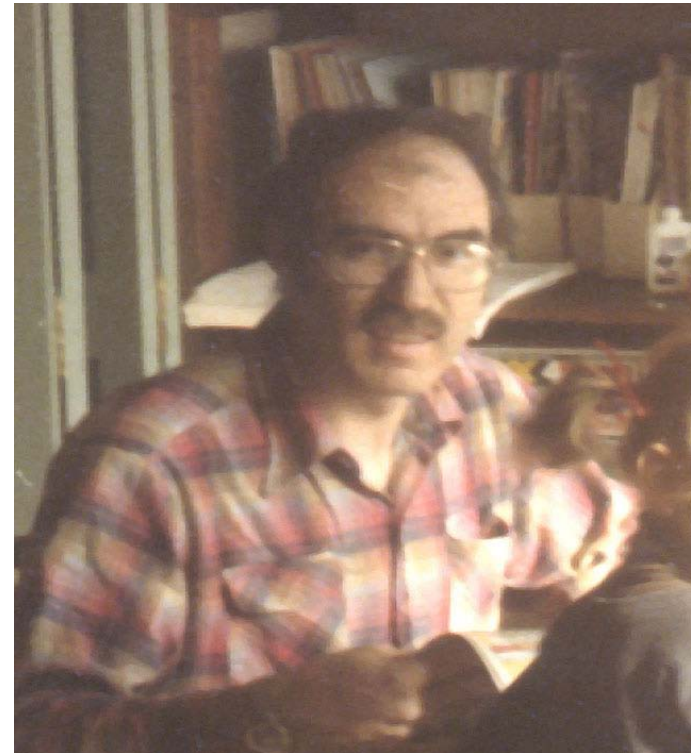
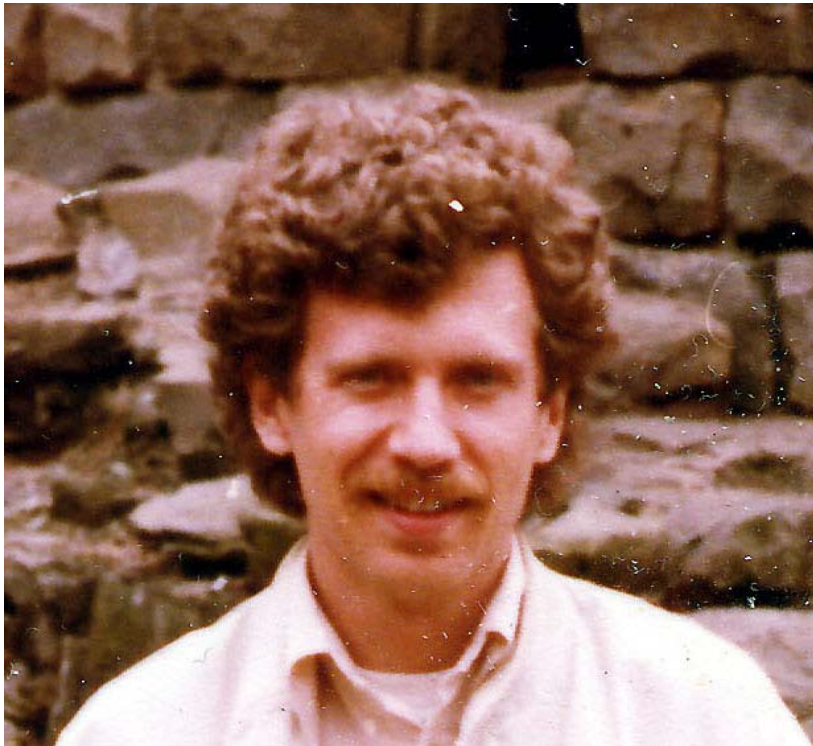


# Outline of My Presentation

- I. *Modifiability* of basic capacities and fundamental abilities
- II. Levels of *attained performance*
- III. *Differential* effects of practice activities
- IV. Deliberate practice versus *play/work*
- V. Becoming an elite athlete:  
*Causal mechanisms* generating changes
- VI. From incremental changes to  
*development* of integrated performance
- VII. Concluding remarks



# Part I: Can the capacity of short-term working memory be influenced by training and, if so, can verbal reports inform us?



Digit span is the number of digits that a person can recall after having a list of digits read at 1 digit per second



32749

5829683

527685329

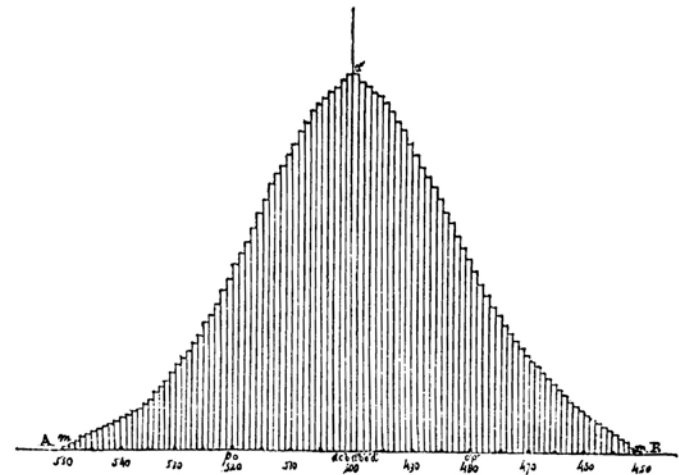
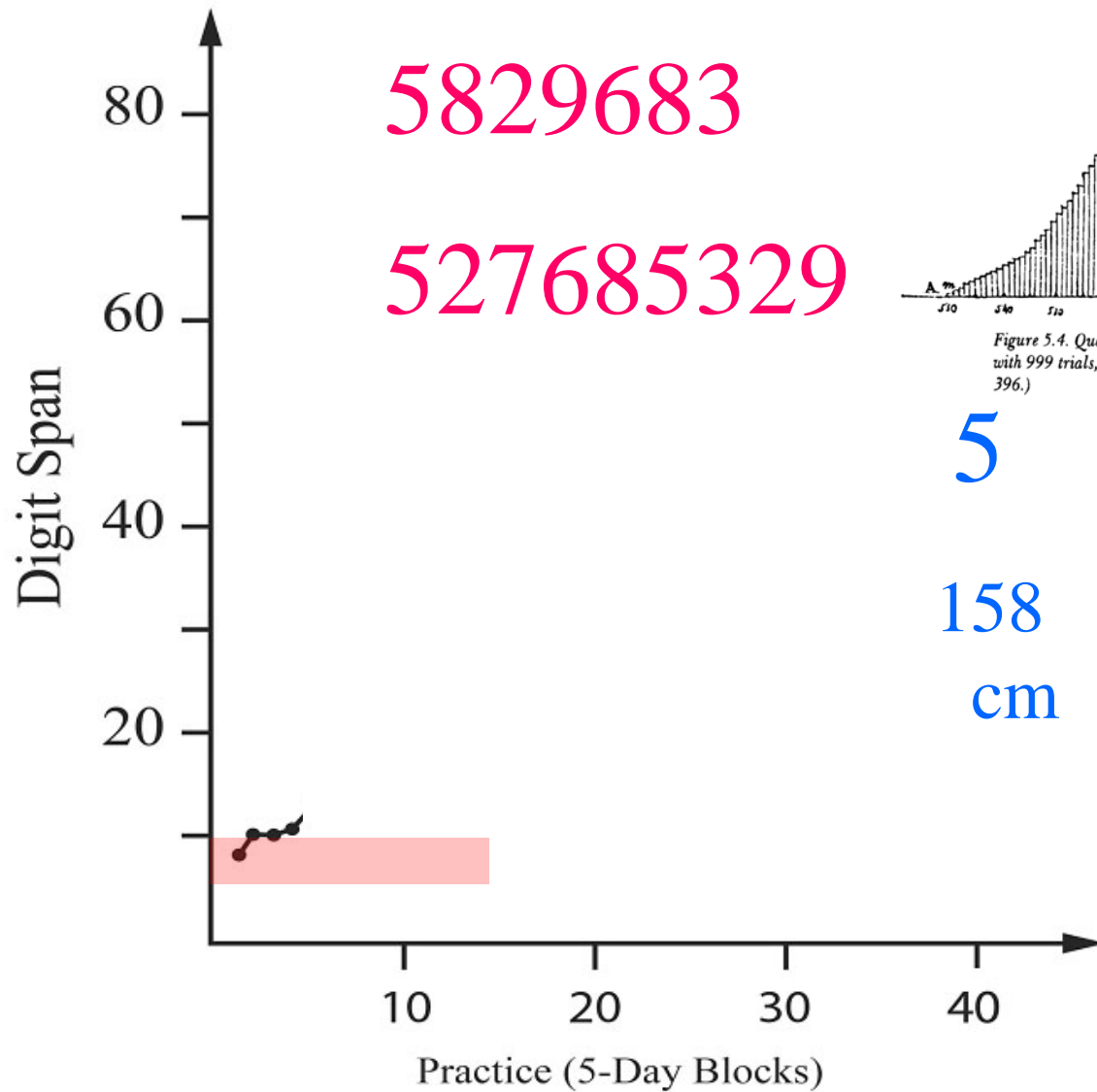


Figure 5.4. Quetelet's 1846 rendition of a symmetric binomial distribution with 999 trials, based upon the table in Figure 5.5. (From Quetelet, 1846, p. 396.)

5

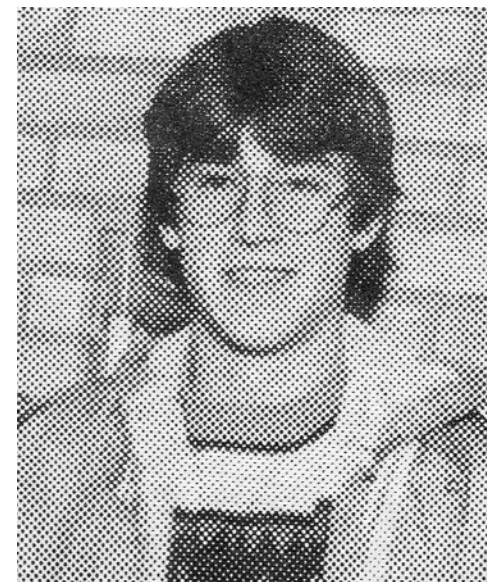
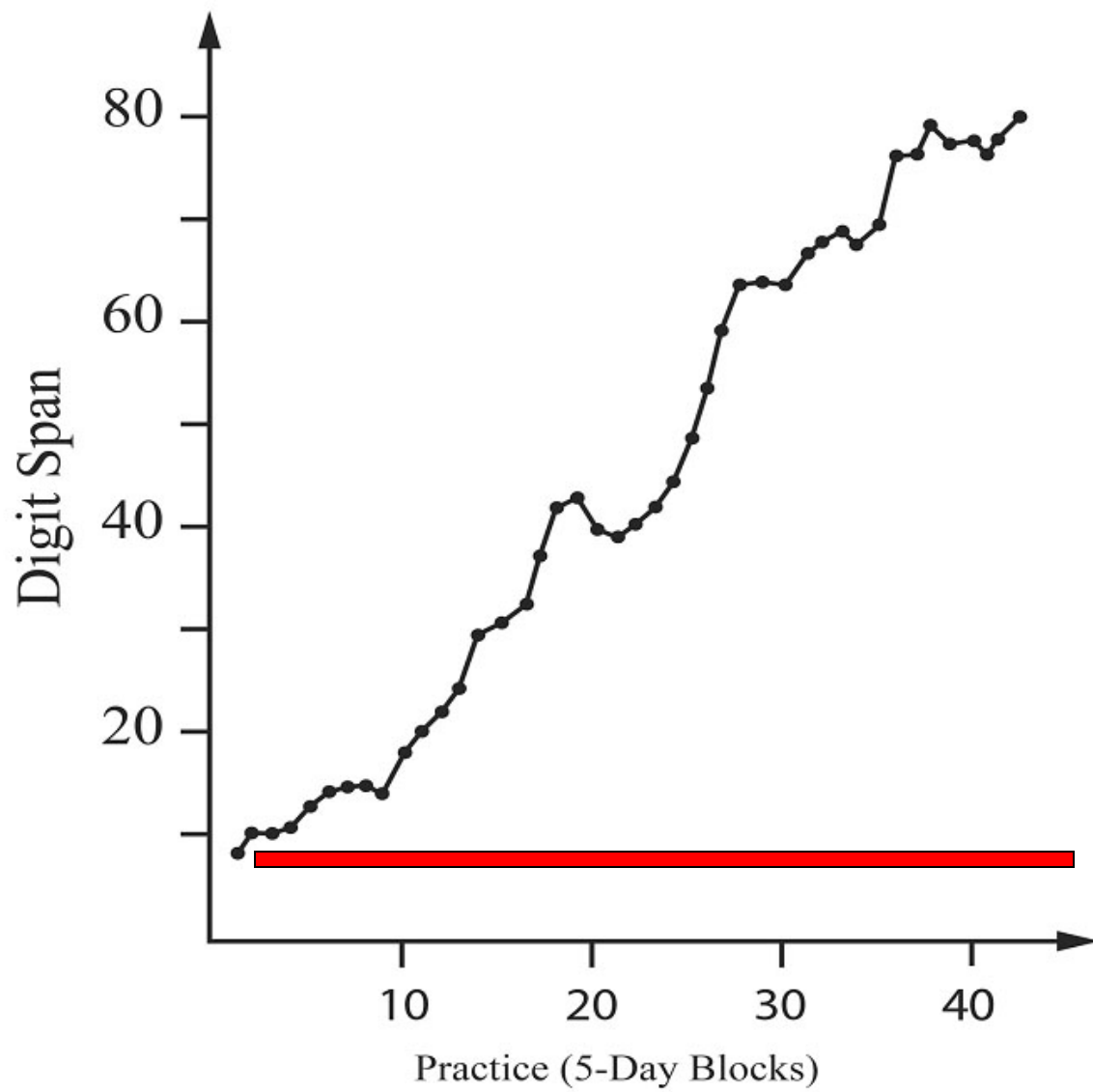
7

9

158  
cm

173  
cm

188  
cm



1462893

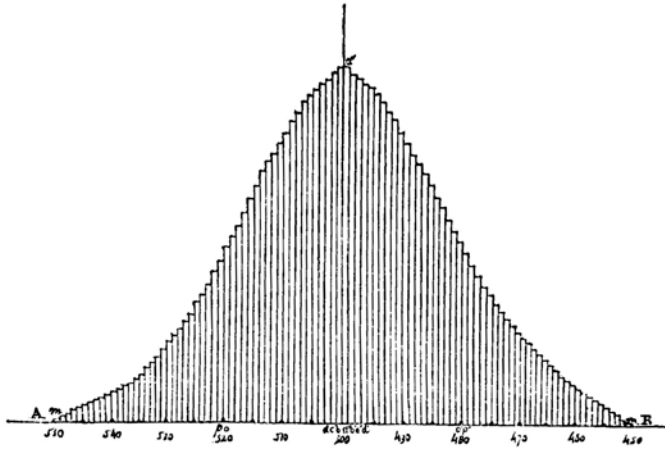
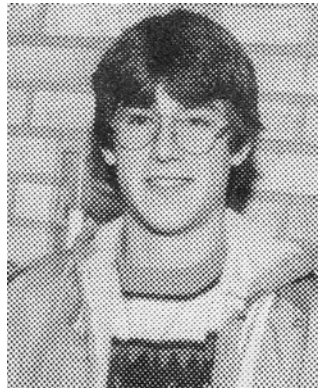


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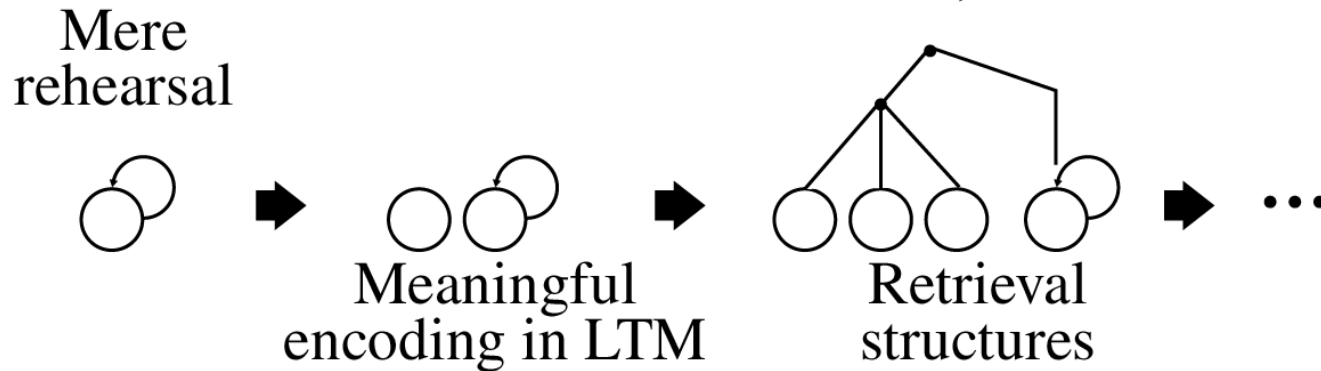
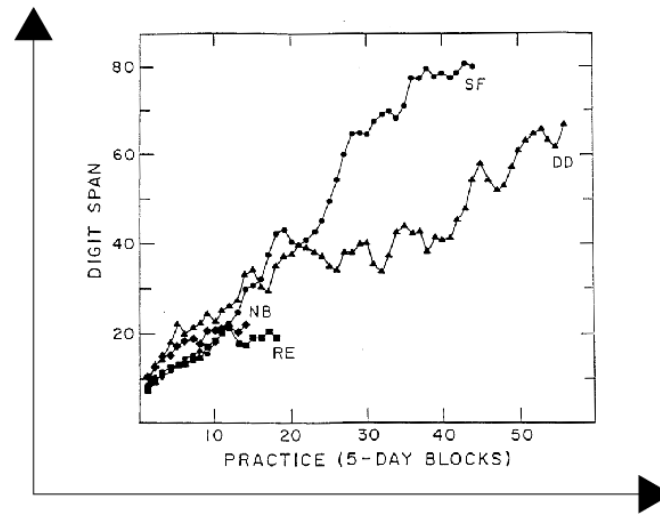
5                      7                      9                      ...                      →                      80

158                      173                      188    705

cm                      cm                      cm    →                      cm



# The Complex Mechanisms Involved in Acquiring Exceptional Digit Span

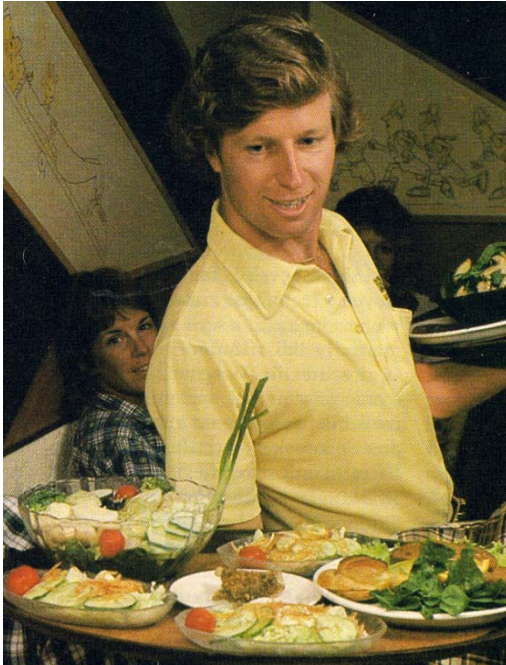


- Confirmed by training studies
- Confirmed by fMRI:s

16 complete  
dinner orders

> 31,000  
digits of pi

> 61,000  
digits of pi



John  
Conrad



Rajan  
Mahadevan

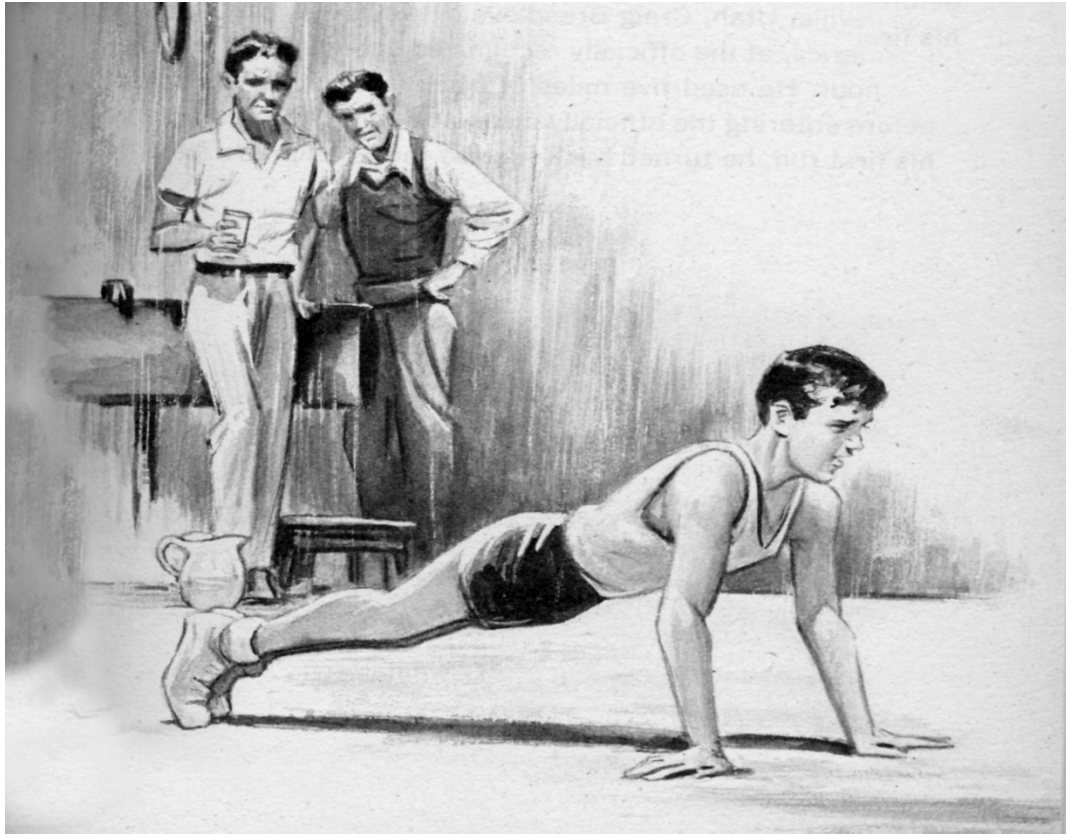


Chao  
Lu



# Limits on *modifiability*?

How many consecutive push-ups  
can someone perform without pause?



# Charles Linster

Non-stop  
push-up records

6,006 Charles Linster (USA)

05-Oct-1965

...

10,507 Minoru Yoshida (JAP)

Oct-1980

Fu Bingli, a kung fu master from China  
12 press ups with right finger









One-arm handstand



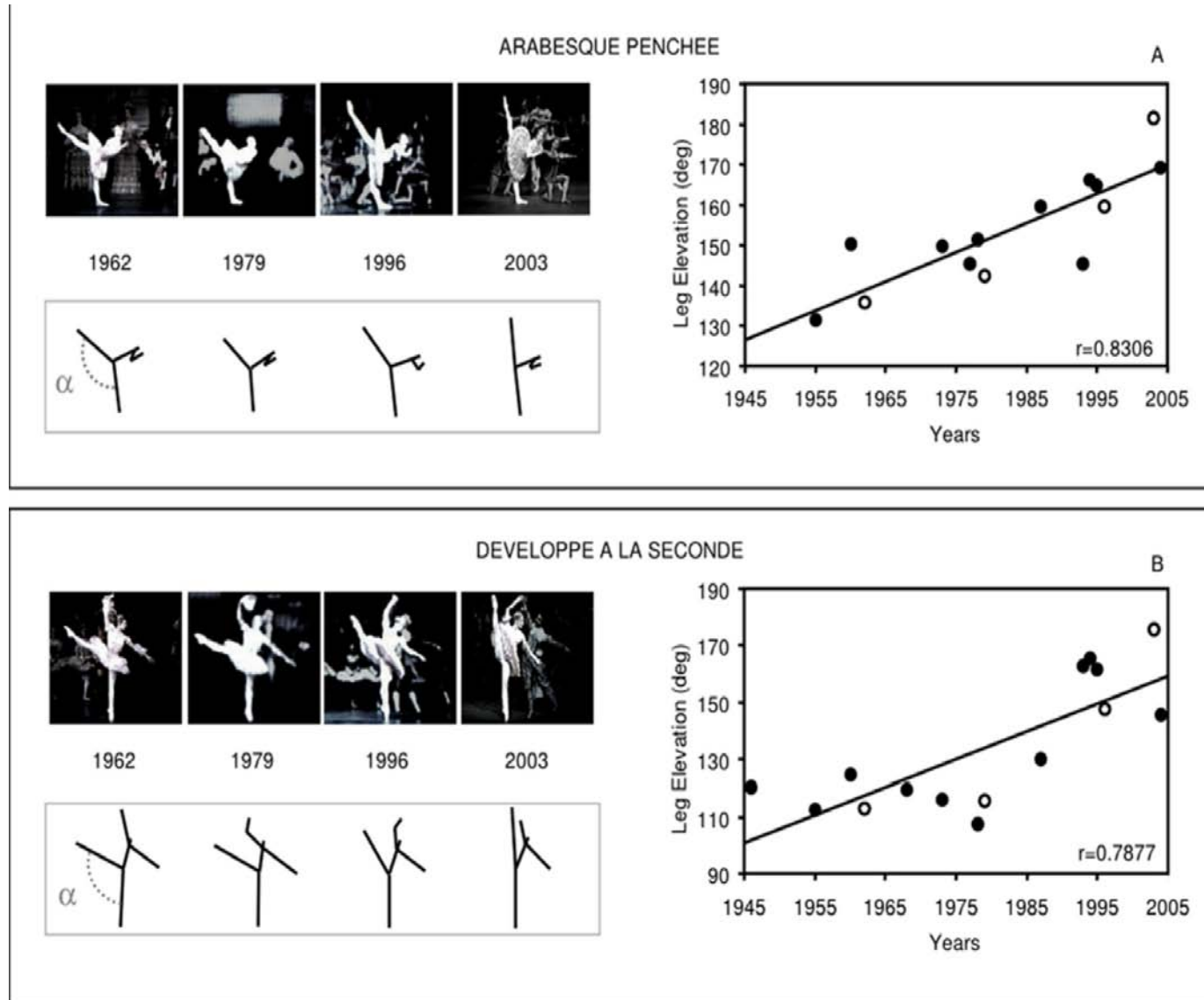
50 yards sprint in 18.7 s  
by Thomas P. Hunt

Guinness book of records distance record is **871 miles**.  
Johann Hurlinger of Austria walked from Vienna to Paris  
in 55 days. For each day he walked on his hands for 10 hours  
at a speed of 1.58 miles per hour.

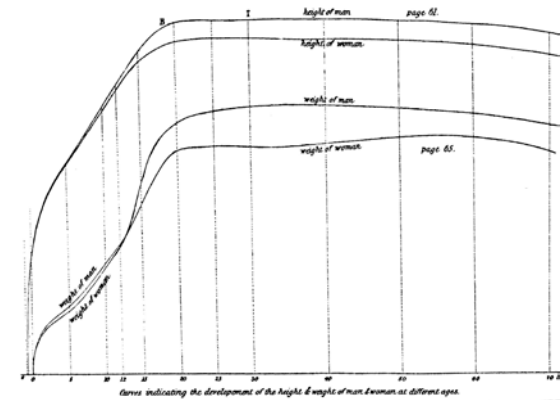
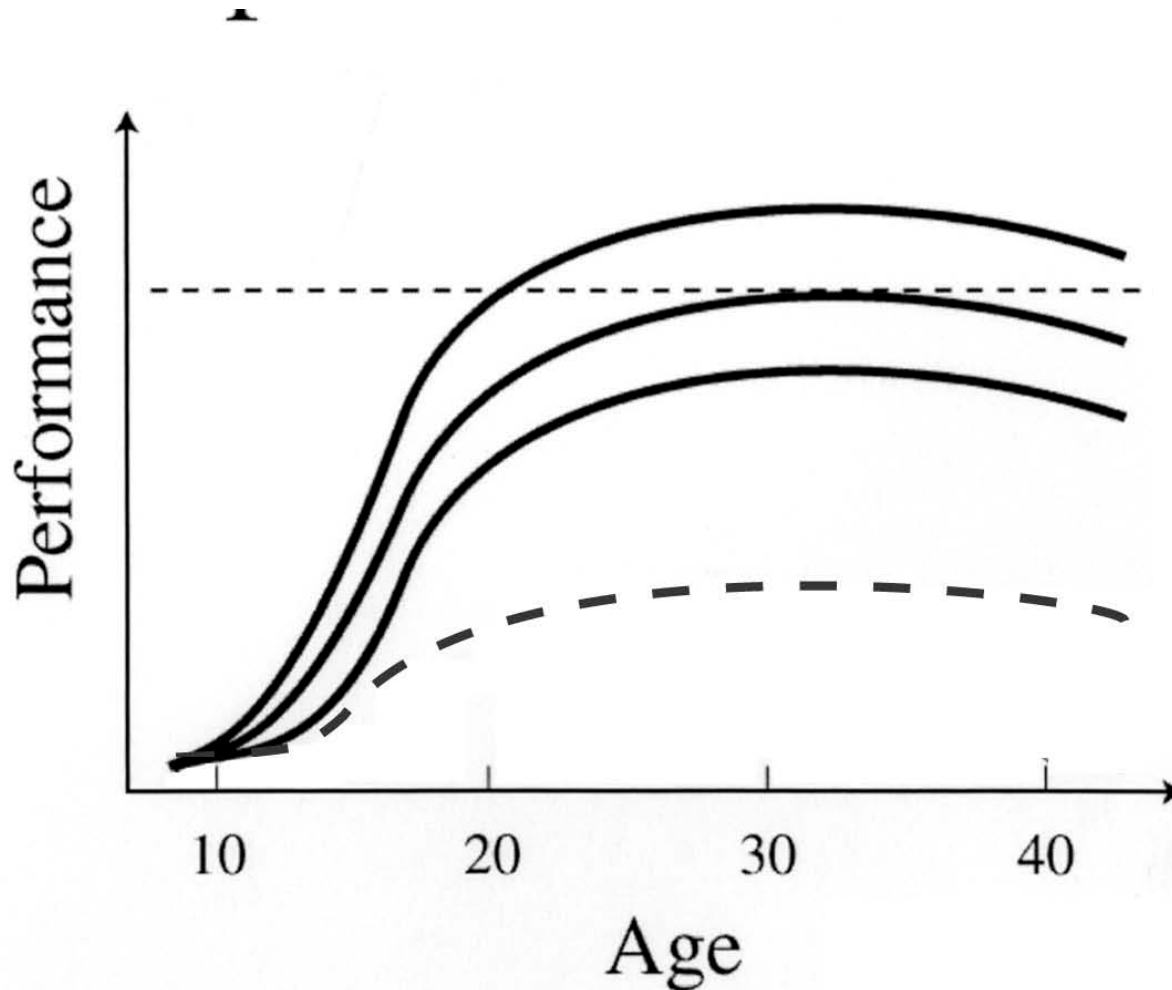
# Matthias Schlitte



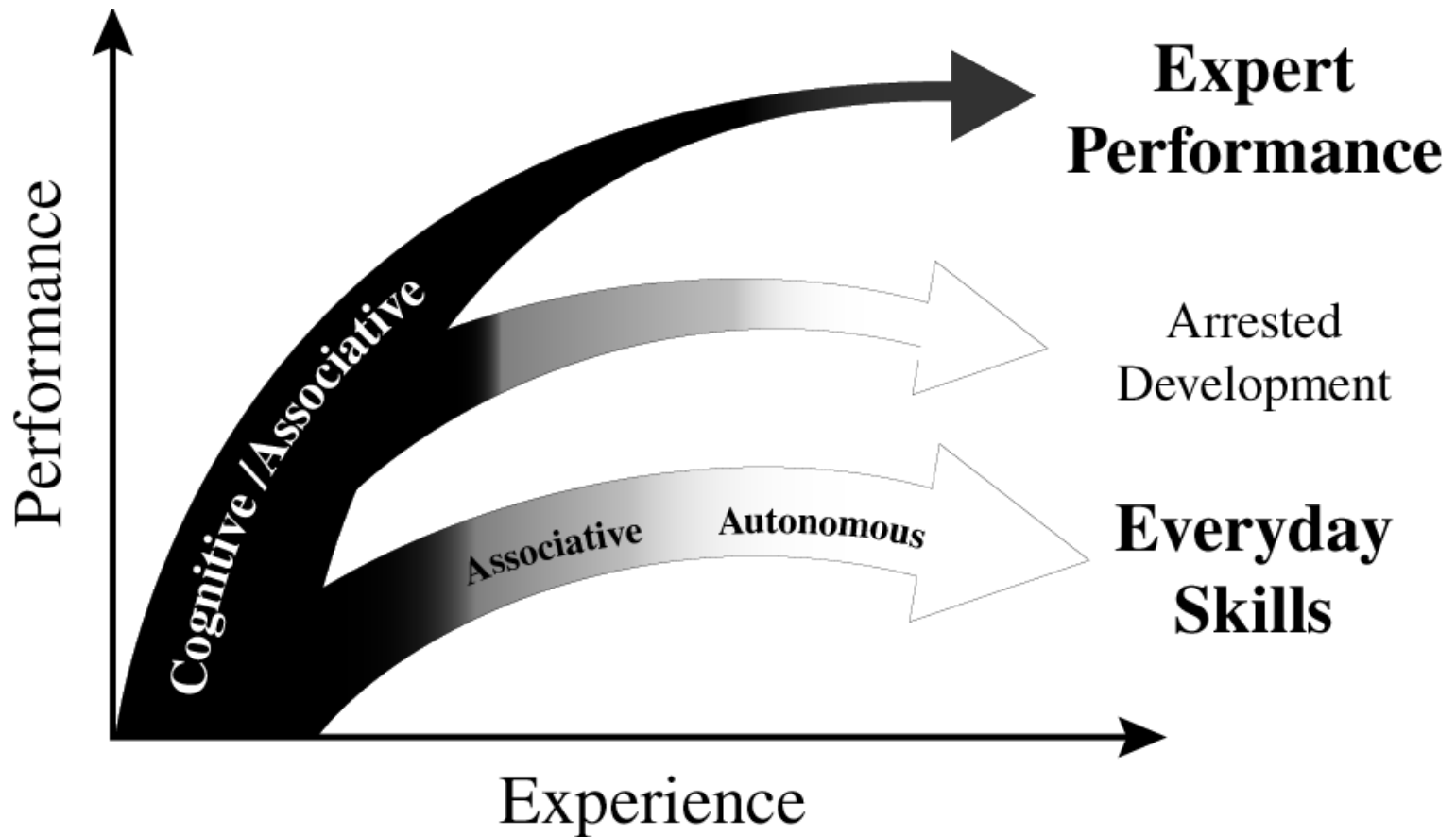
# Changes in ballet during the last 50 years



## II. Levels of Attained Performance



# The Development of Expert Performance





In 1904 they discussed outlawing  
double summersaults because  
they were dangerous and impossible to master

# Overcoming Firm Limits on Performance

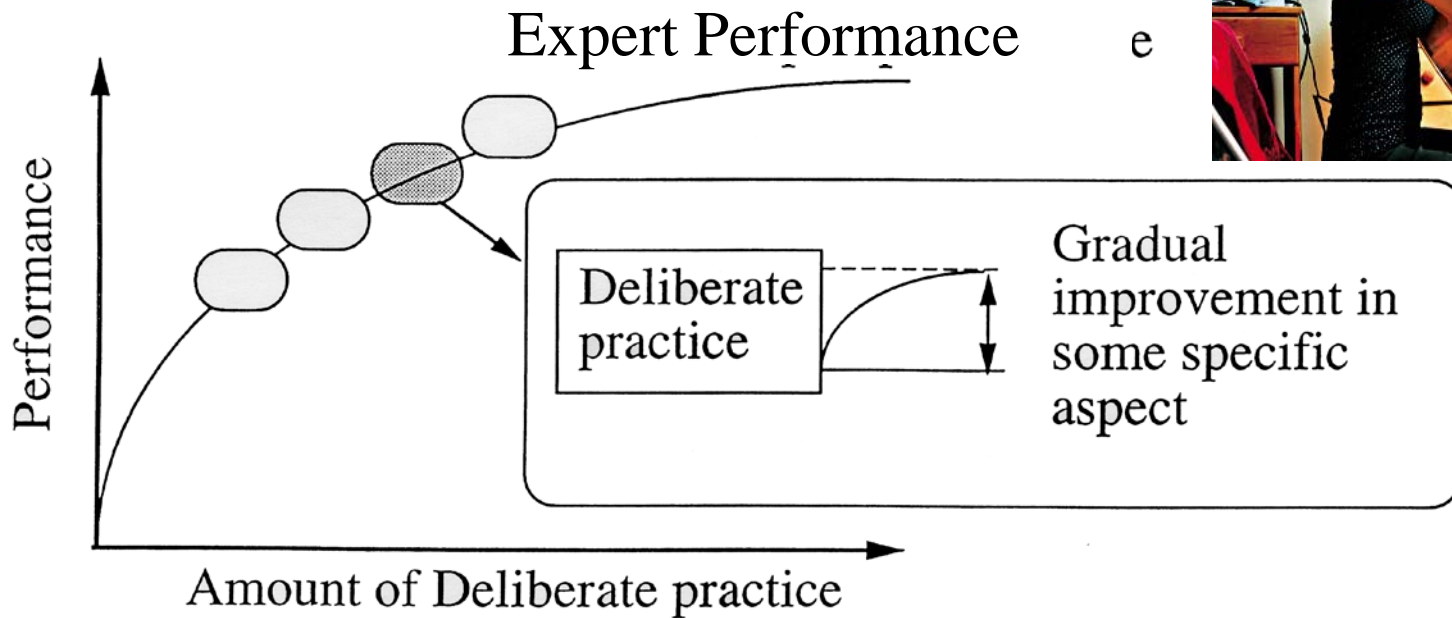


Salchow



# The acquisition of expert music performance through deliberate practice

## Design and Sequencing of Training Activities

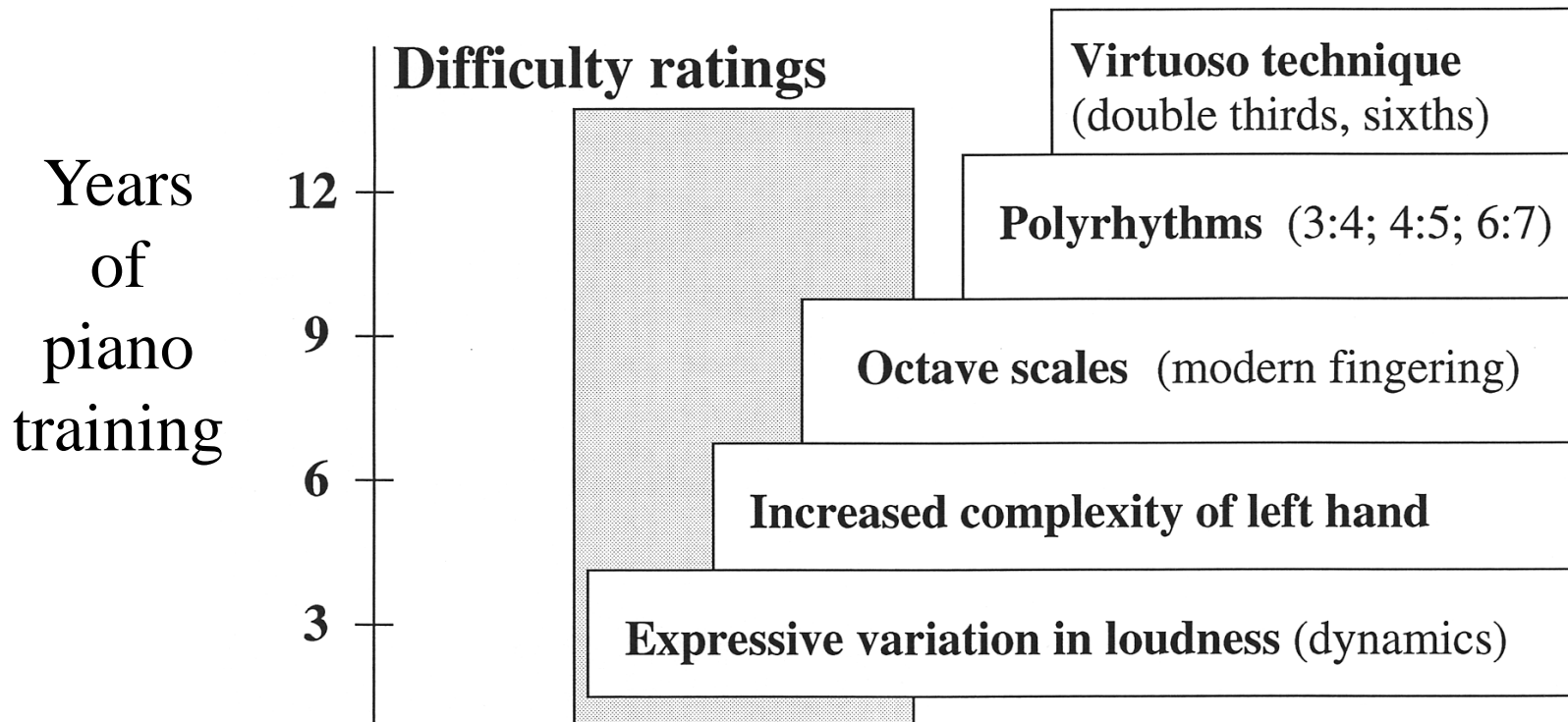


Professional teachers and coaches

- \* Monitor students' development
- \* design training tasks for individual students



# Increase in Complexity and Control as a Function of Years of Piano Training



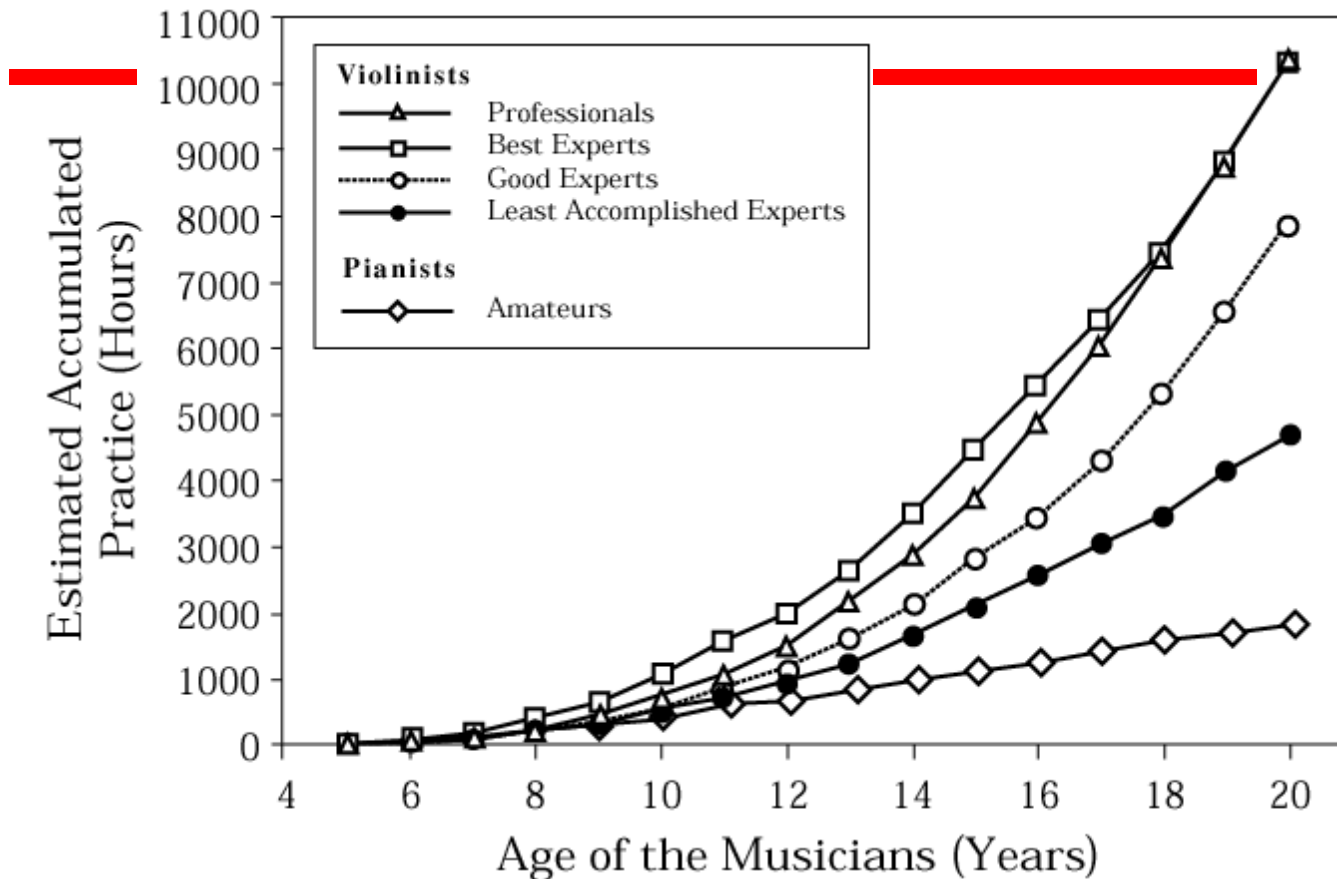
# Deliberate Practice

“individualized training activities especially designed by a coach or teacher to improve specific aspects of an individual's performance through repetition and successive refinement.

To receive maximal benefit from feedback, individuals have to monitor their training with full concentration, which is effortful and limits the duration of daily training”.

(Ericson & Lehmann, 1996, pp. 278-279)

# Accumulated Amount of Practice Alone During the Development of Amateurs and Expert Musicians



# III. Differential Effects of Practice Activities

Rated Relevance for Improvement from Doing X  
on a scale from 1 to 7 (Charness, Krampe, & Mayr, 1996)

Active participation  
in chess tournaments

Playing chess games  
outside of chess  
tournaments

Serious analysis of  
positions alone

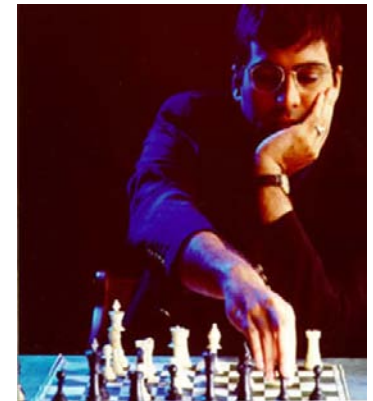
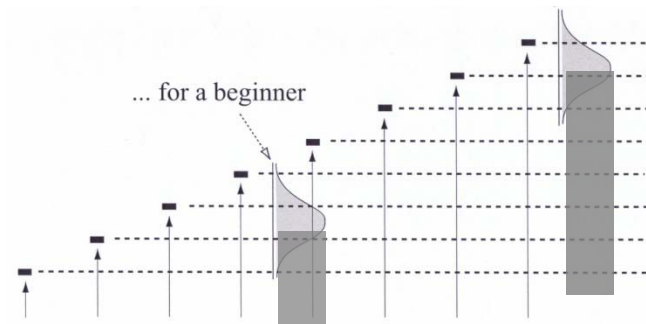
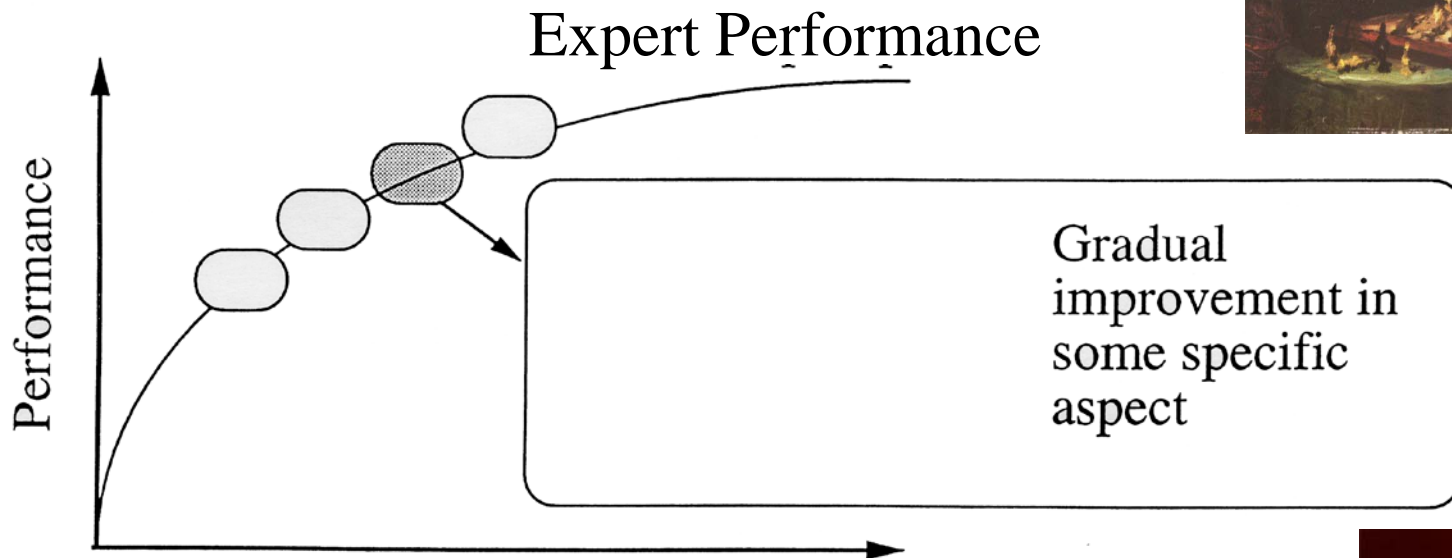
Rated Relevance for Improvement from Doing X  
on a scale from 1 to 7 (Charness, Krampe, & Mayr, 1996)

Active participation in chess tournaments	6.1
--	-----

Playing chess games outside of chess tournaments	3.6
--	-----

Serious analysis of positions alone	5.9
--	-----

# Effects and Dose-Response Relations to Practice Activities

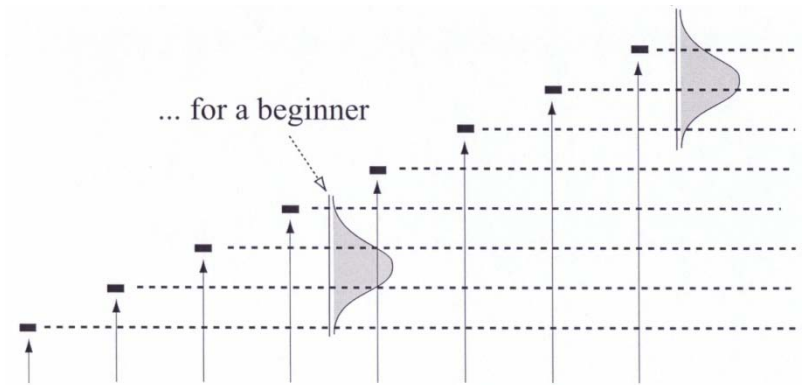


# Rated Relevance for Improvement from Doing X on a scale from 1 to 7 (Charness, Krampe, & Mayr, 1996)

Active participation in chess tournaments	6.1	No correlation
Playing chess games outside of chess tournaments	3.6	Negative correlation
Serious analysis of positions alone	5.9	Positive correlation

# Deliberate Practice in Chess: Discovering Accurate Immediate Feedback

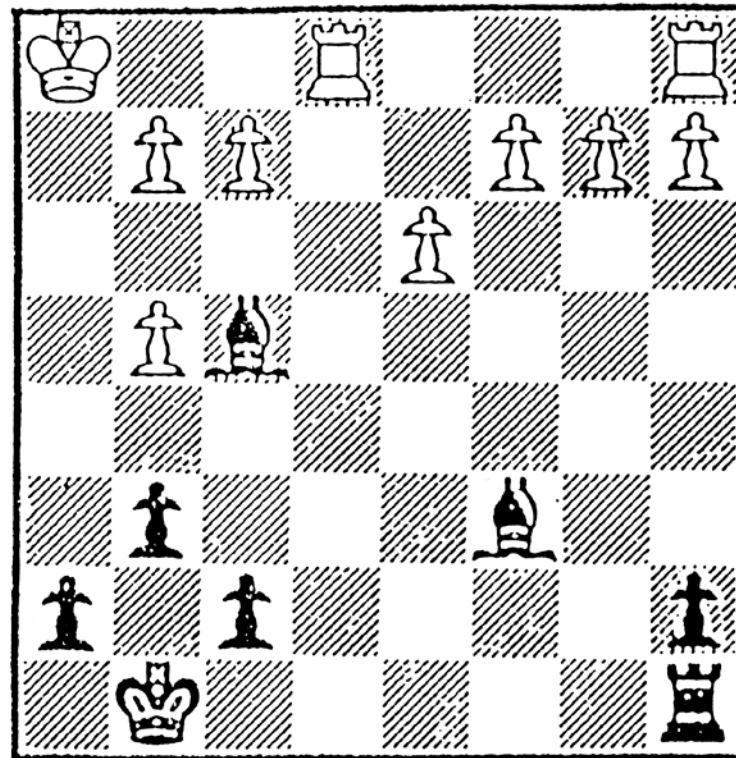
How would even a chess player  
know if he/she played  
the best possible chess move  
for a given position?





# Simulated Play Against World Class Players

Study published games by chess masters



Position B

Black's move

Make predictions for each next move

Check if your prediction was correct, if not, study the chess position until you understand why that move was played

# Practice Alone by Skill Group

Charness, Krampe & Mayr, 1995

## The First 10 Yrs of Practice Alone

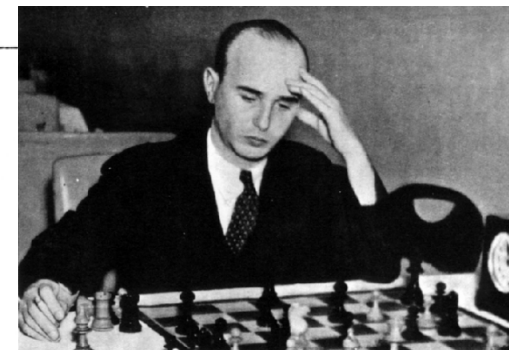
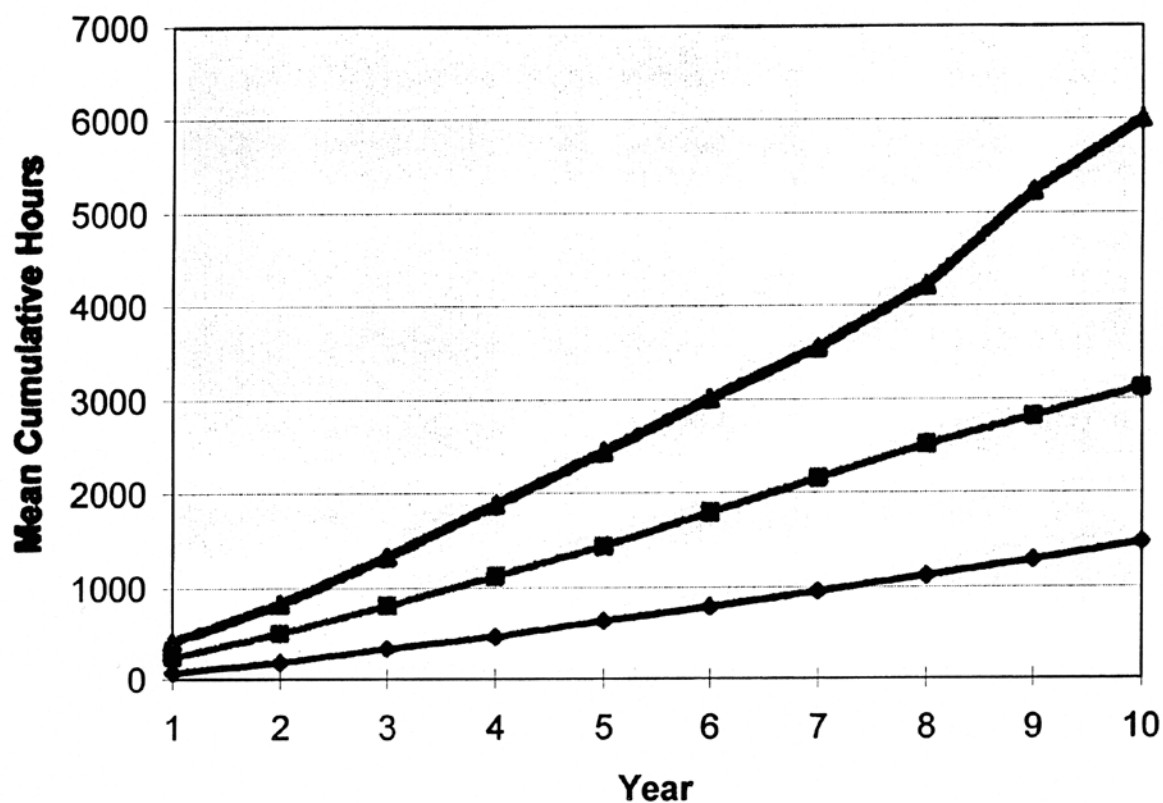


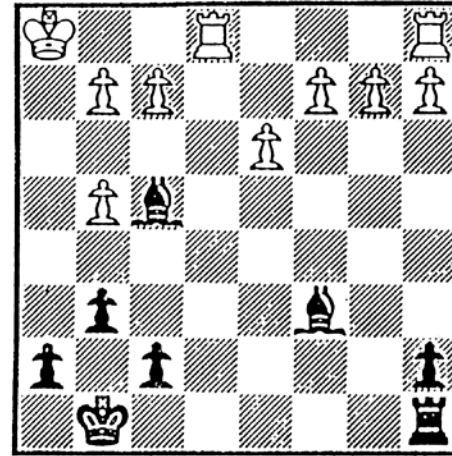
Photo  
SAMUEL RESEVSKY  
U.S. champion, in a characteristic pose

Frank Kross, New Rochelle

- ◆ Elo=1800
- Elo = 2200
- Elo=2550

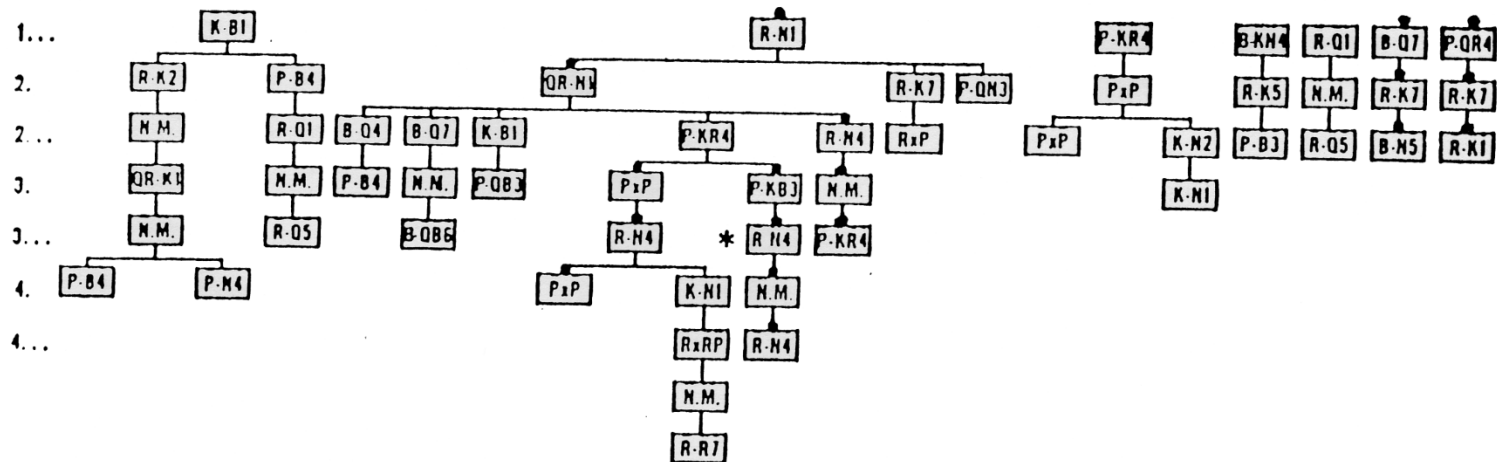
# Learning from Making an Incorrect Move

- \* What aspect was overlooked
- \* When could this aspect have been discovered
- \* How to avoid similar mistakes in the future
- \* Develop new skills by deliberate practice



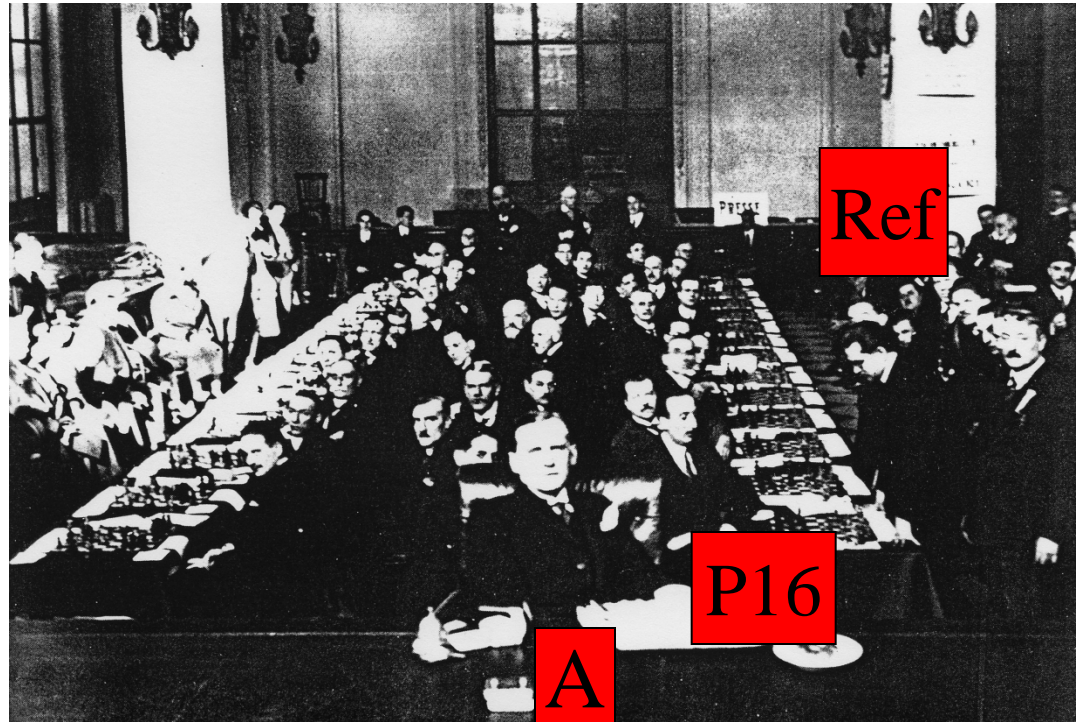
## Position B

## Black on move



# Exceptional abilities

## Blindfold Chess



Alekhine beat most of the 30 skilled players while playing them simultaneously under blindfold conditions

# Acquired Mental Representations

**Music** *“Imagined music experience”*

**Golf** *“Image of desired ball trajectory”*

Desired performance goal



Representation  
for how to execute  
the performance



Representation  
for monitoring one's  
performance

**Music** *“Playing a piece of music”*

*“Listening to the played music  
as experienced by an audience”*

**Golf** *“Execute desired shot”*

*“Comparison between desired  
and actual shot”*



# Expert Performers are Better at Analyzing Situations

(Nevett  
& French,  
1997)



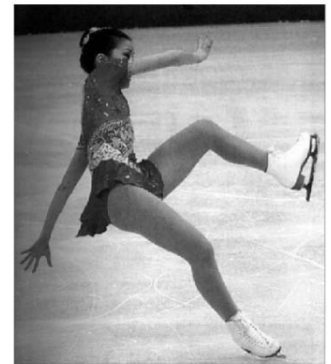
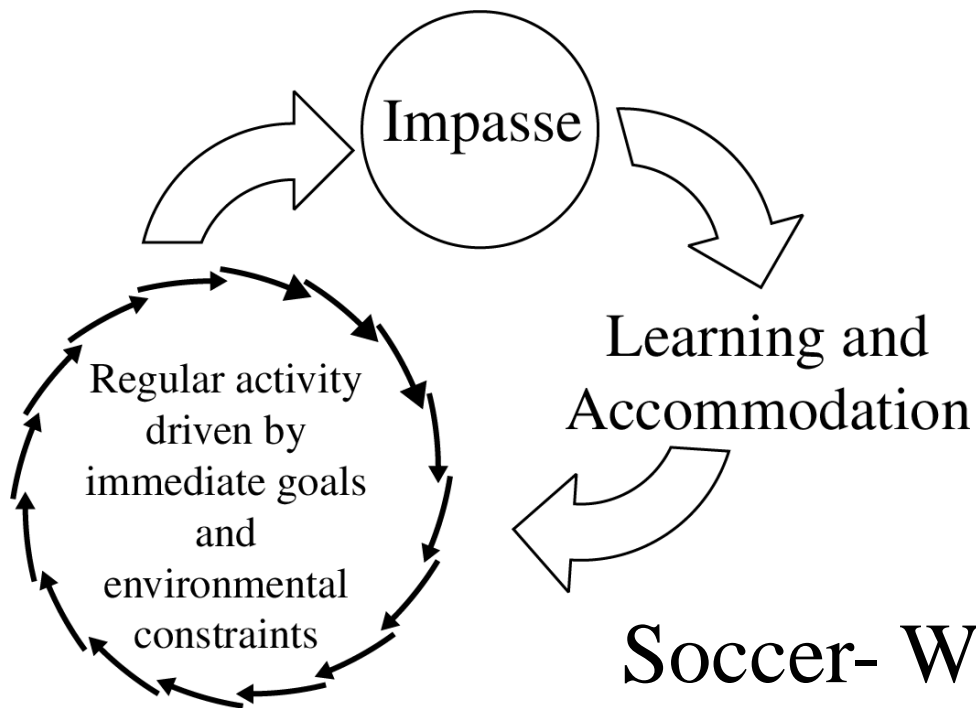
(Ward &  
Williams,  
2003)

(Tuffiash,  
Roring, &  
Ericsson,  
2007)



chess

# VI. IV. Deliberate practice versus play



At the limit of one's ability

Soccer- Ward et al. (2007)

Darts – Duffy et al. (2004)

Gymnastics – Law et al. (2007)



# The problem with learning *during* work and play



Andy Murray (Scotland) in 2010

# The problem with learning *during* work and play



# Expert Performers are Better at Analyzing Situations

(Nevett  
& French,  
1997)



(Ward &  
Williams,  
2003)

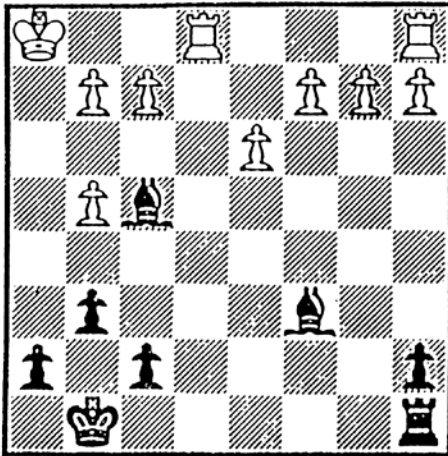
(Tuffiash,  
Roring, &  
Ericsson,  
2007)



chess

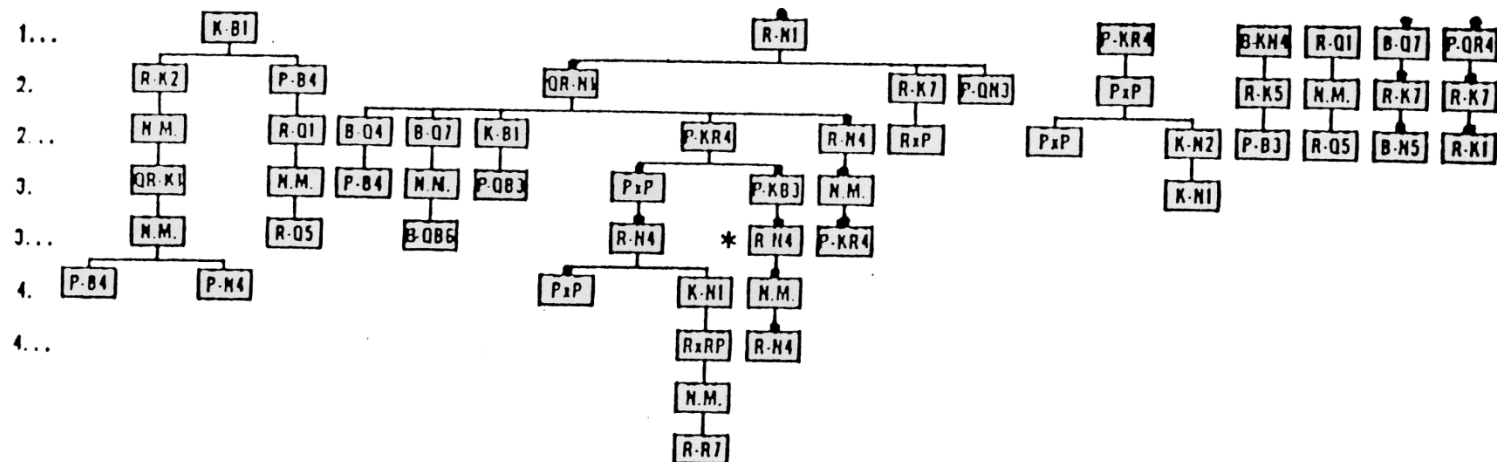


# Learning from an Incorrect Action of Anticipation

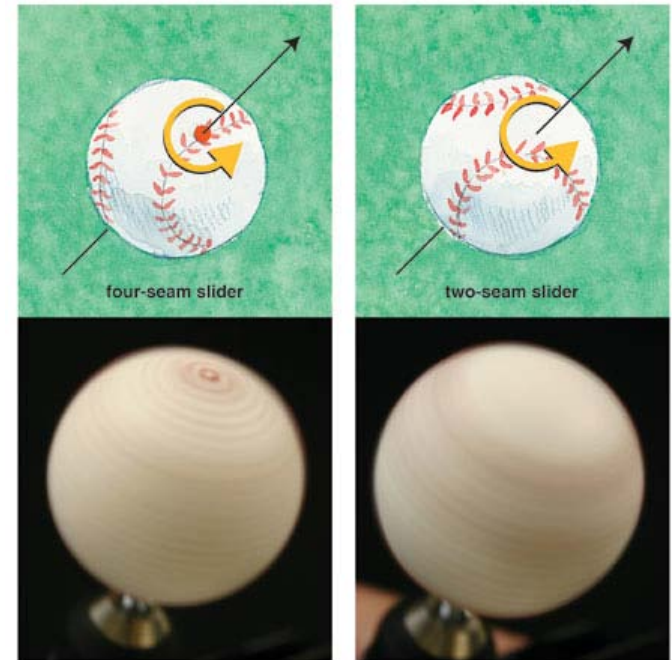


What aspect was overlooked

- \* When could this aspect have been discovered
- \* How to avoid similar mistakes in the future
- \* Develop new skills by deliberate practice



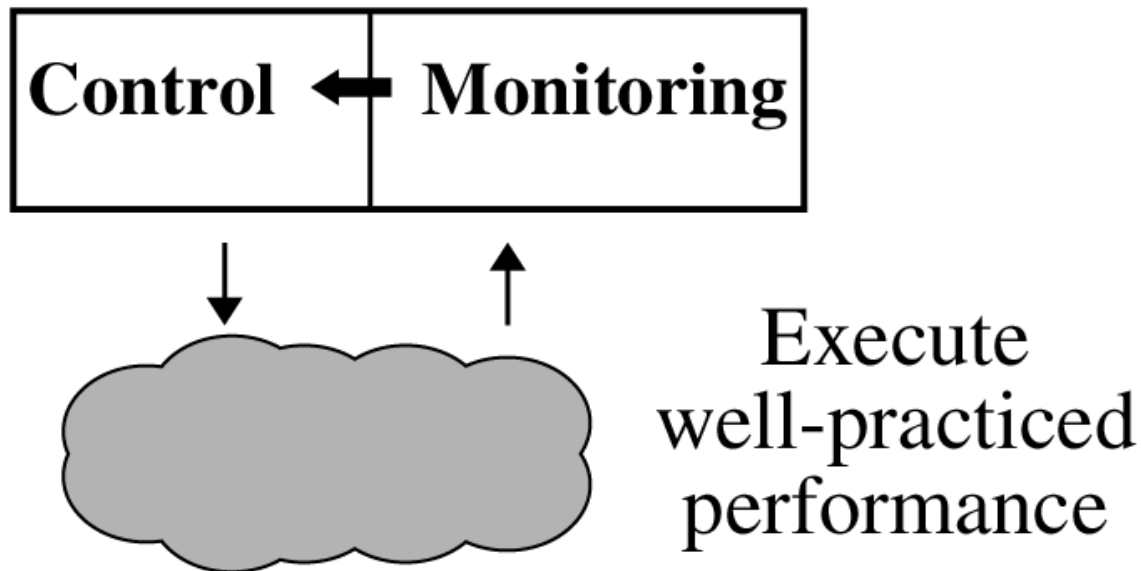
# Perceptual cues used by batters to predict ball path



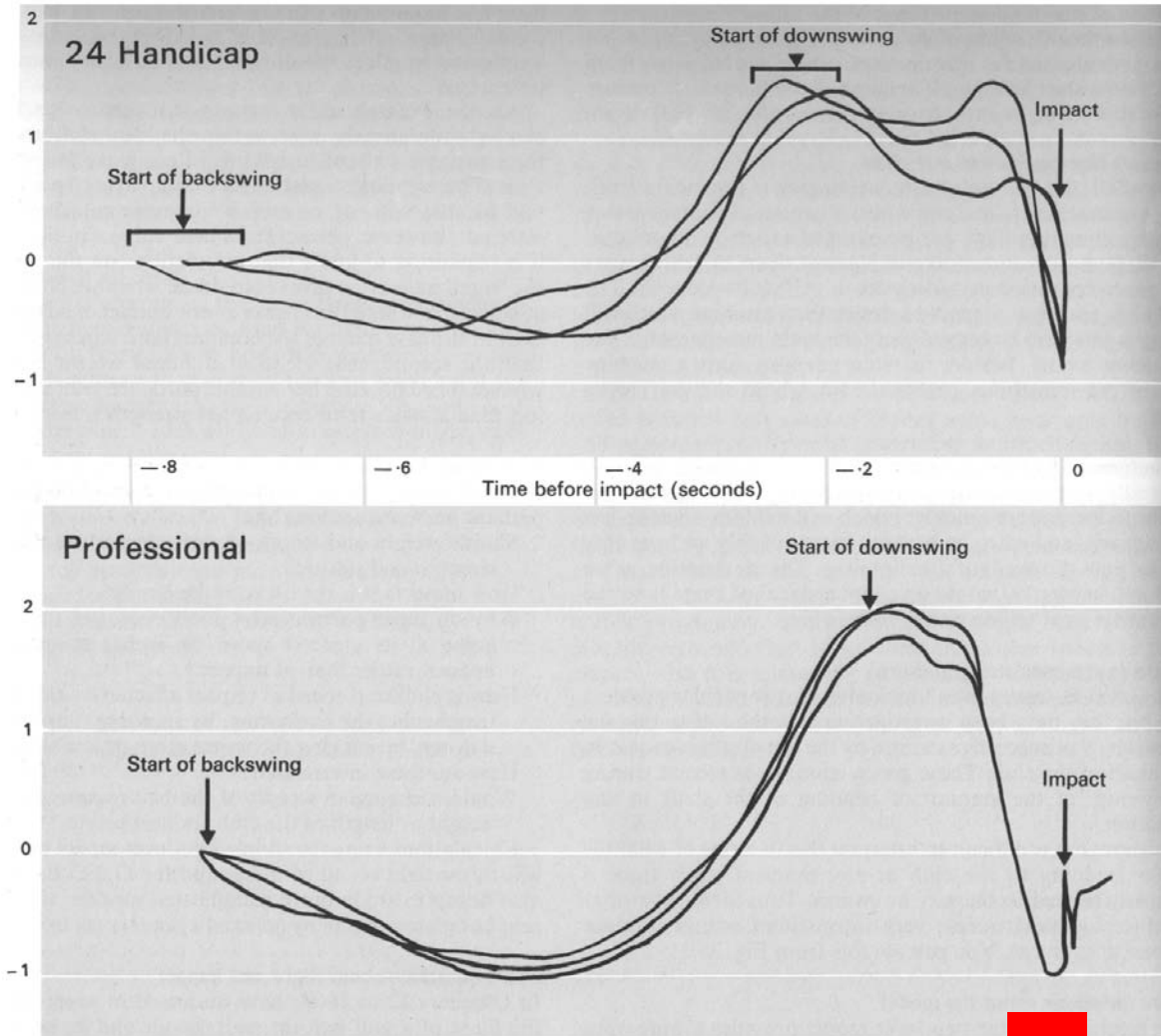
(Bahill, A. T., Baldwin, D. G., & Venkateswaran, J., 2005  
*American Scientist*, 93, 218-)

# The Quest for Control

Experts design many types of mechanisms for controlling their performance



# Three Swings with a Driver by Two Golfers

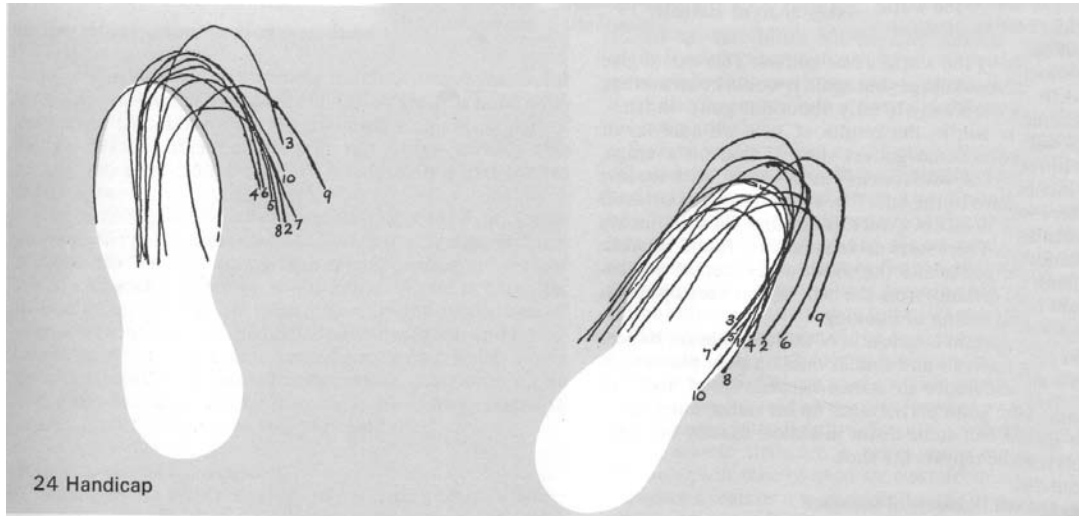


Recreational  
Golfer

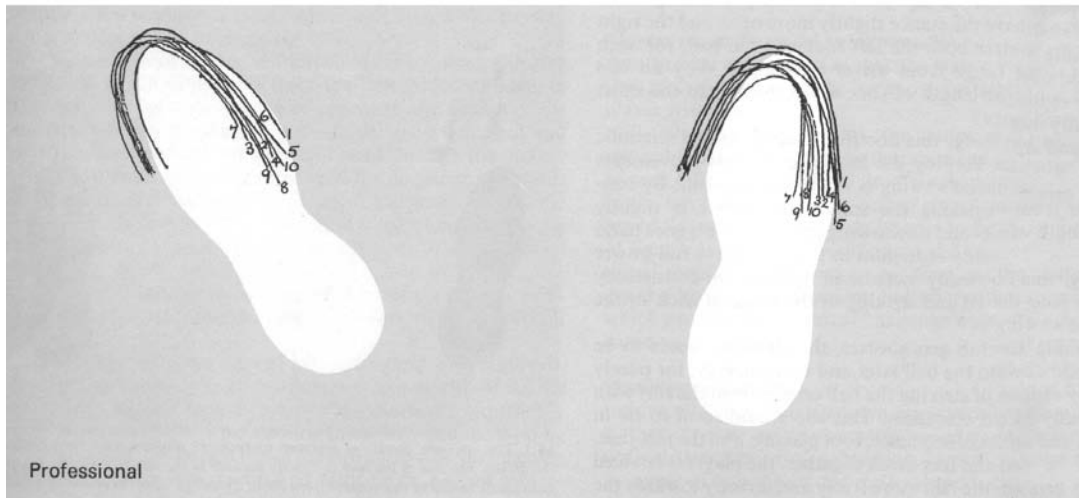
Expert



# Consistency of the Stance of Two Golfers



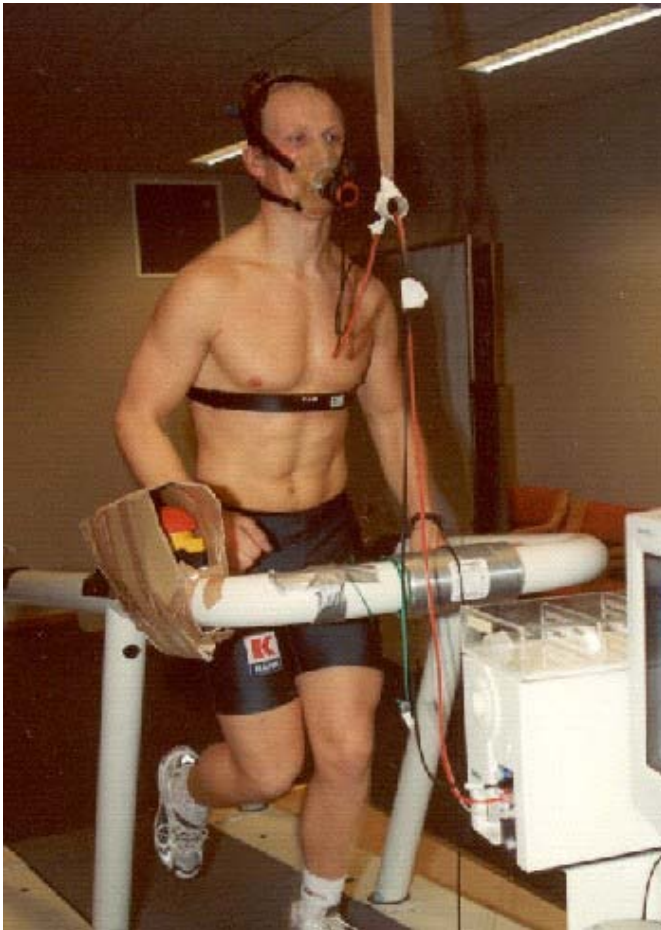
Recreational  
Golfer



Expert

# V. Becoming an Elite Athlete

Causal mechanisms generating changes



Maximal  
capacity ( $\text{VO}_2\text{max}$ )

Running economy  
(metabolic cost  
at race pace) is  
a better predictor

# How can deliberate practice change the body?

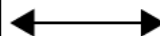
## *Machines and Computers*

Unmodifiable  
Basic units and parts  
Basic Processes  
Capacities

Modifiable  
Skills  
Knowledge  
Strategies

**Hardware**

**Software**



**Bioware**

Regeneration and  
reorganization at the cellular level  
Development

*Biological Organisms*

# The Adaptation of Bones



**Original**

**4-5 months  
later**

**4 years  
later**

(from Frost, 1973, p.  
400)

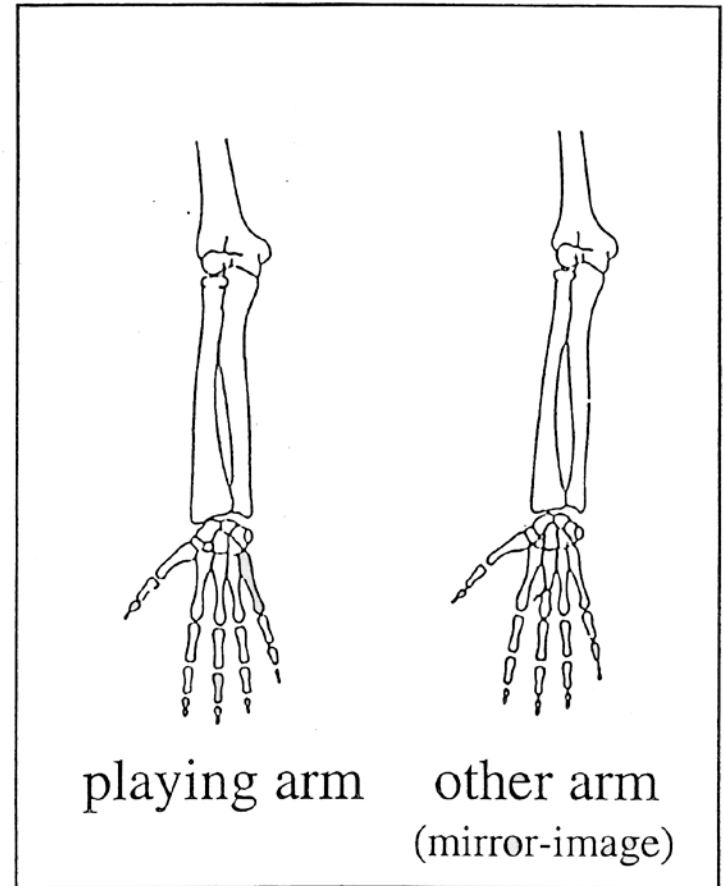
# The Adaptation of Bones in Elite Tennis Players



**Original**

**4-5 months  
later**

**4 years  
later**



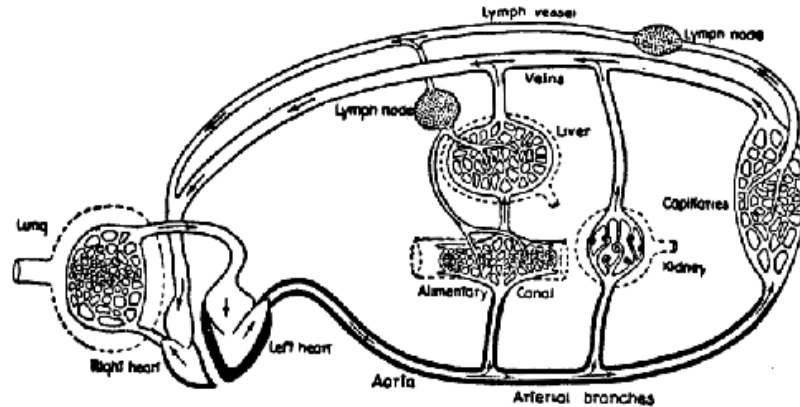
playing arm

other arm  
(mirror-image)

after Jokl

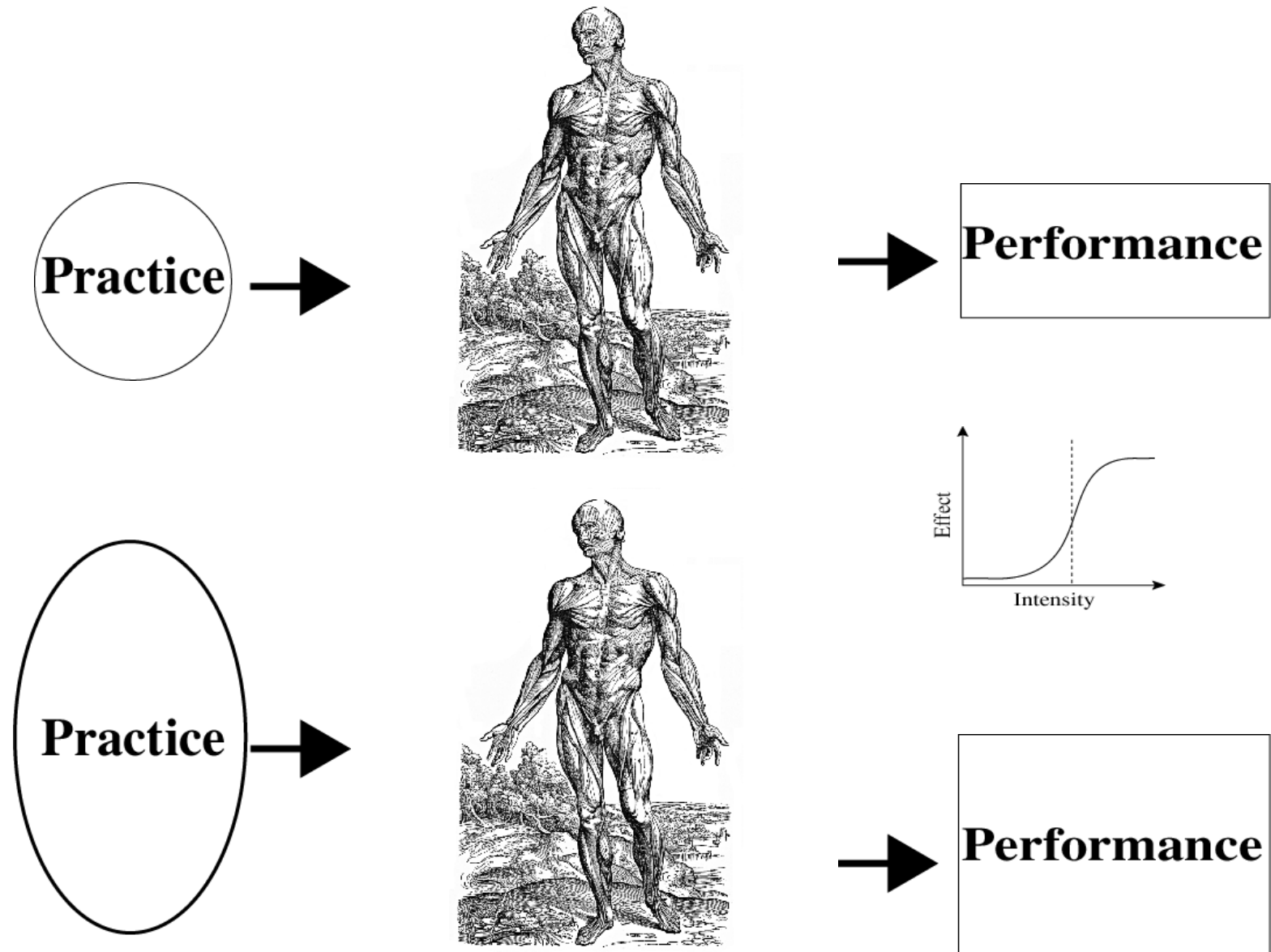
# Homeostasis (Cannon's fluid matrix)

Adaptation to changed environmental conditions while preserving

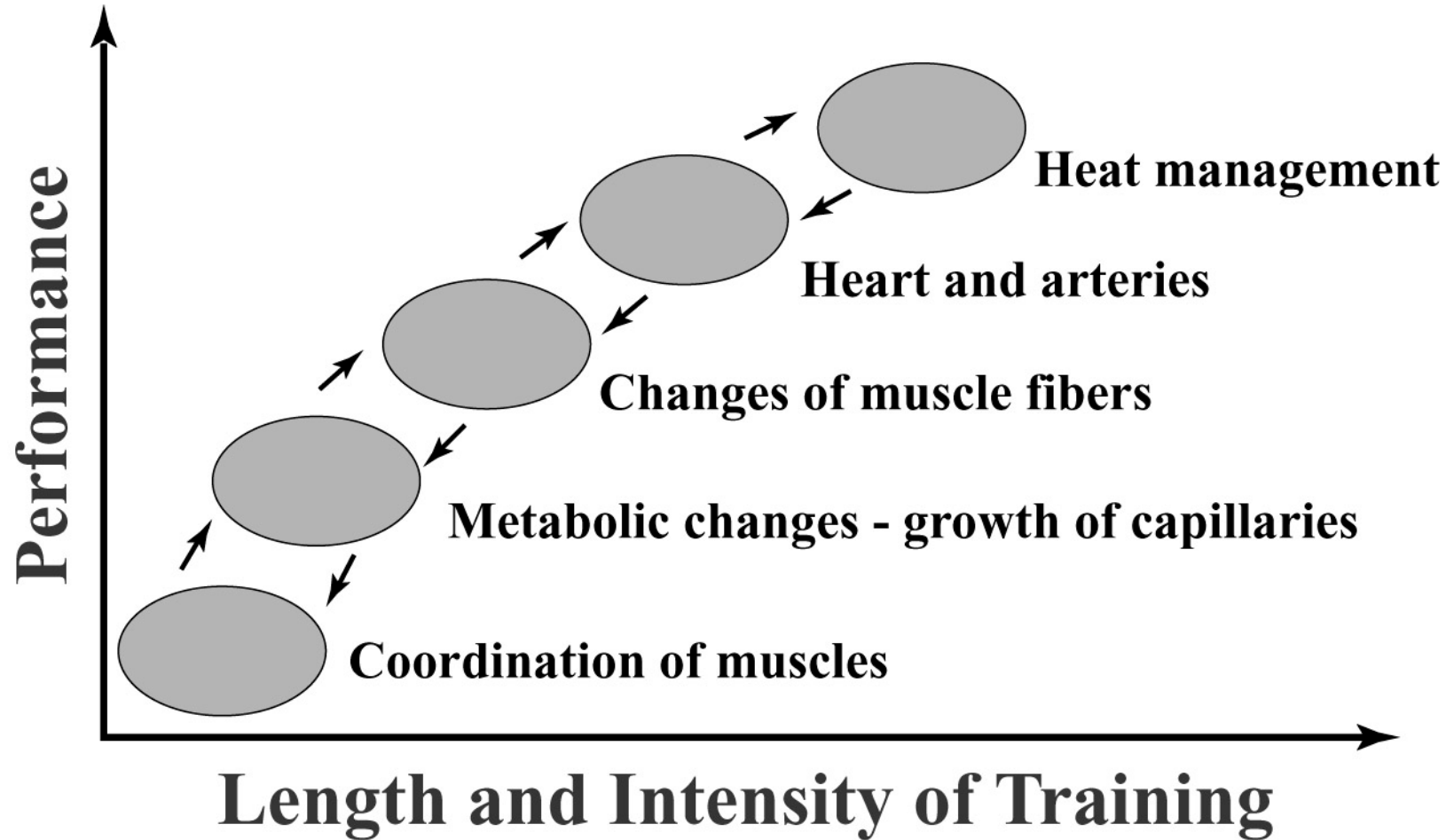


Temperature  
Fluids  
Blood Sugar  
Oxygen in blood

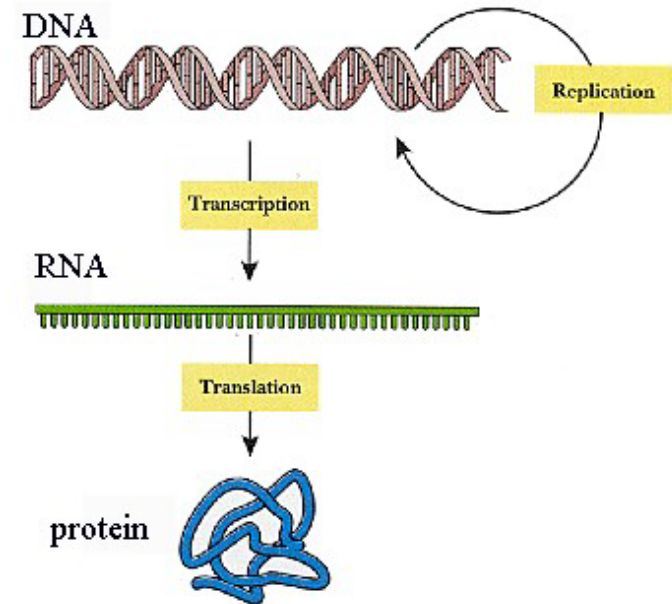
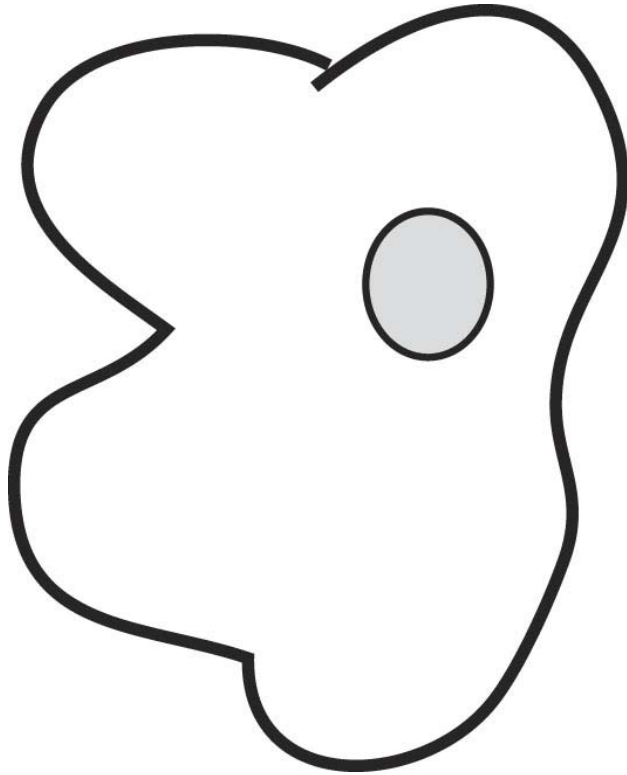
# Increase of Fitness





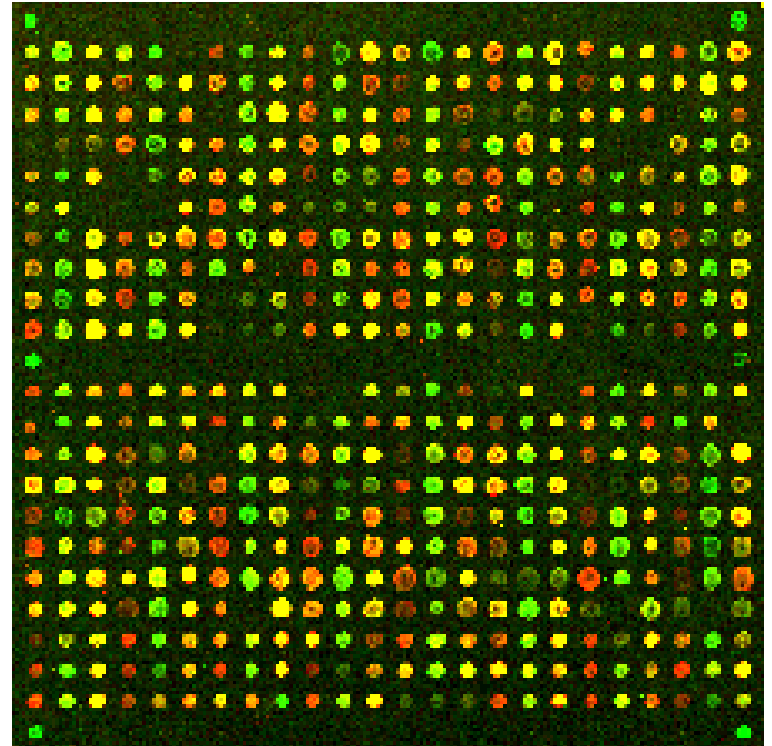
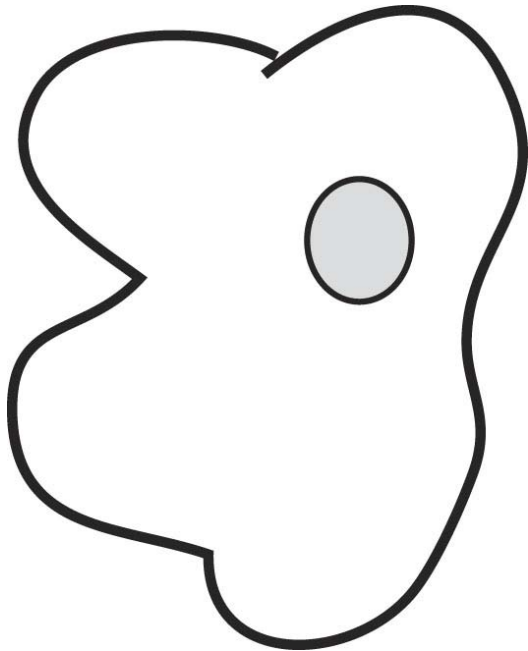


# Cells and Bacteria can Change to Improve Functionality



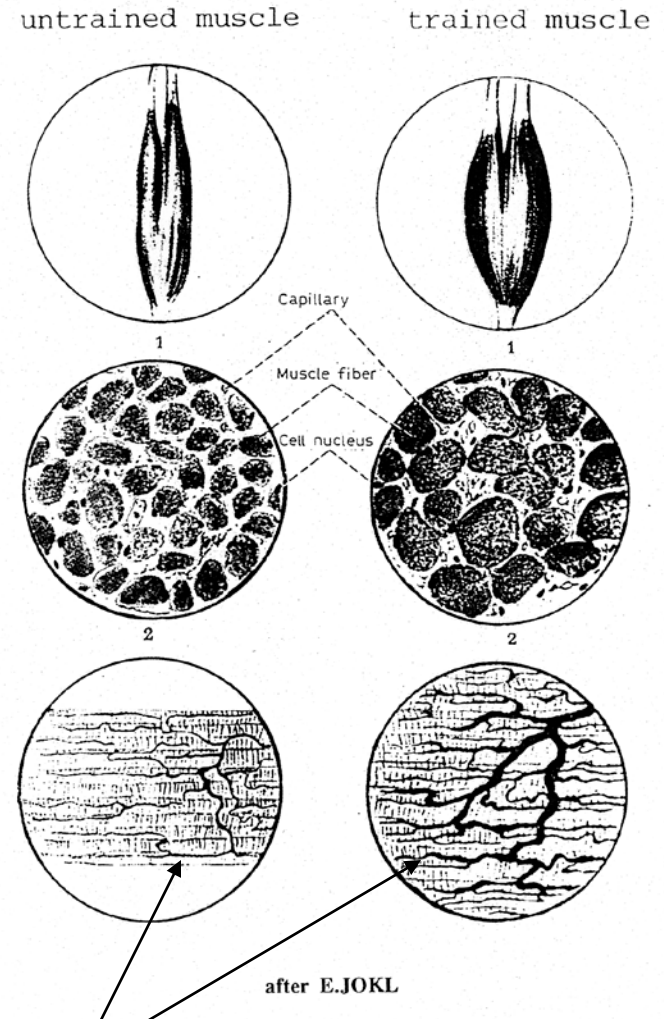
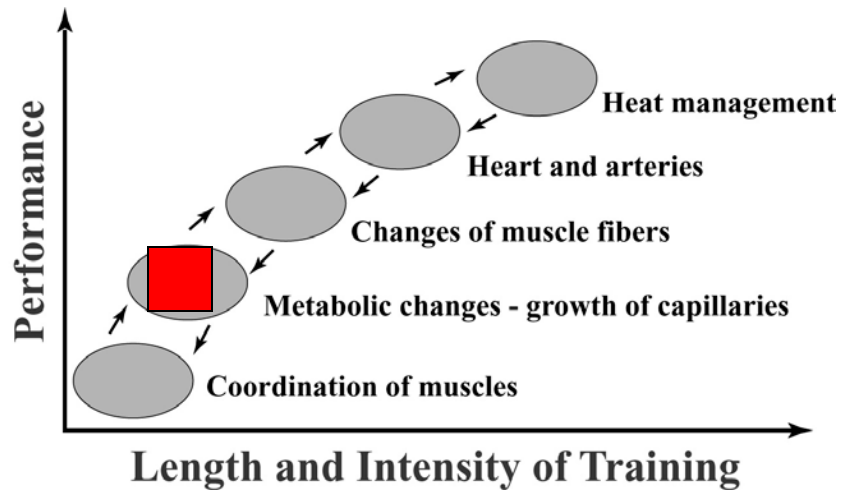
Restricting access to oxygen

# Turning on Genes by Changing the Environment for Cells and Bacteria



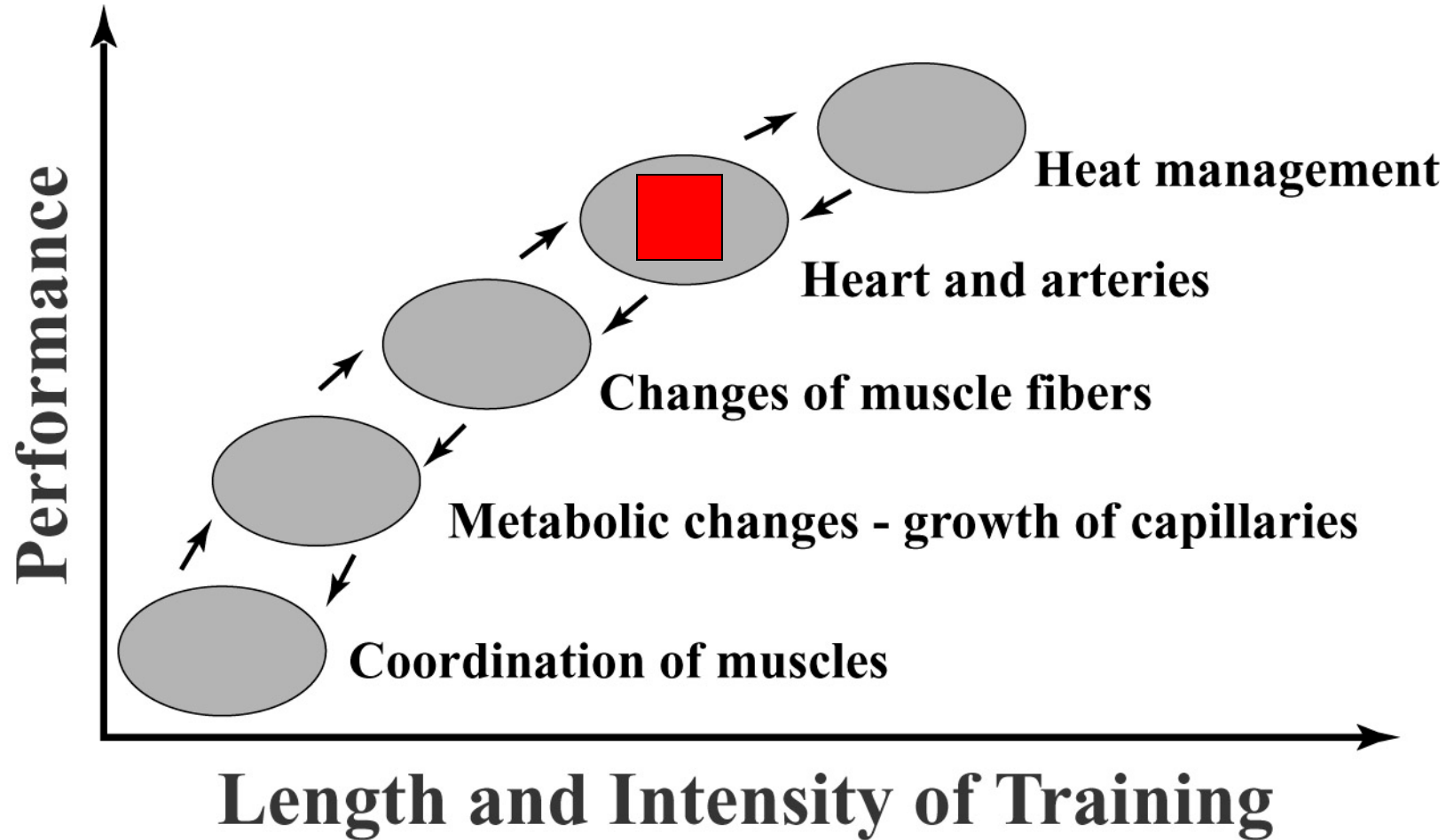
Exercise → Turns on over 100 genes in humans

# Changes observed in most amateur athletes

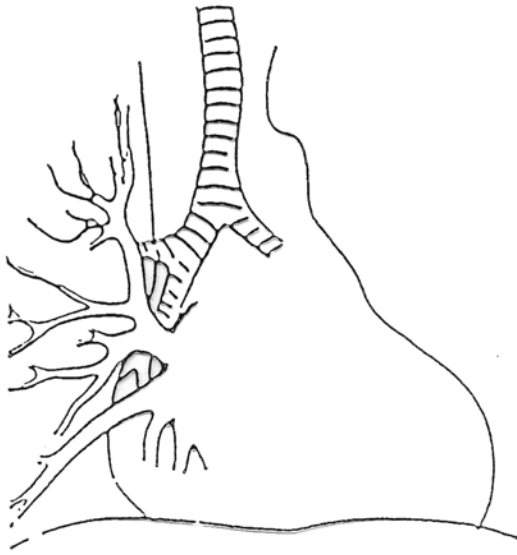


**Reduced Oxygen in Blood →**

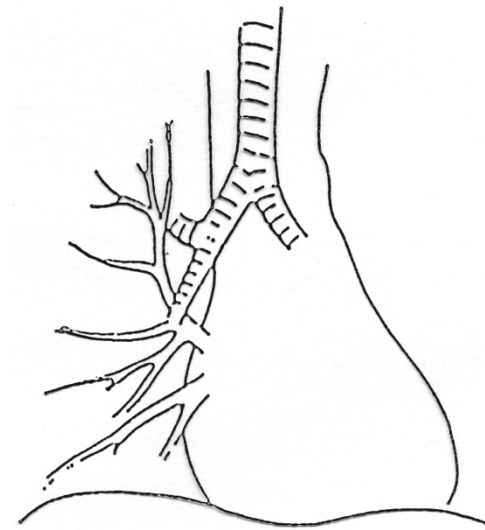
**Growth of Capillaries**



# Size of the Heart and Endurance Training



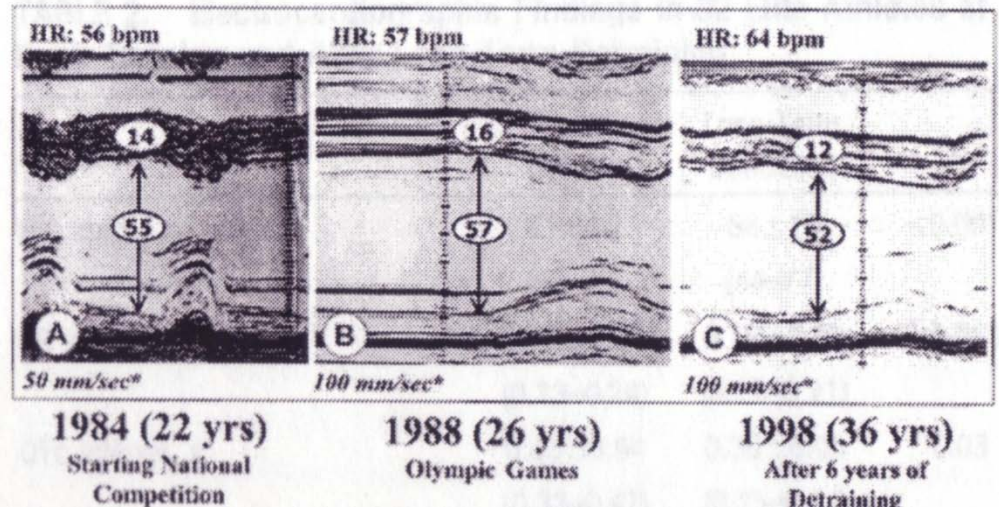
Heart of  
champion cyclist



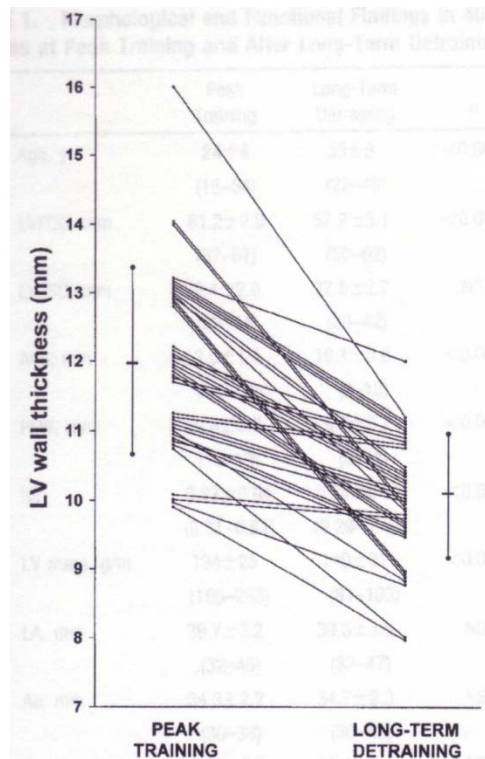
Heart of  
untrained man of  
same age

# Changes in the Heart

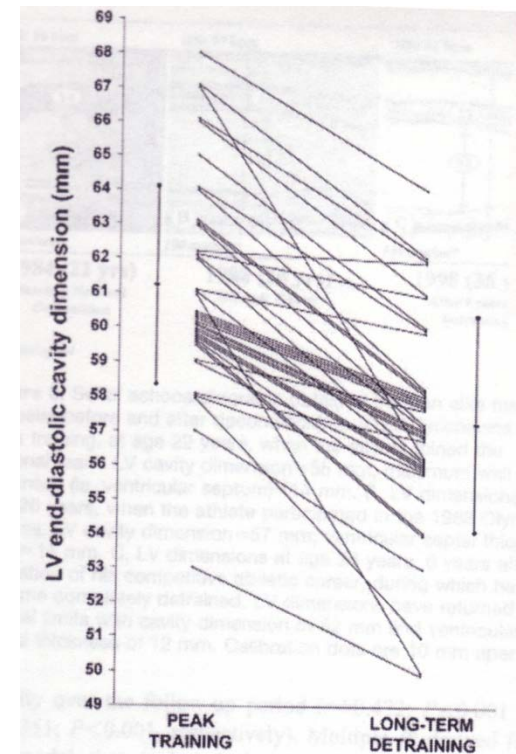
(A. Pelliccia et al., 2002, Circulation, 105, 944-9)



Thickness of the wall

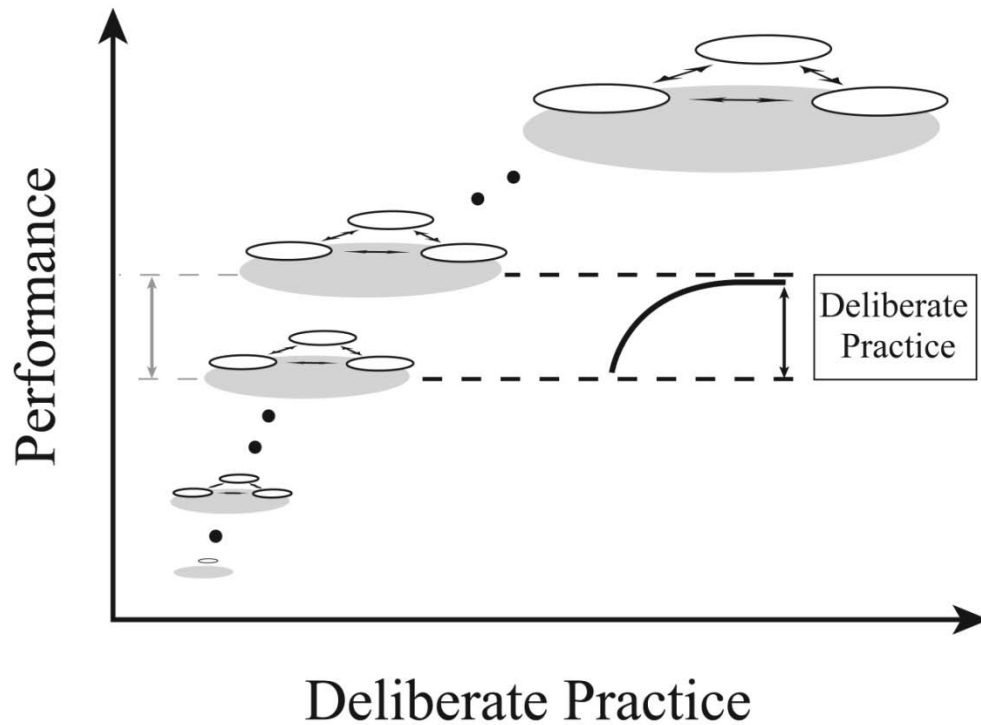


Size of left ventricle

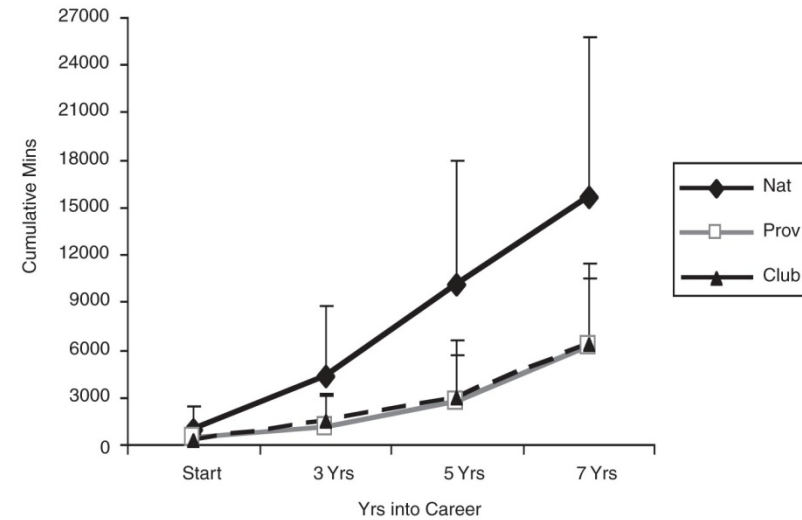




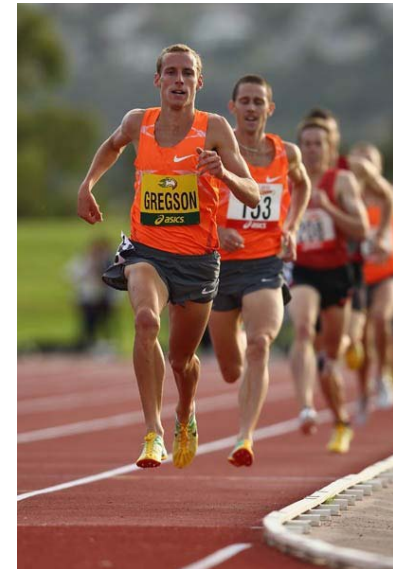
# A Sequence of Targeted Changes



## Middle distance runners

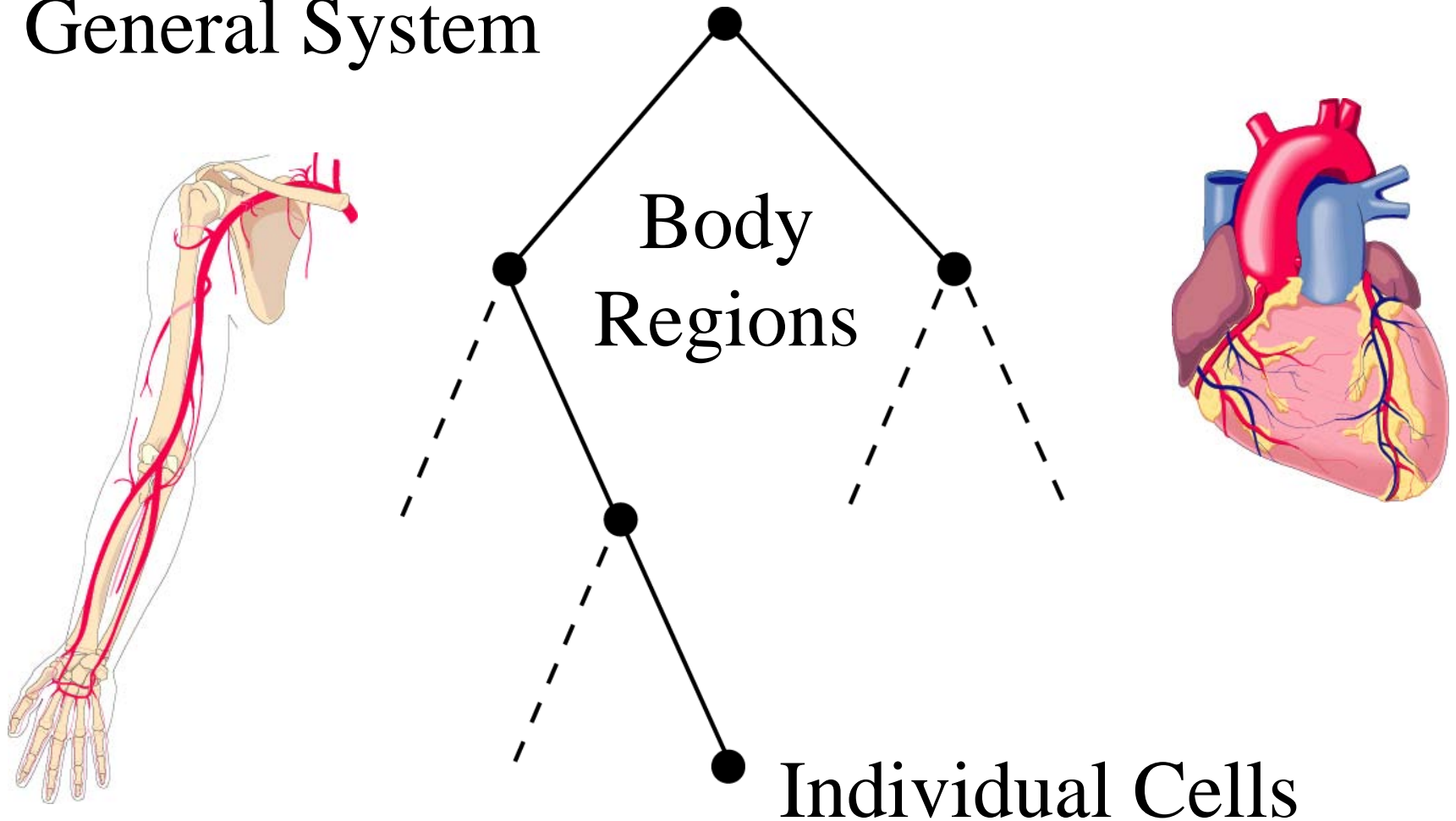


Young & Salmela, 2010



# The Challenge of Inducing Specific Overload in Highly Trained Athletes:

General System



# Deliberate Practice at the Elite Levels?



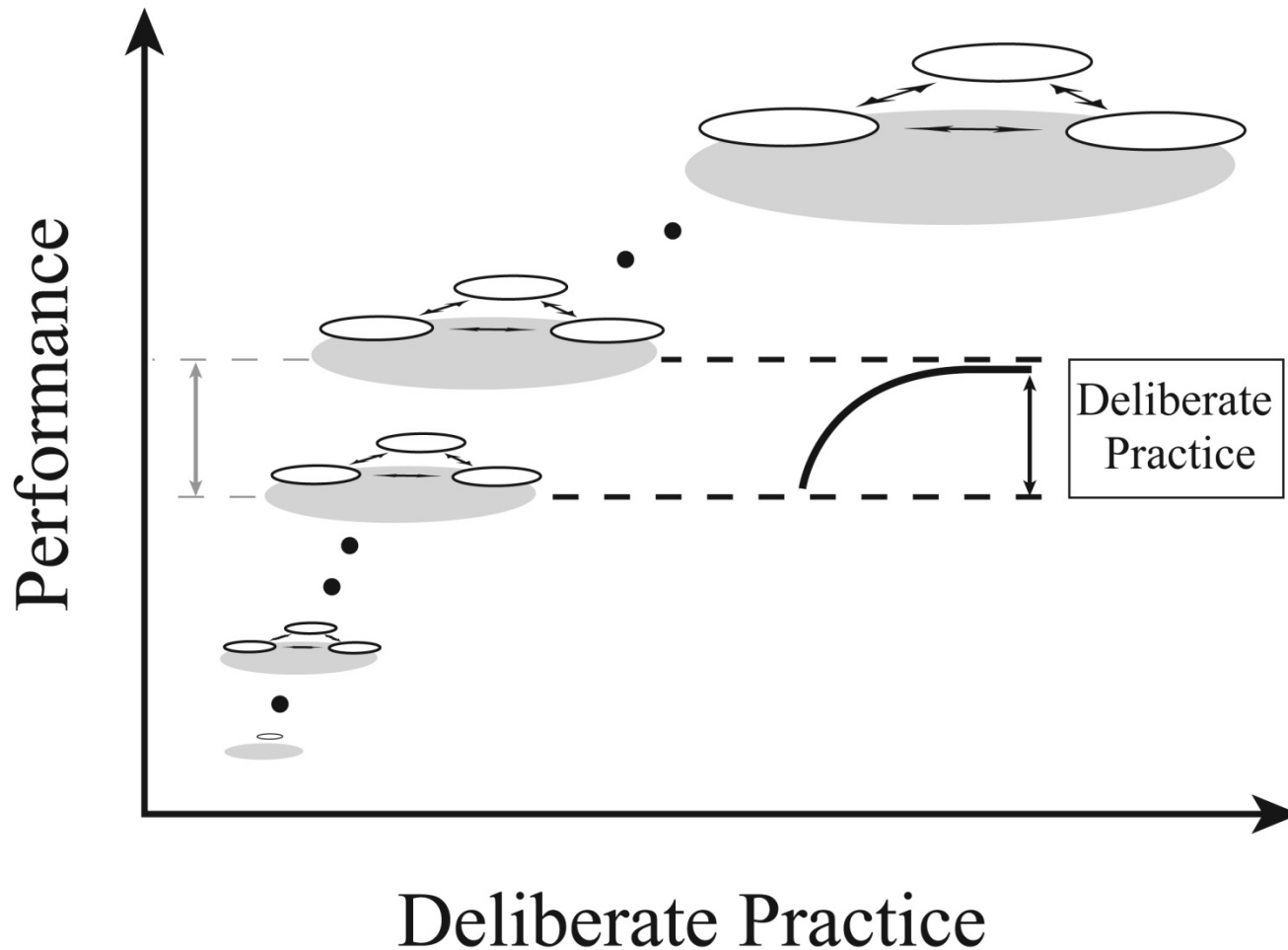
## **Experimental and Control Groups of Elite Junior Soccer Players**

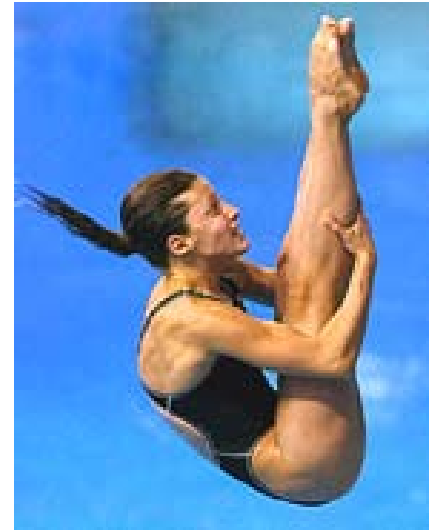
*Interval training  
four times with  
4 min at 90-95%  
twice a week  
for 8 weeks*

- **VO2 max**
- **running economy**
- **involvement with ball during matches**

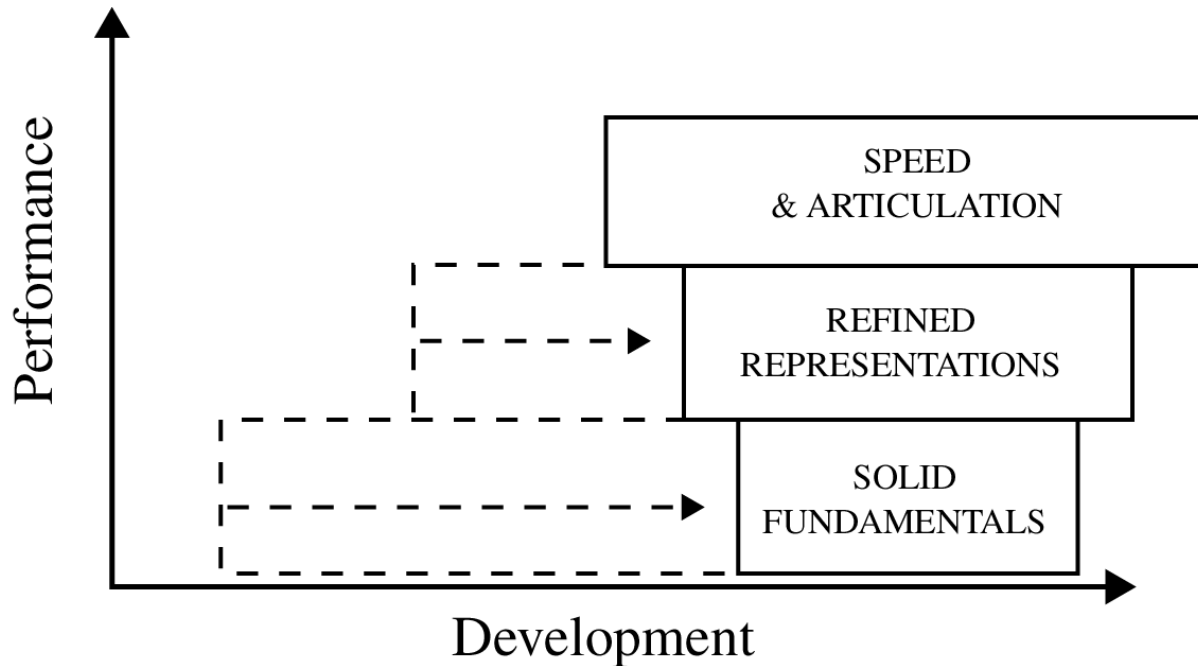
(J. Helgerud, L. C., Engen, U. Wisloff, J. Hoff, Aerobic endurance training improves soccer performance, *Medicine & Science in Sport & Exercise*, 33, 1925-1931, 2001)

# IV. From Incremental Changes to *Development* of Integrated Performance



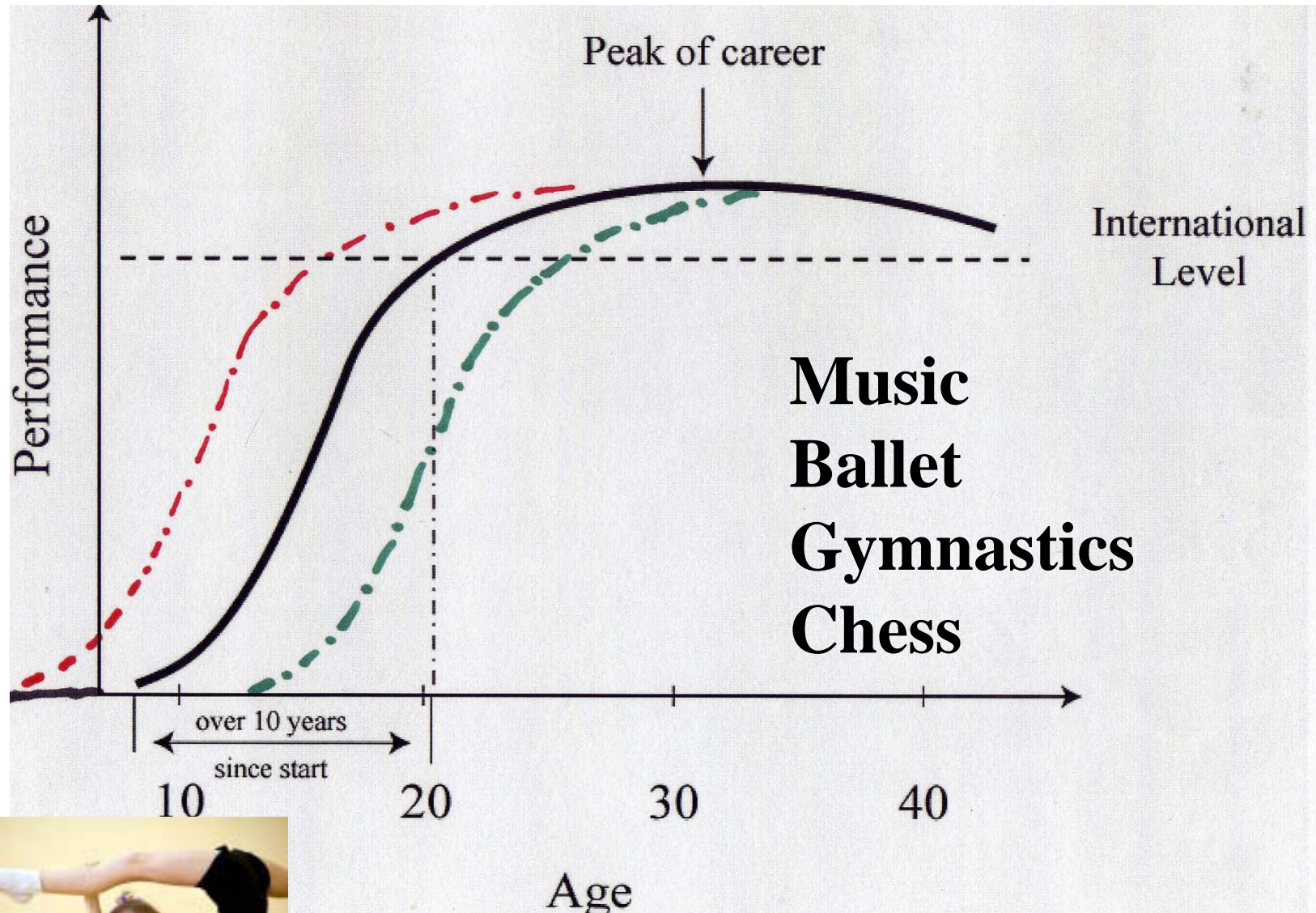


## Prerequisites for Future Elite Performance Hierarchical Building Blocks

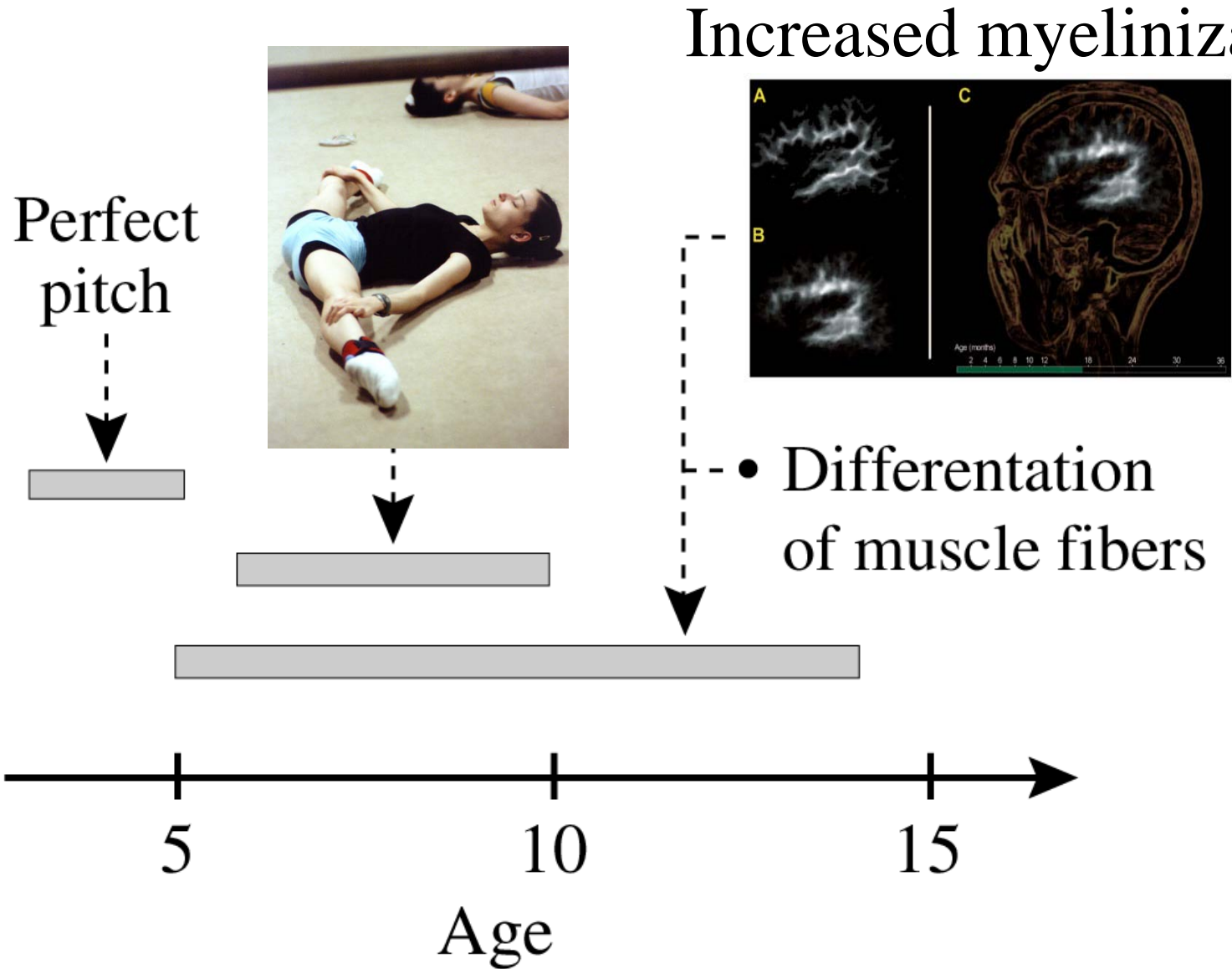




# Other Effects: Starting and Peak Ages

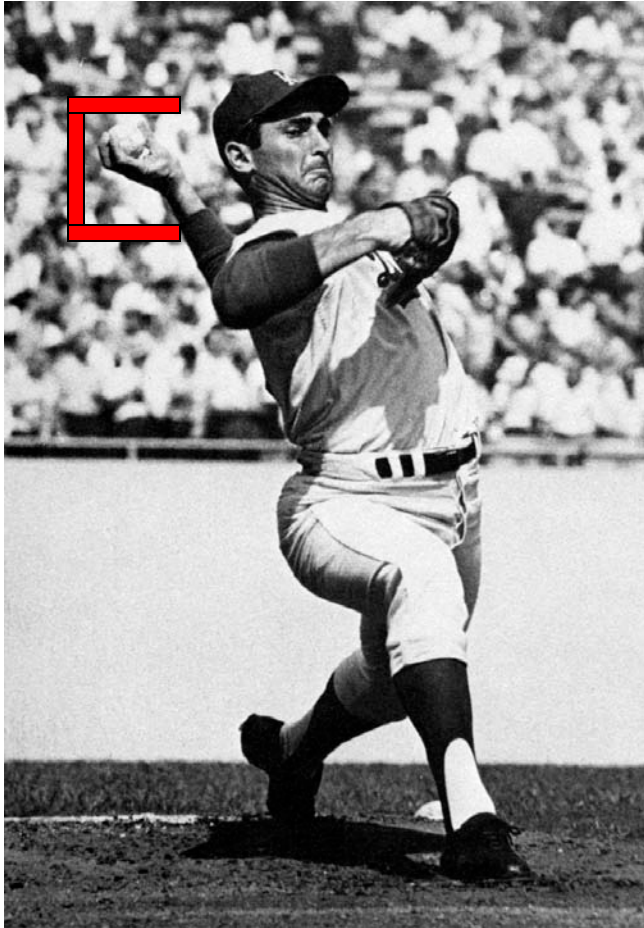


# Modifying the Course of Development





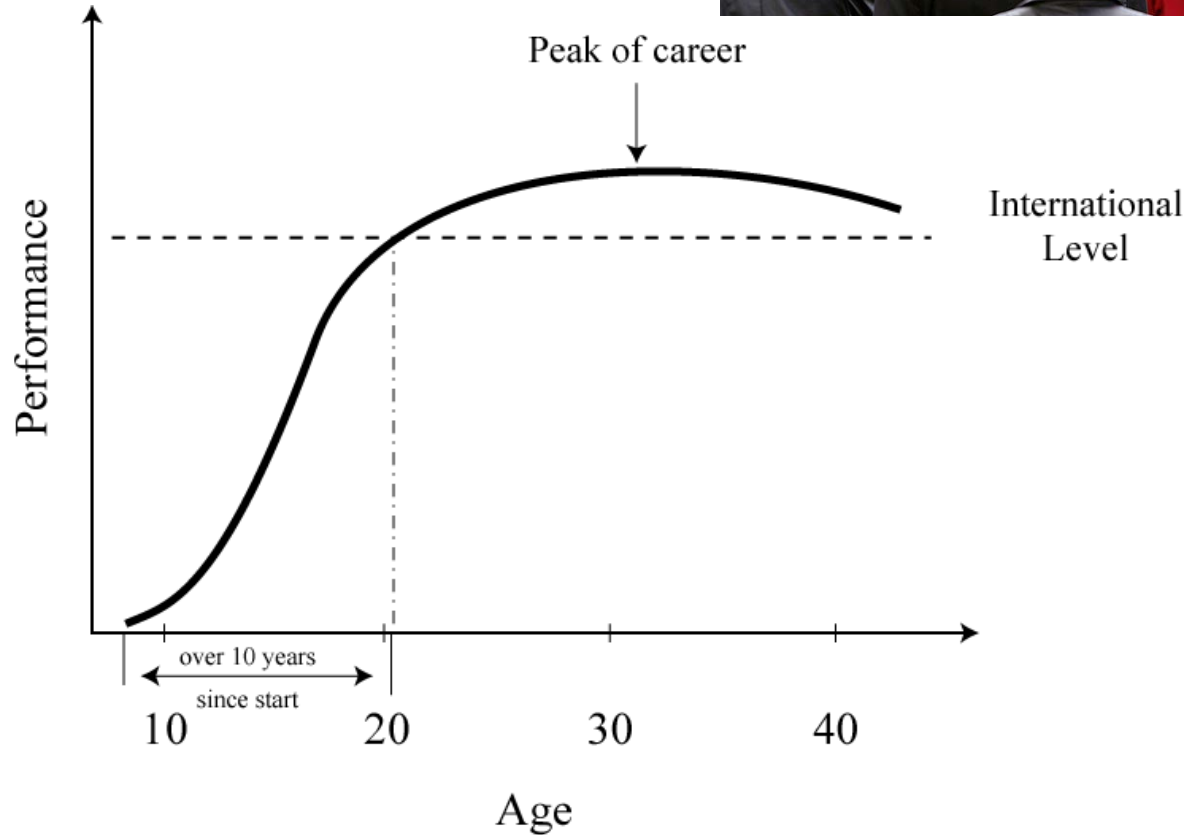
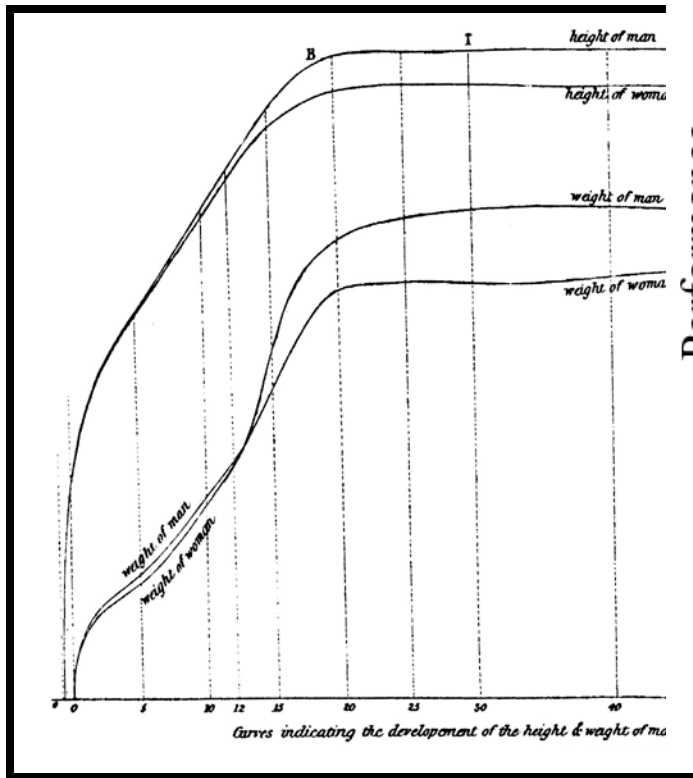
# Developmental Interactions and Windows



Can **anyone** attain  
this type of  
shoulder  
flexibility?

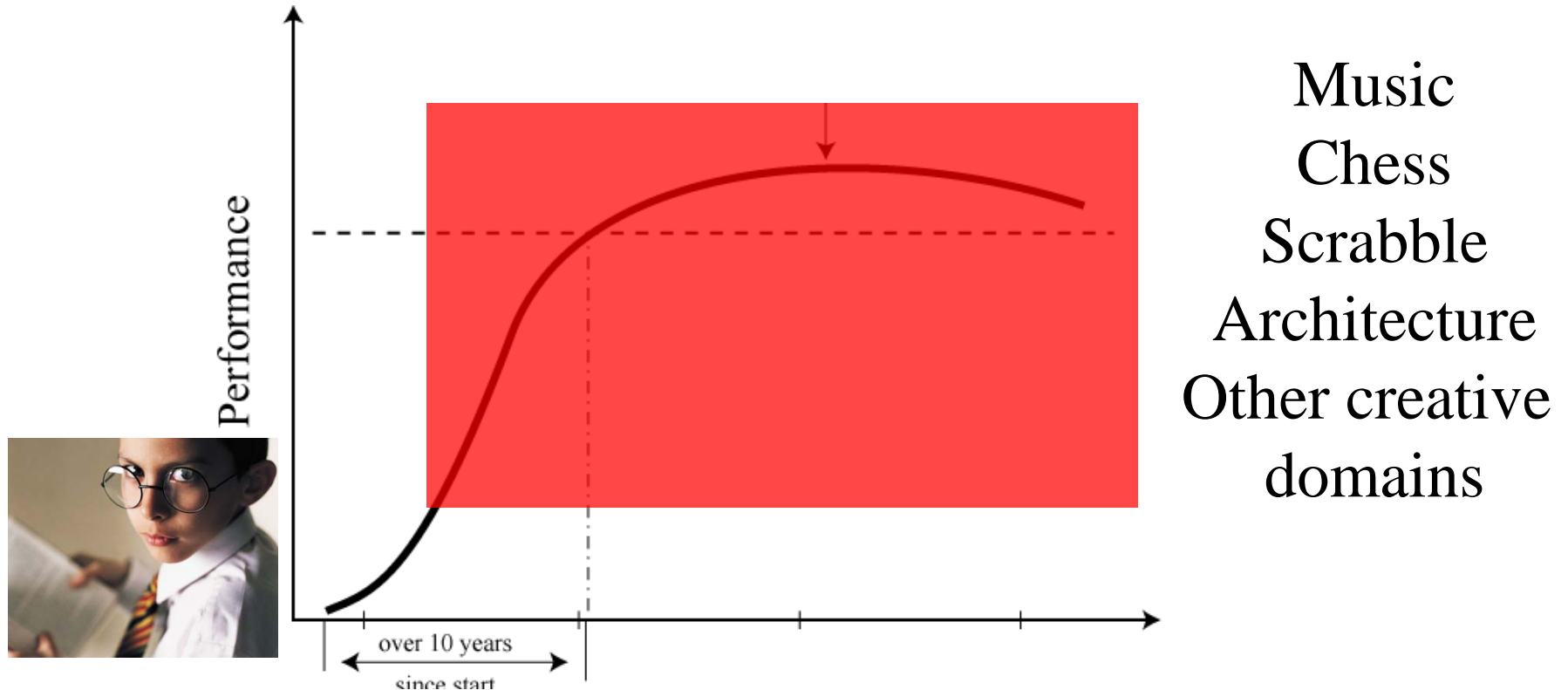
*Shoulder Joints of Expert Pitchers and Handball Players*

# The Development of Height and Performance



Quetelet (1842 / 1969)

# Declining Influence of Cognitive Abilities and IQ: The Constructed Nature of Expert Performance



## VII. Concluding remarks

Focus on mastery of a single domain

Long-term plan to reach mastery

Sequential plan with goals and deliberate practice

Optimizing training duration and frequency  
sleep and rest

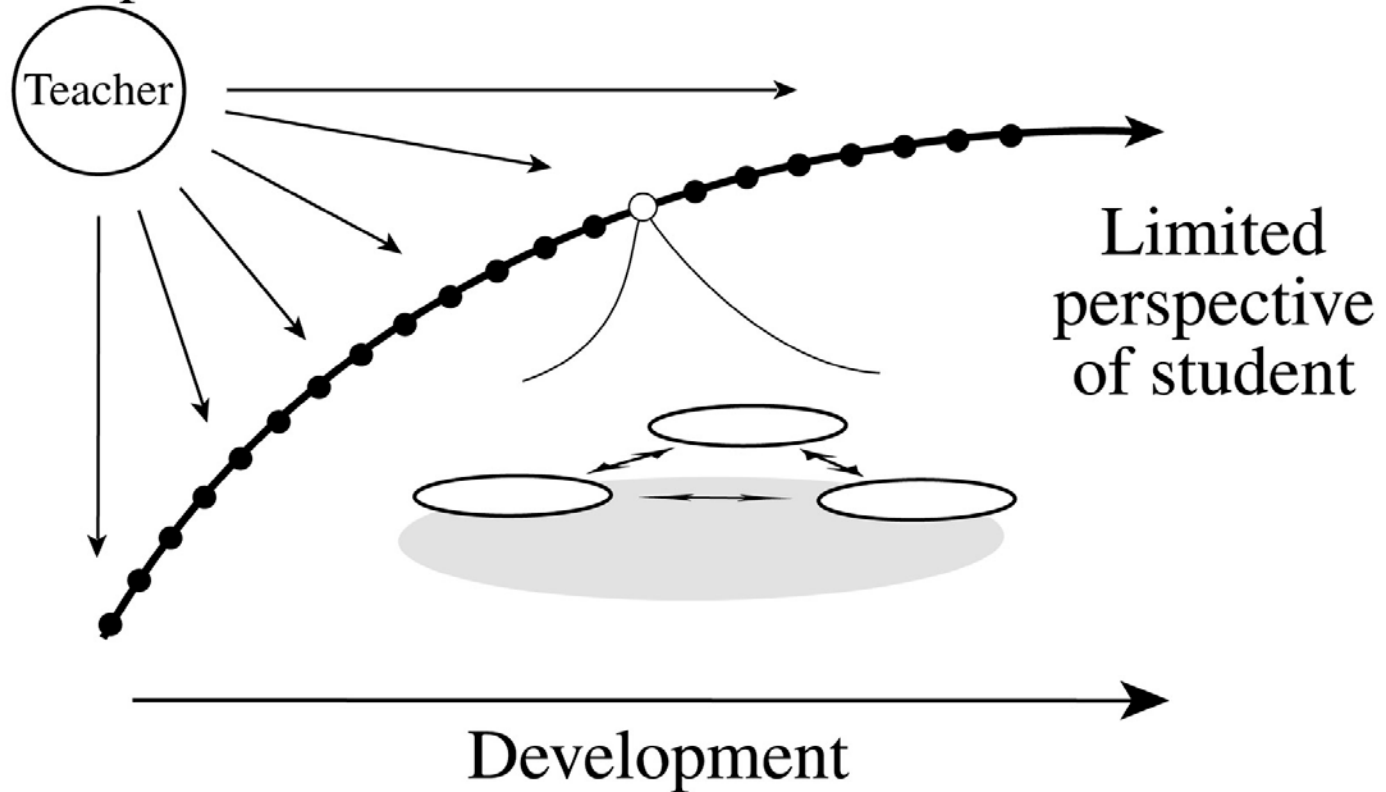
Relative age effects and placebo effects

# Going Beyond One's Current Ability

Guidance

Feedback

Anticipation of future demands



# Deliberate Practice



Task  
difficulty



Too  
easy



Optimal

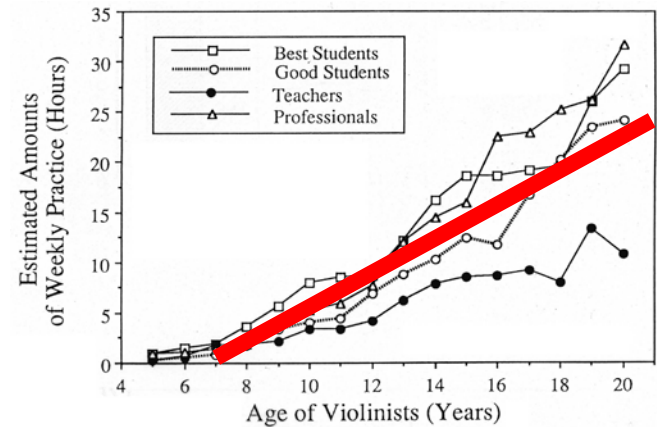
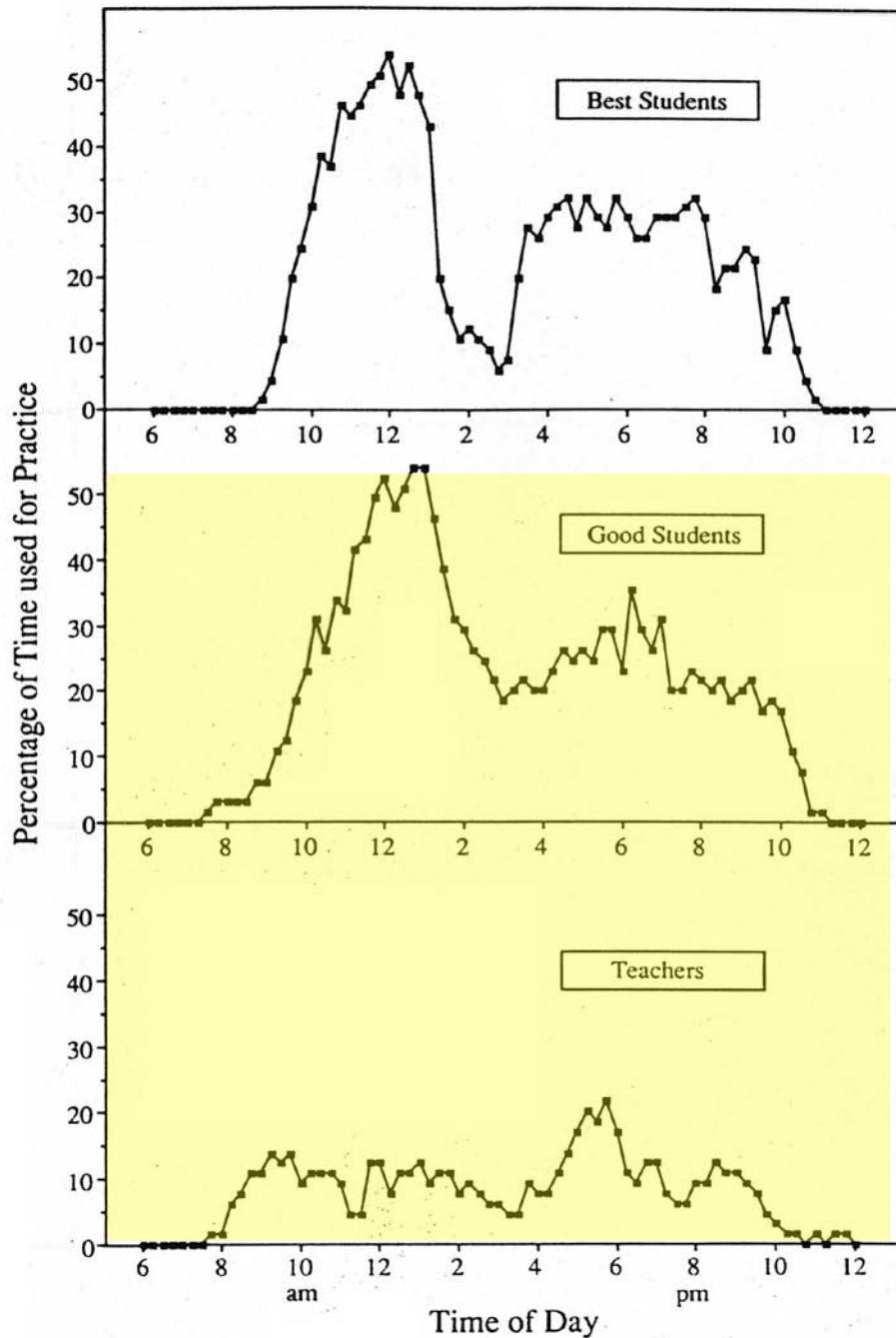
Too  
difficult



Self-monitoring  
Problem solving

4-5 Hour Limit of full concentration

# Percentage of Time that They Engaged in *Deliberate Practice*





# Does Perceived Talent matter?

## Birthdays of the Best 16 Soccer Players (14-Year Olds)

Selected by the **English Football Association** to  
their **School of Excellence**

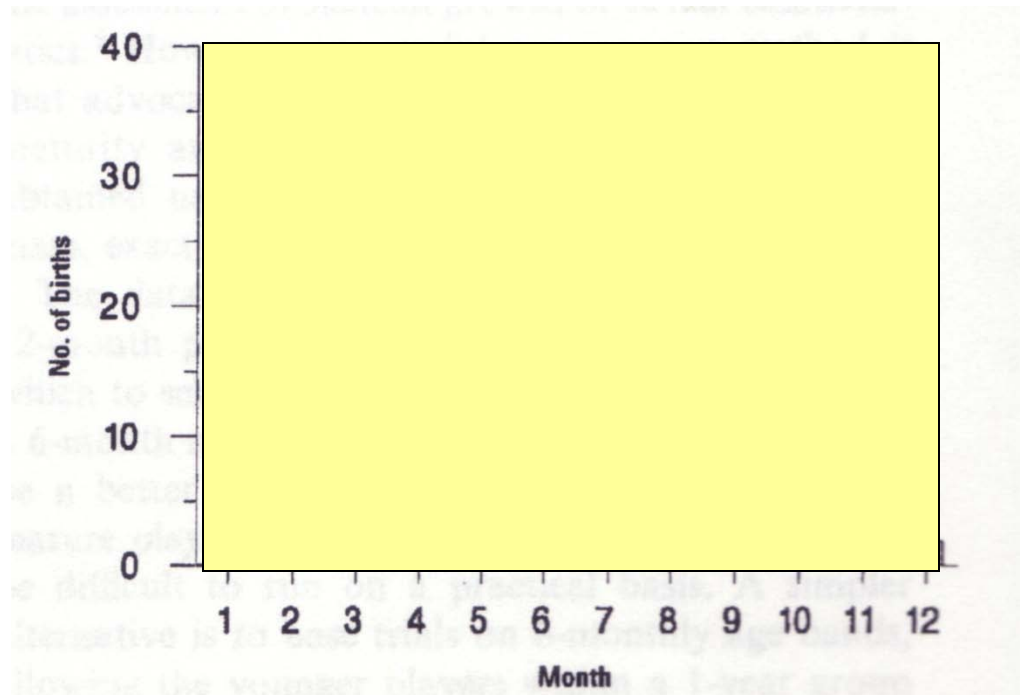


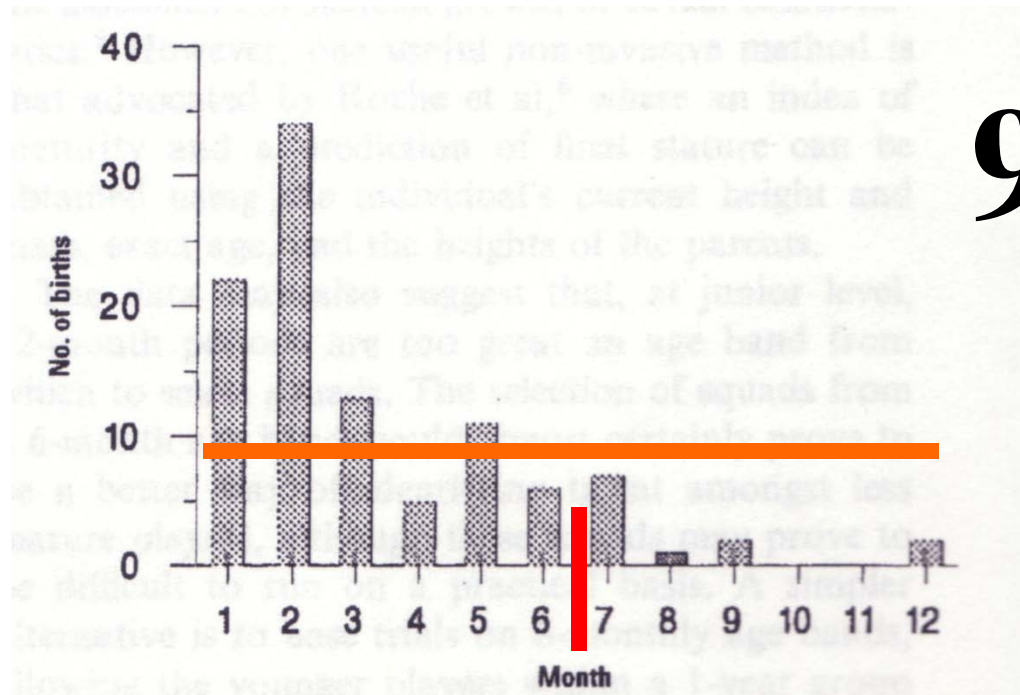
Fig. 3—FA School of Excellence birth dates.

(Brewer, Balsom, & Davis, Seasonal birth distribution amongst European soccer players, Sports Exercise and Injury, 1995, 1, 154-157.)

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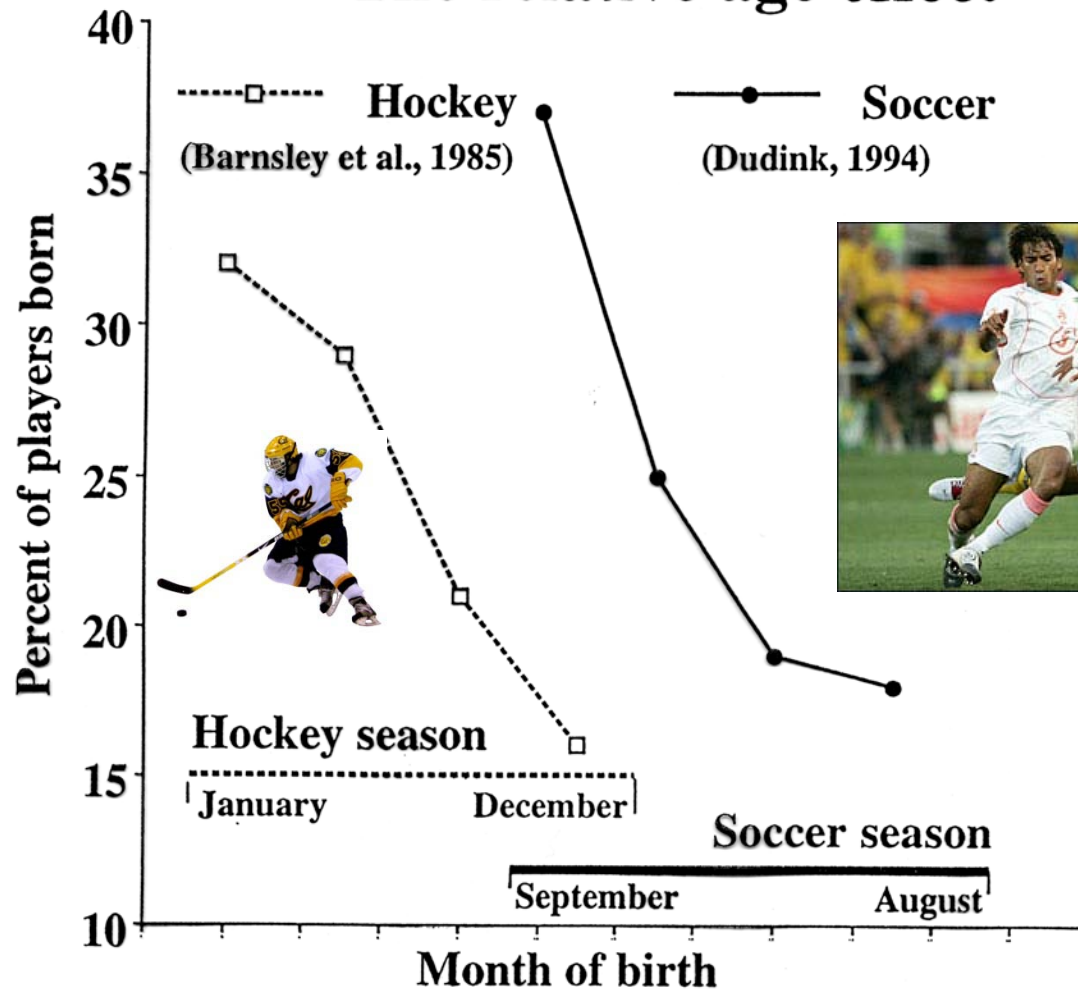


9:1

Fig. 3—FA School of Excellence birth dates.

(Brewer, Balsom, & Davis, Seasonal birth distribution amongst European soccer players, Sports Exercise and Injury, 1995, 1, 154-157.)

# Stability of individual differences: The relative age effect

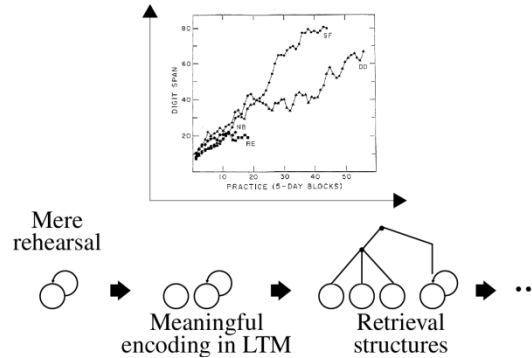


# Placebo effects for sub-elite athletes (Beedie & Foad, 2009)



# How Should We Think of *Limits* for Complex Systems?

What is the maximal digit span?



What is the fastest marathon?

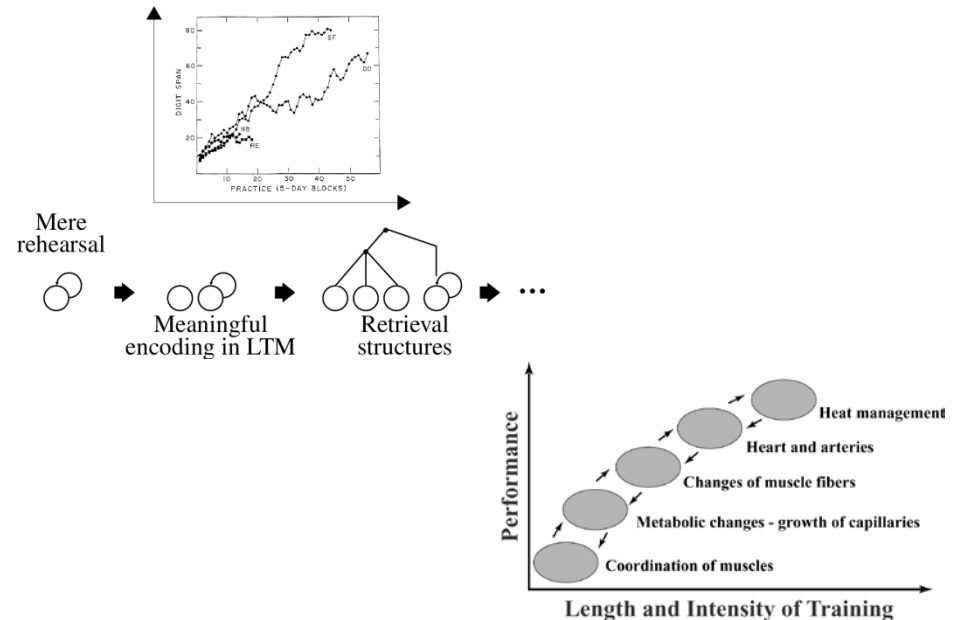
How big can a city be?

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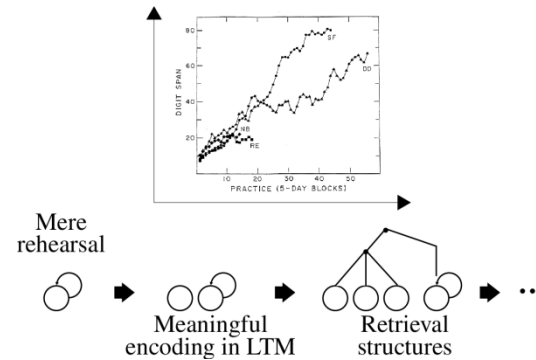
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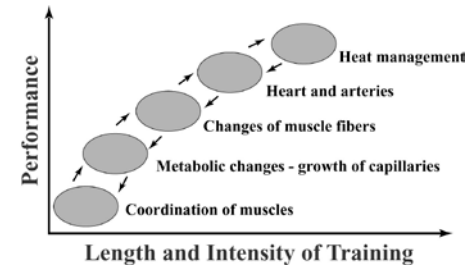


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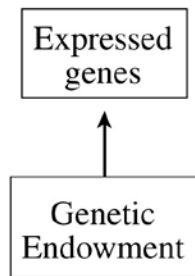
Pompeii 79 AD



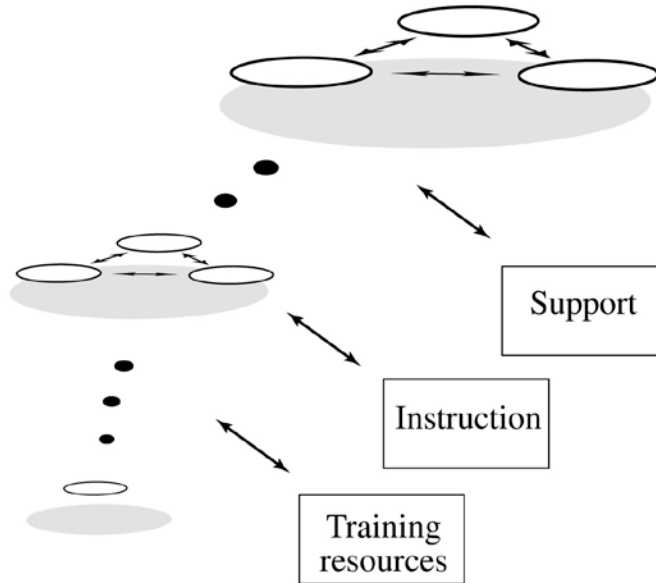
*The changing nature of constraints*



# The Complex Process of Acquisition of Expert Performance



**Nature**



**Nurture**

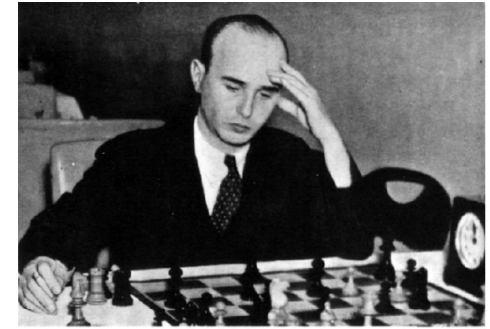
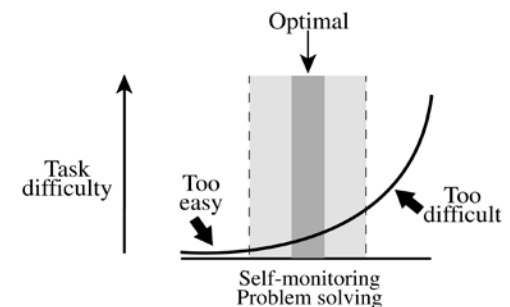


Photo  
SAMUEL RESEVSKY  
U.S. champion, in a characteristic pose



## The Challenge of Deliberate Practice



4-5 Hour Limit of full concentration











# A Hypothetical Map of the Steps of Development toward Expert Performance

