University of Suffolk – Open Lecture Series

Digital Archaeoludology:
AI for Ancient Games

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Game AI & Search (DKE)
Maastricht University

4/3/2020
Ipswich, UK

Maastricht University

Outline

Background
- Evidence of Ancient Games

Digital Ludeme Project
- Ludemes
- Measuring Games
- Mapping Games

Games are Ubiquitous

All humans play games
All human cultures have their particular games

Games can shed insight into the cultures in which they're played

Don't know much about *how* most ancient games were actually played

Evidence of Games

Evidence of ancient board games:
- Over 5,000 years
- Beginning of recorded history

Possibly older?
- Some neolithic finds "new stone age"
- Not clearly games

Israel c.7000BC
Part of a game board? Probably not

Jordan 8–7000BC
Mancala on grinding stone? Probably not

Oldest Known Board Games

Ancient Egypt

Mehen (c.3100BC)
- Pieces found
- No rules

Senet (c.3000BC)
- Hundreds of sets found, many complete
- No rules

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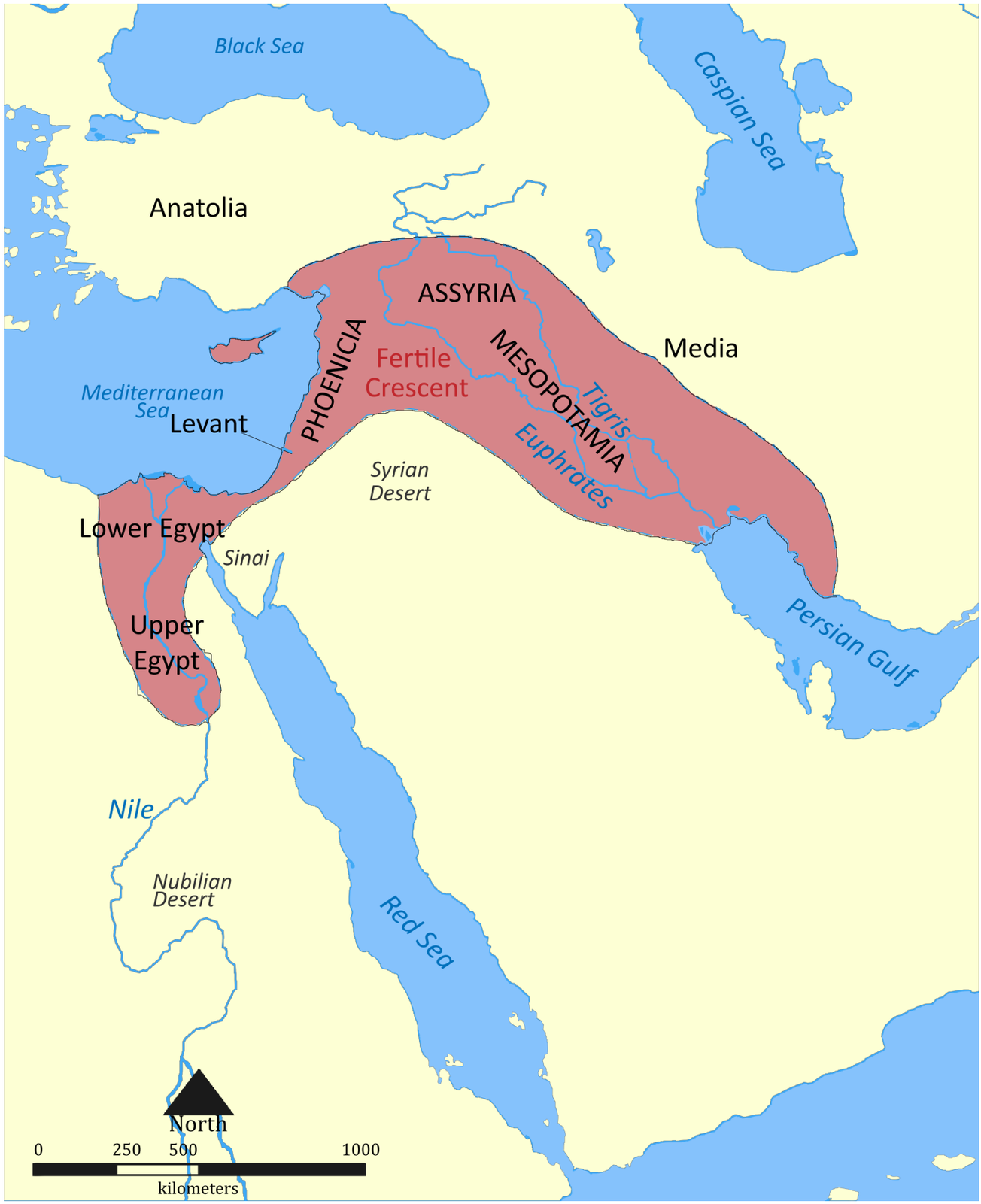
Fertile Crescent

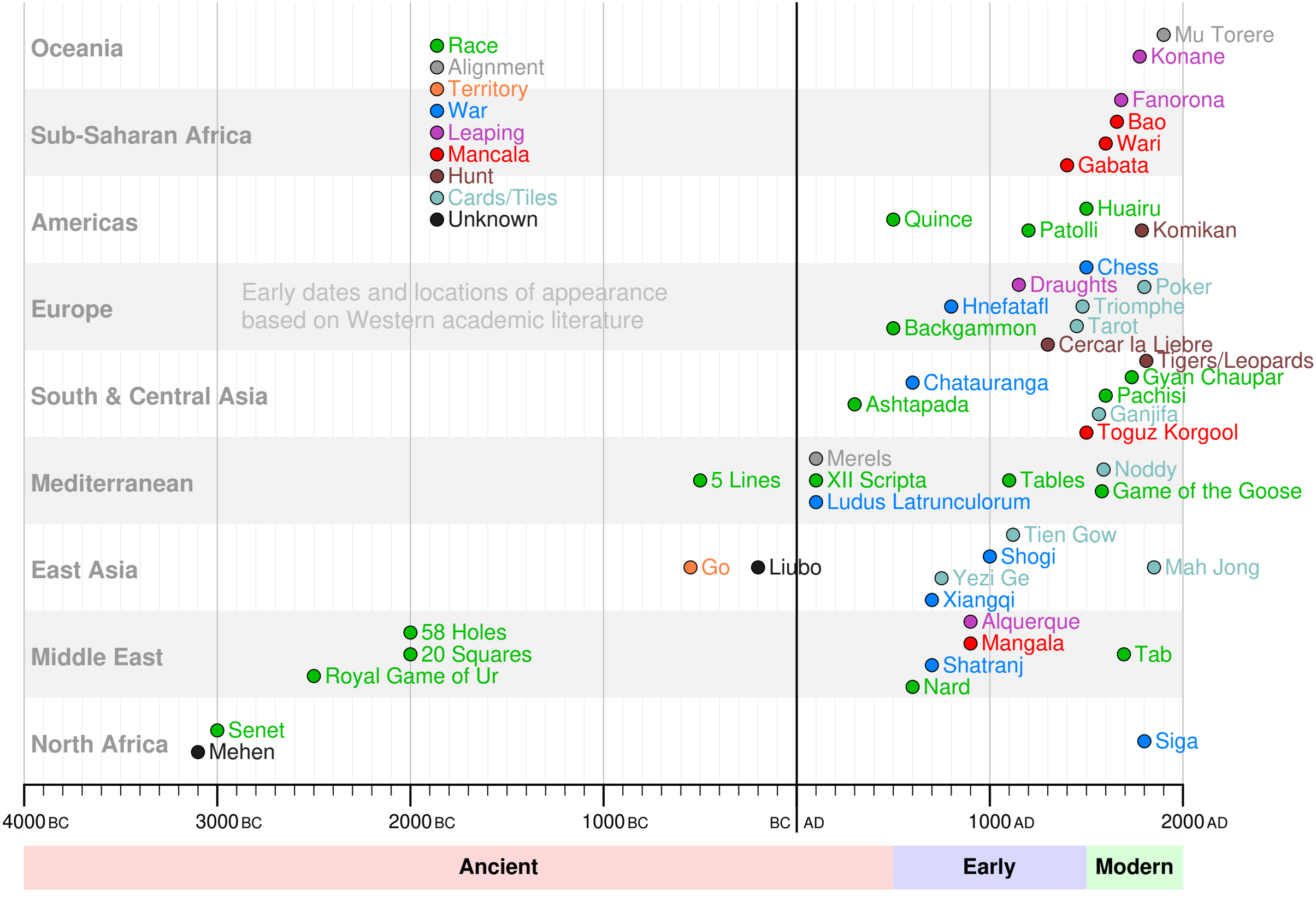
"Cradle of Civilisation"
- Key birthplace of games

Games from:
- Egypt
- Mesopotamia

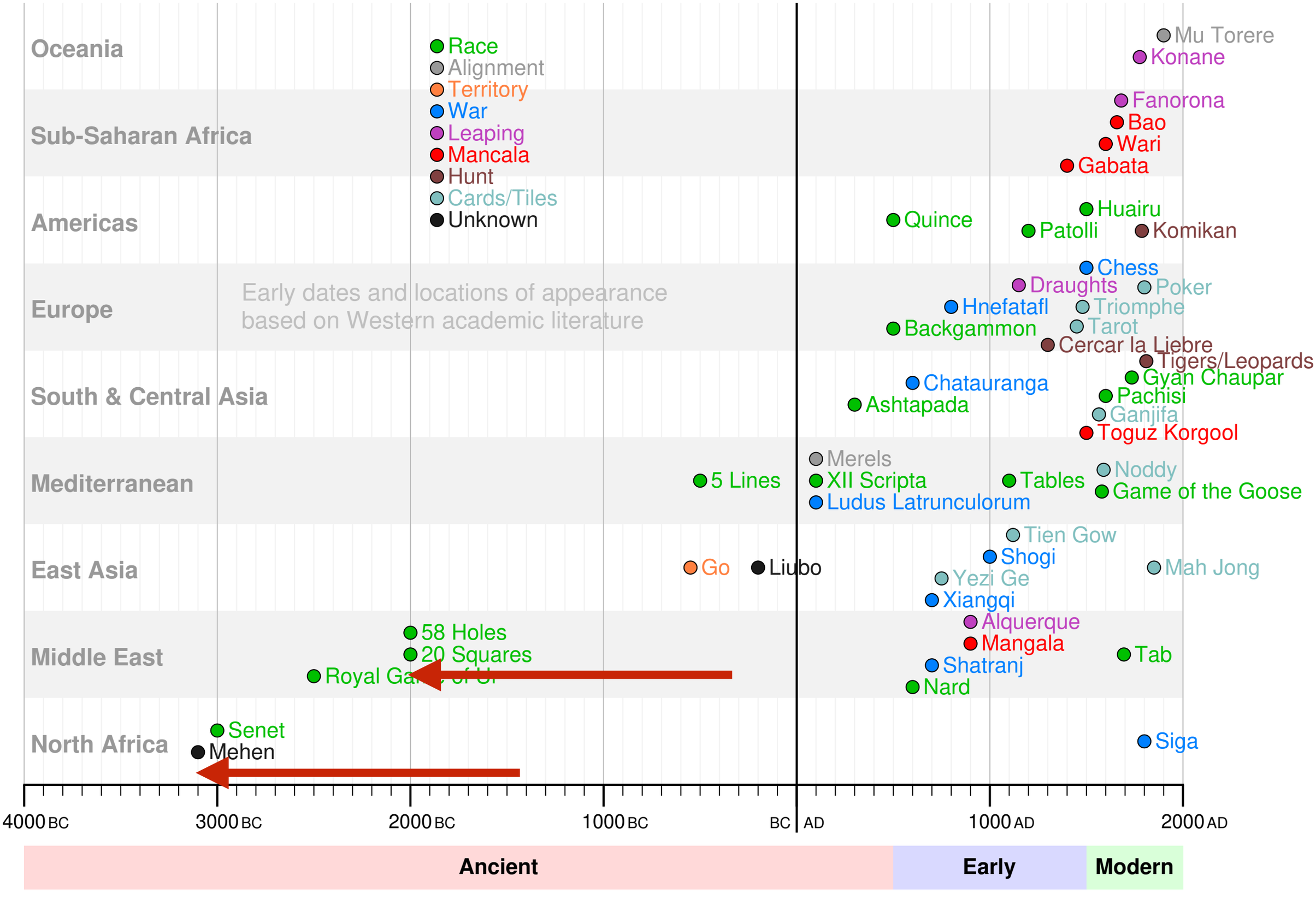
Routes of transmission:
- Along Levant to Cyprus, Mediterranean and Europe
- Trade routes to Middle East and Asia



Timeline


Oceania
Sub-Saharan Africa
Americas
Europe
South & Central Asia
Mediterranean
East Asia
Middle East
North Africa
Race
Alignment
Territory
War
Leaping
Mancala
Hunt
Cards/Tiles
Unknown
Early dates and locations of appearance
based on Western academic literature
Mu Torere
Konane
Fanorona
Bao
Wari
Gabata
Huairu
Quince
Patolli
Komikan
Chess
Draughts
Poker
Hnefatafl
Triomphe
Backgammon
Tarot
Cercar la Liebre
Tigers/Leopards
Gyan Chaupar
Chatauranga
Pachisi
Ashtapada
Ganjifa
Toguz Korgool
Merels
5 Lines
XII Scripta
Tables
Noddy
Game of the Goose
Ludus Latrunculorum
Tien Gow
Shogi
Go
Liubo
Mah Jong
Yezi Ge
Xiangqi
Alquerque
58 Holes
Mangala
20 Squares
Tab
Royal Game of Ur
Shatranj
Nard
Senet
Siga
Mehen
4000 BC
3000 BC
2000 BC
1000 BC
BC
AD
1000 AD
2000 AD
Ancient
Early
Modern

Timeline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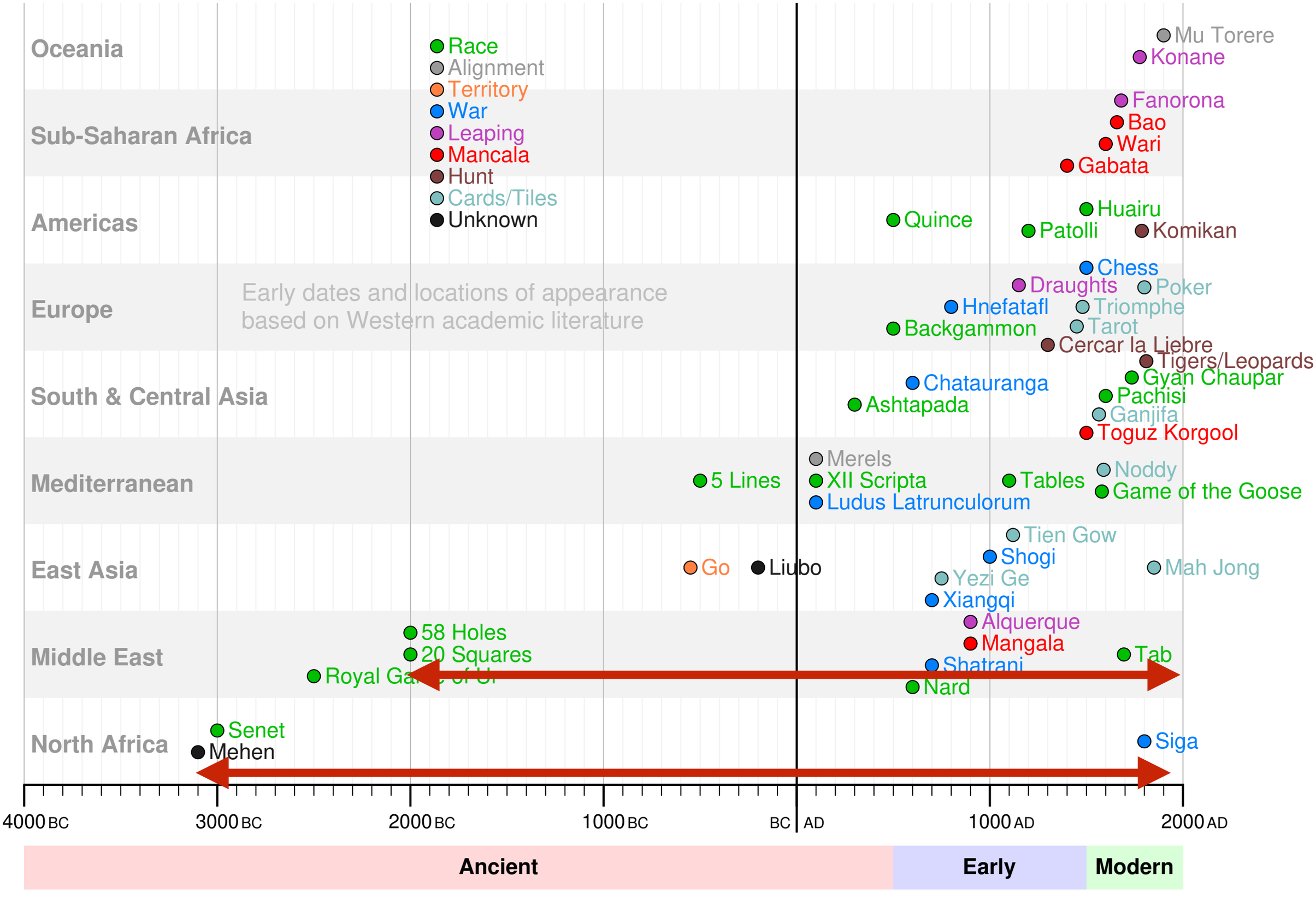
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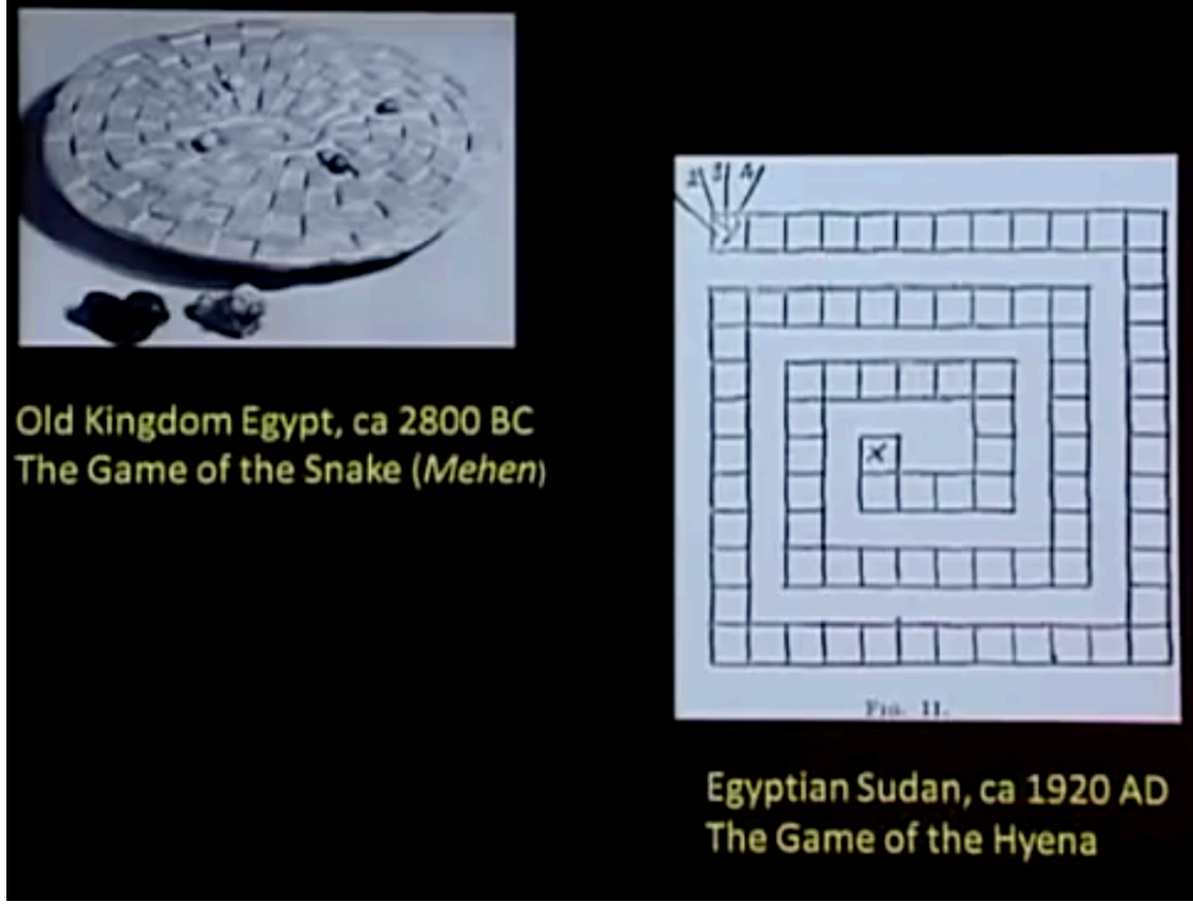
Longevity

Mehen

- Played in Egypt c.3,100BC
- Still played in 1920?
- 5,000 year lineage

20 Squares

- Played in Mesopotamia c.2,000BC
- Still played in 1990s (Cochin, India)
- 4,000 year lineage

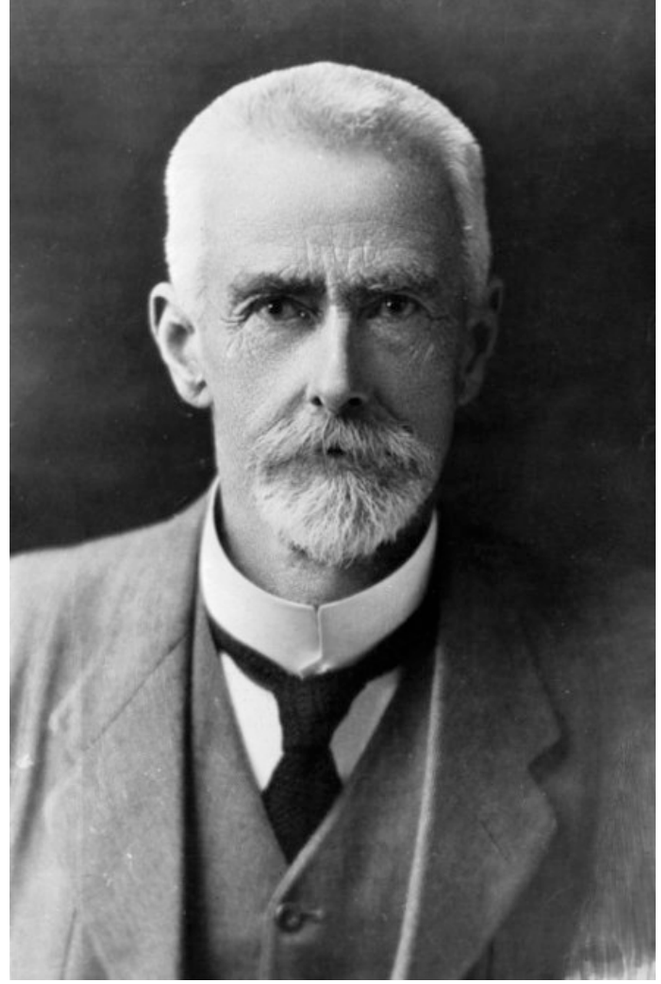


Finkel “Games of the Ancient World” (2016)

Permanence of Games

Some games have lasted longer than:
- Any human civilisation
- Any modern religion

"Nothing is more persistent than the games of a people.
– Best, *Games and Pastimes of the Maori* (1925)



Elsdon Best
Ethnologist
(1856–1931)

Why?

Games are Mathematical

Games are mathematical entities:
- Embody mathematical constants/truths

Playing surface:
- Tiling
- Graph of adjacencies

Movement rules:
- Geometry
- Arithmetic
- Logic

Cultural Artefacts

Games are unusual cultural artefacts

Other cultural facets:
- Language, music, cooking, etc.
- Can’t reliably compare with 5,000 years ago

But with games we can:
- “move forwards 3 spaces”, “hop over enemy piece”, …
- Same now as 5,000 years ago

Rule sets change over time, the rules themselves do not

If we know the rules, we know the game!

Problem: We almost never know the rules for ancient games

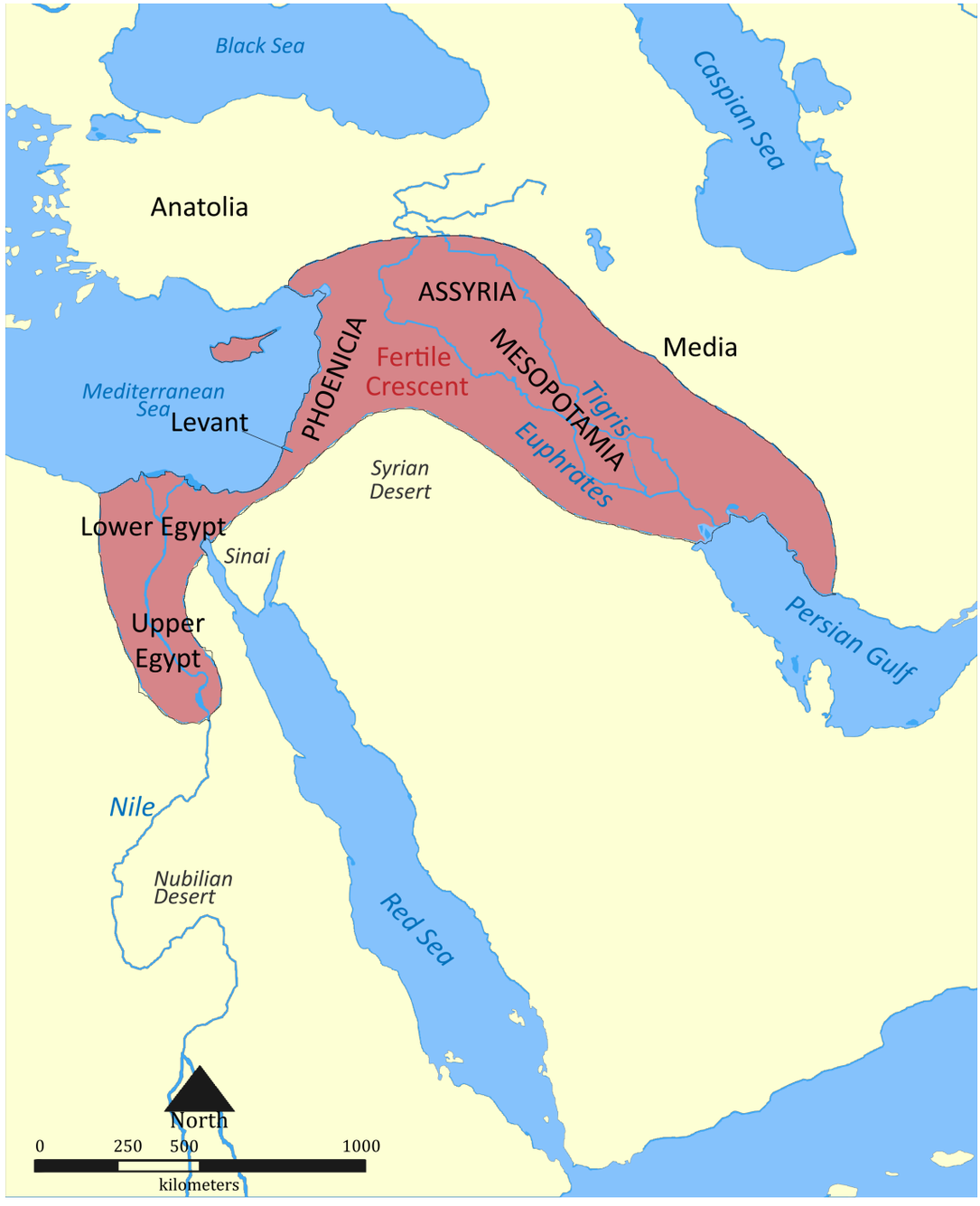
Lack of Record

Fertile Crescent:
- An original source of writing
- World's first libraries (c.2,500BC)

Writing was a rare skill:
- Only important events recorded
- Games not important enough to document

Games passed on by oral tradition:
- Taught one-to-one

Good: Huge variation we see today
Bad: No records of ancient rule sets



Senet

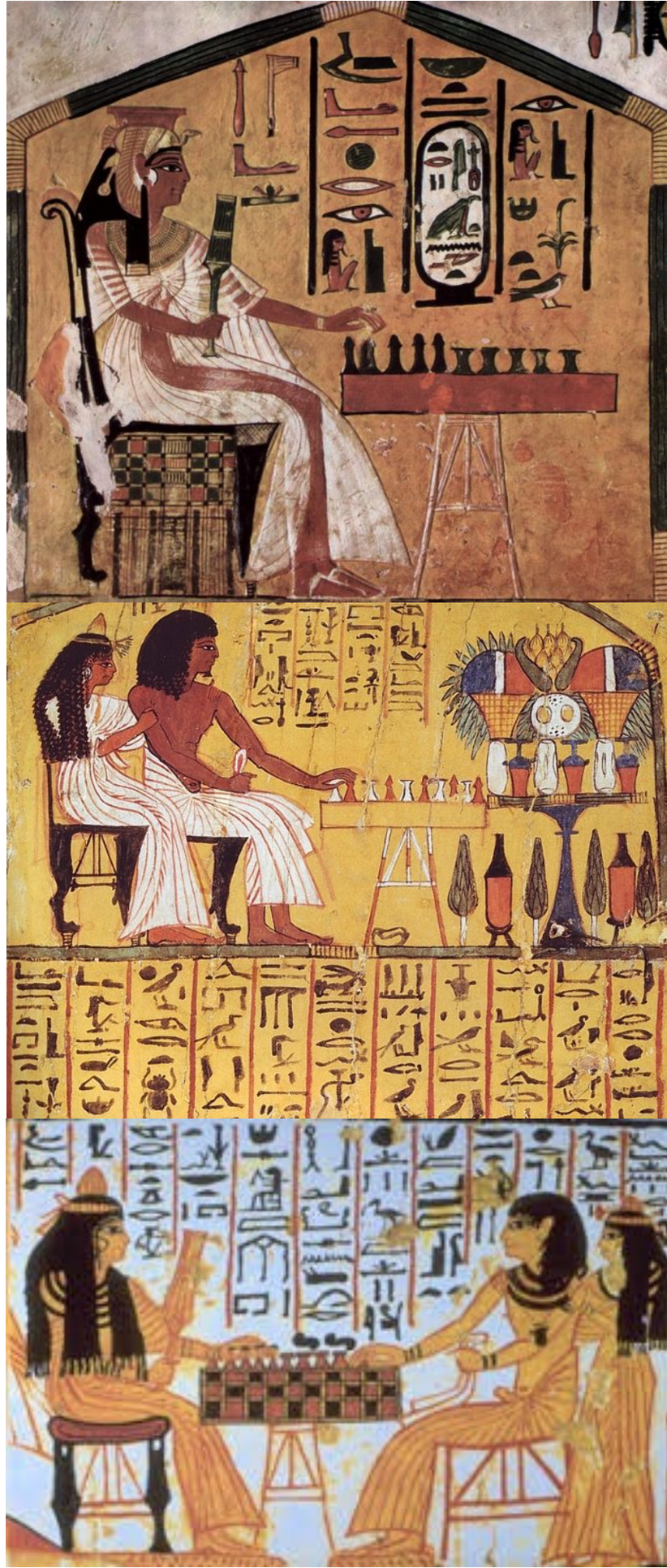
Egypt (c.3000BC)

No original rule sets found

What we know:

- From Egyptian art:
  - Two players
  - Some starting positions

- From evidence:
  - Two piece types
  - 3x10 board

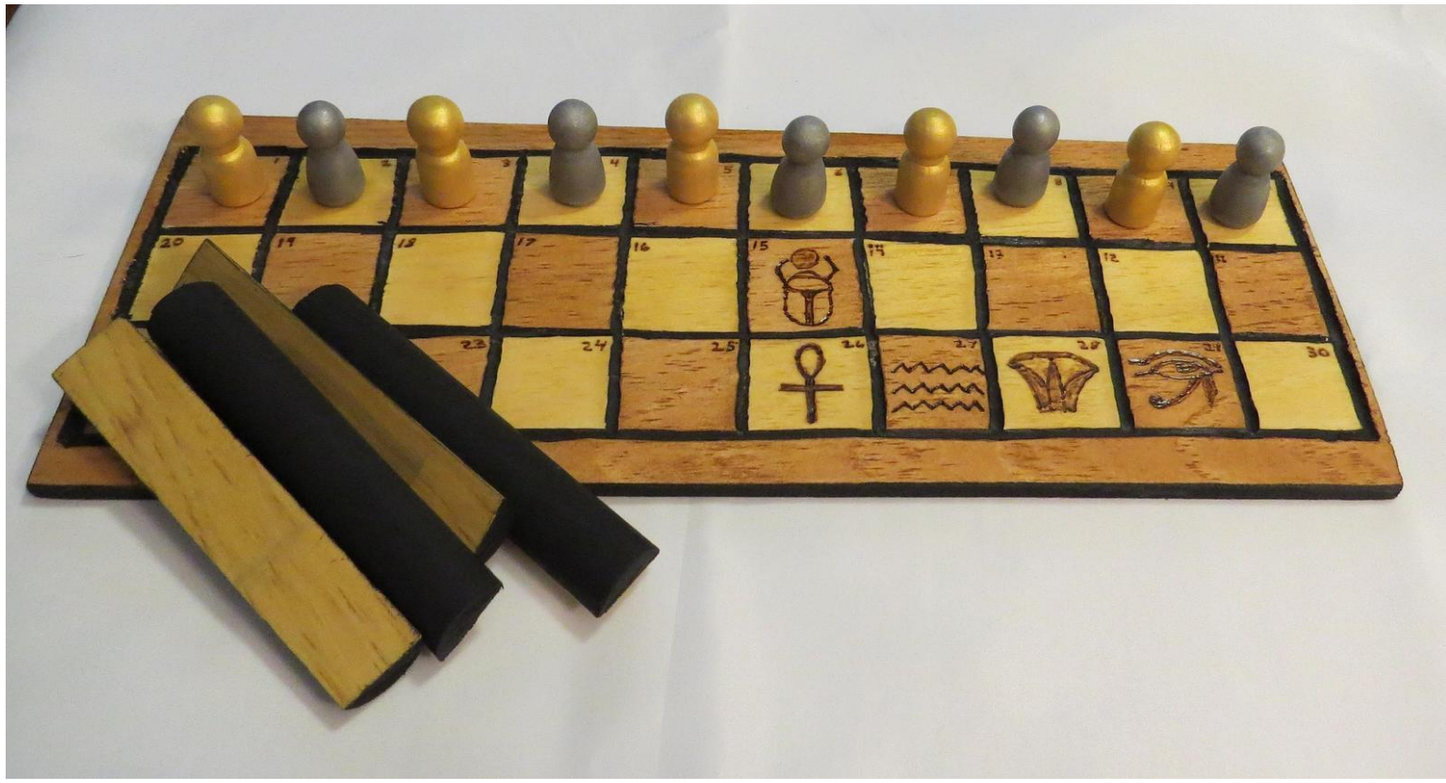


Senet

Any two boards will probably be different

Special symbols:

- 15th cell
  - Entry point?
  - Exit point?
- Ankh (life)
  - Regeneration point?
- Water
  - River to afterlife



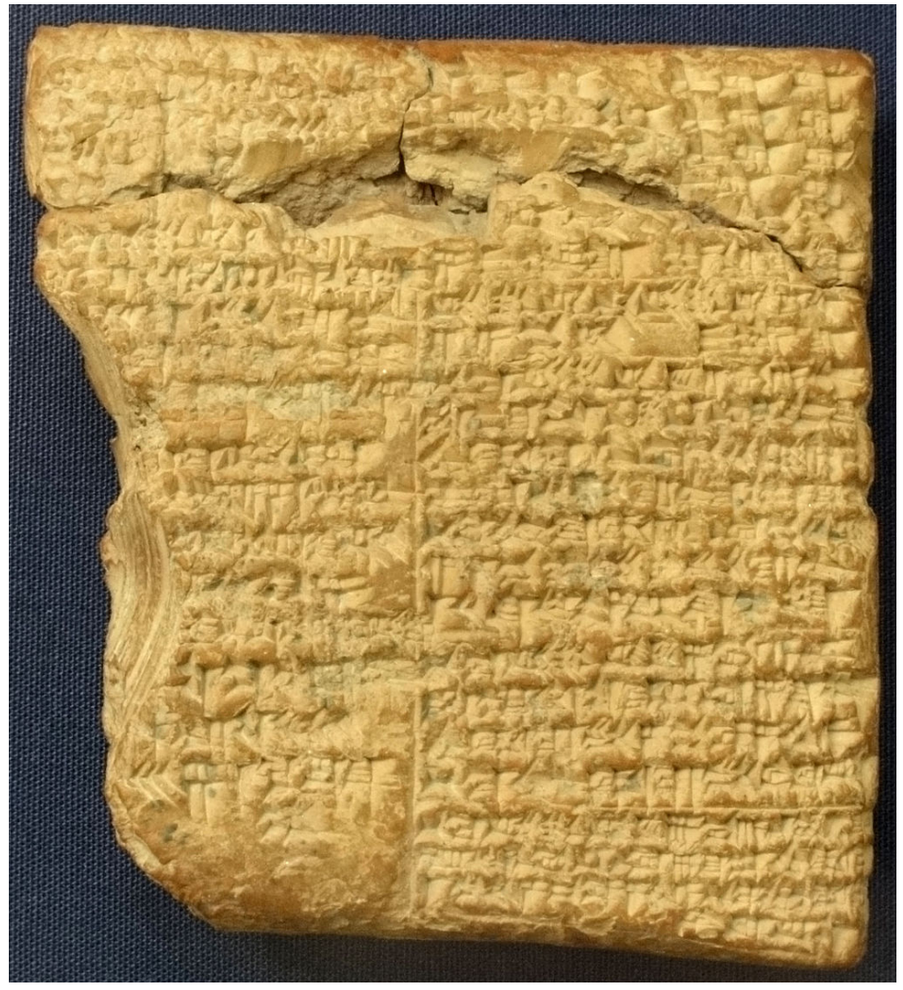
About a dozen plausible reconstructions

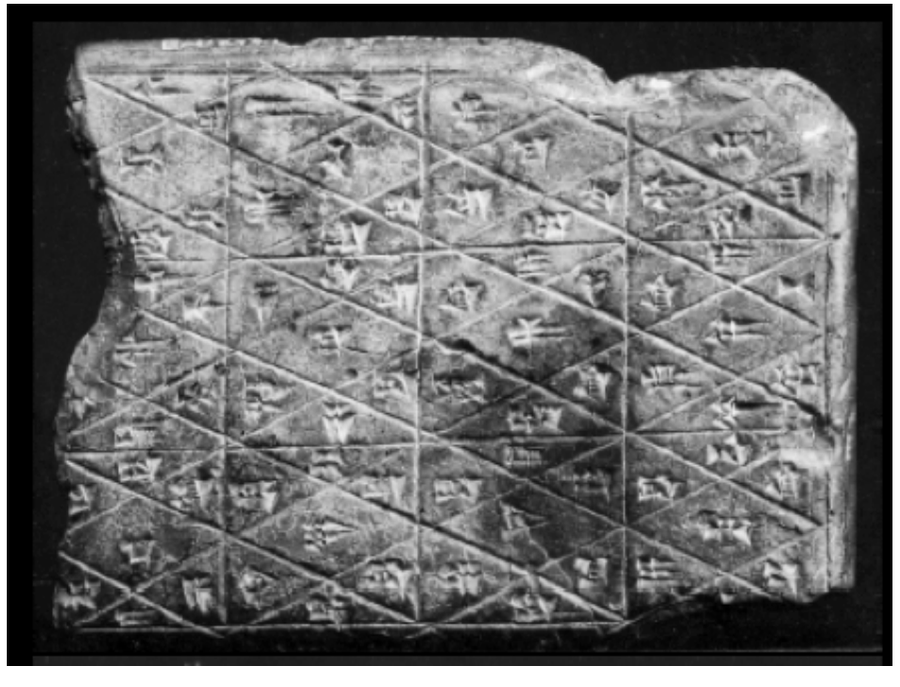
First Known Rules

Sumerian cuneiform tablets
- Mesopotamia, 177BC

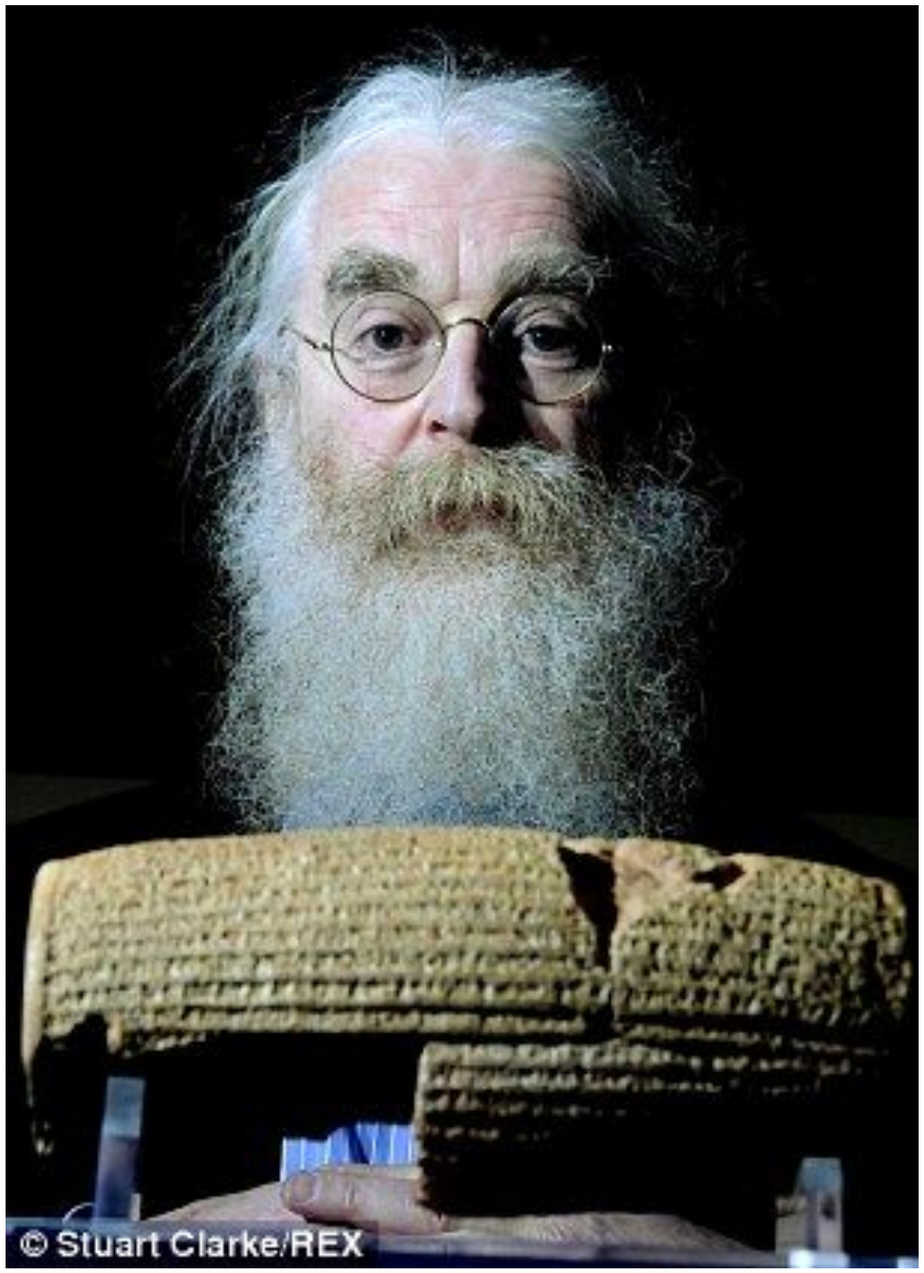
British Museum (top)
- One of 130,000

Parisian Studio (bottom)
- Destroyed 1940s
- Photo survived

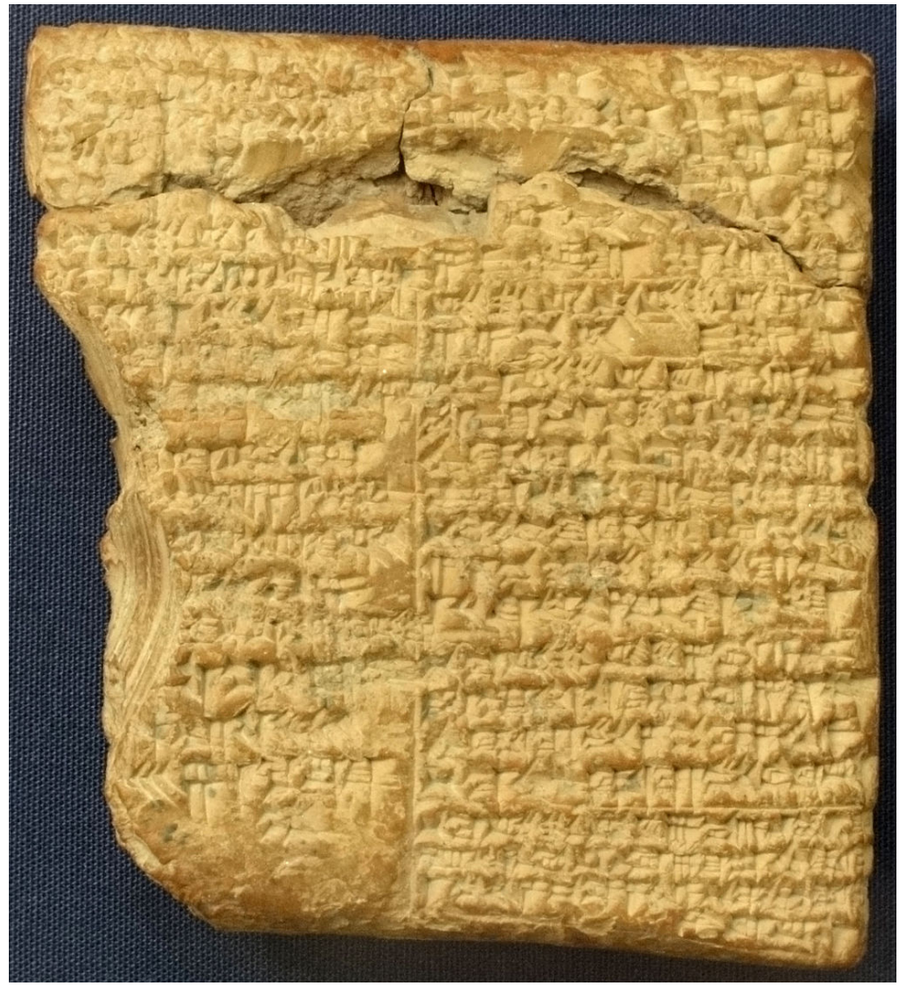


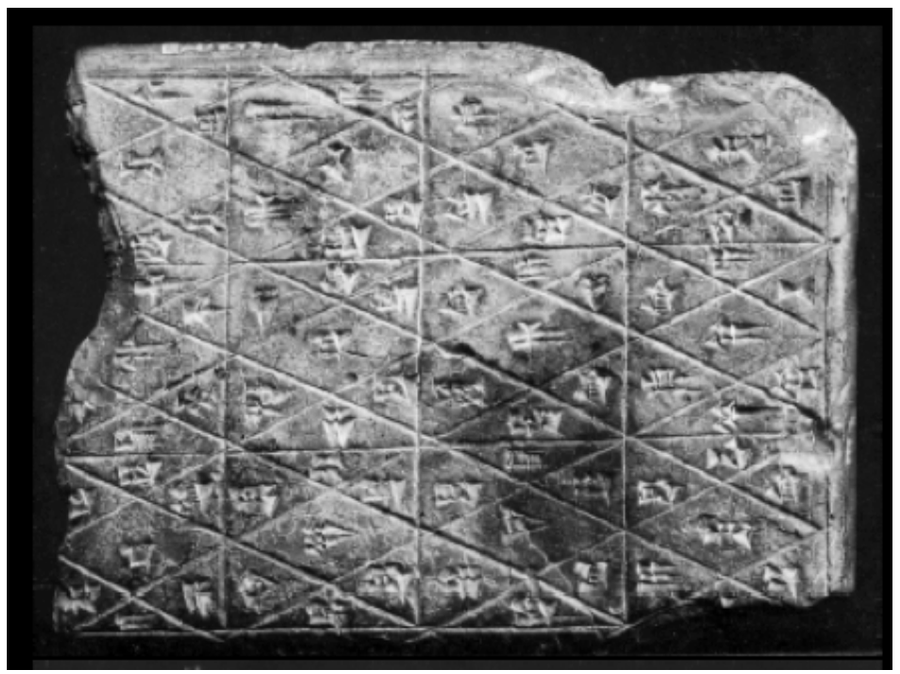


First Known Rules



Irving Finkel (1990)
Curator, British Museum

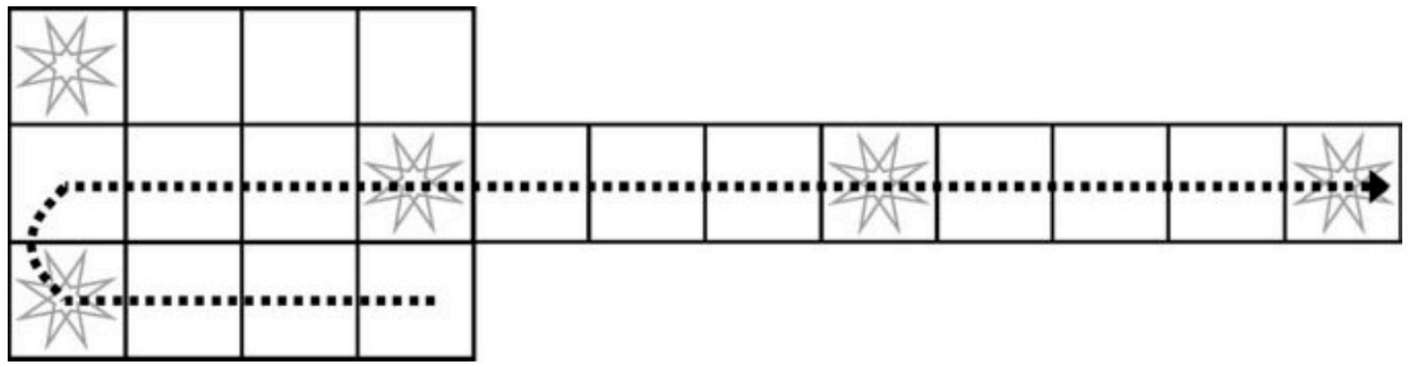




20 Squares / Royal Game of Ur

Traced back to 20 Squares:

- Royal Game of Ur



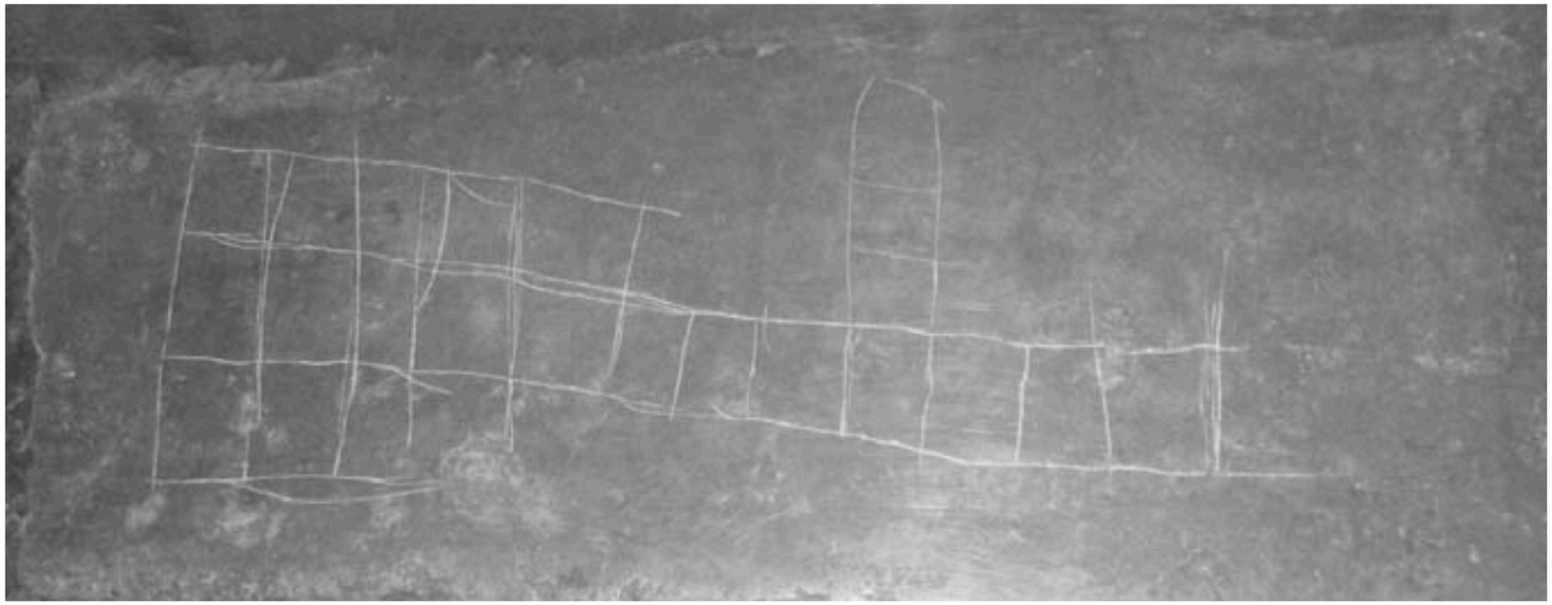
Timeline:

- c.2000BC
  Played in Mesopotamia
- c.177BC
  Tablets written
- 1990
  Interpreted and reconstructed

Game not mentioned by name

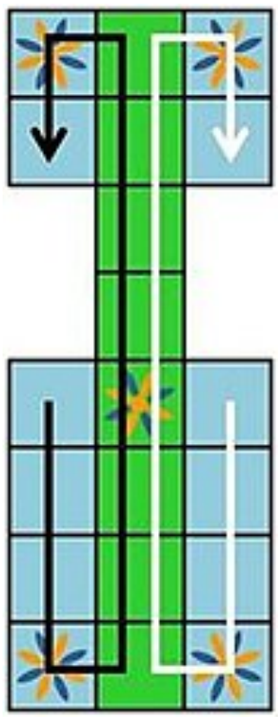
20 Squares / Royal Game of Ur

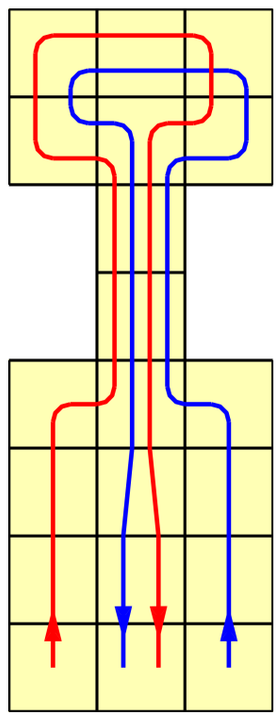
20 Squares:
- Which board?

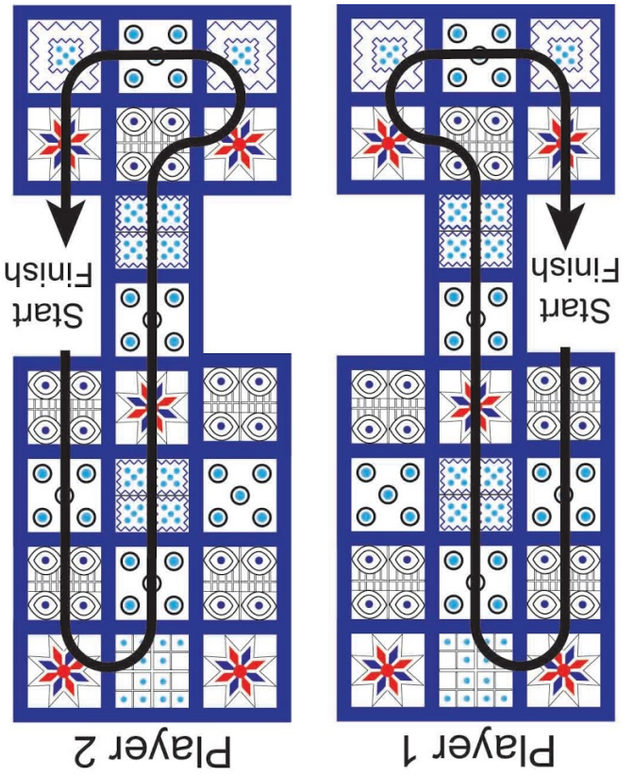


Royal Game of Ur:
- Which track?

Many questions, even if we have the rules







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Transcription Errors

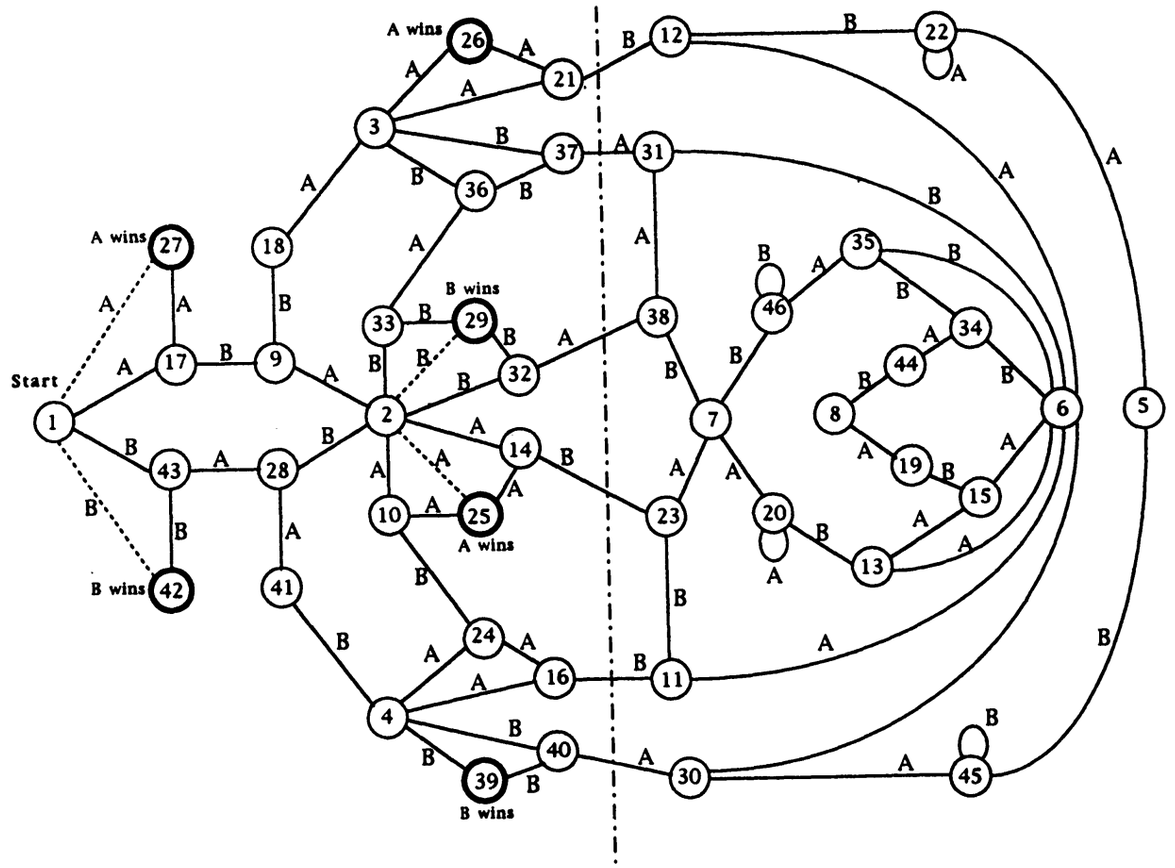
Mu Torere (New Zealand, 18thC)
- Full knowledge
- Living players

Move a piece of your colour
<u>adjacent to an enemy piece</u>
to the adjacent empty point.

Some accounts simplify this:

Move a piece of your colour
to the adjacent empty point.

Win on first move!



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Invented Traditions

Birrguu Matya (Australian Aboriginal, late 19thC)

Marketed as traditional game

Identical to Small Merels

Is a clear outlier

- No other strategy board games in this culture

Meggitt (1958)

- Afghani camel herders
- German missionary

Invented Traditions

Surakarta

- Named after traditional Javanese capital
- National game of Java?

But…

- Can’t find anyone from Java who knows it!
- Game invented for Ravensburger 1972 edition?

Lost Heritage

Losing evidence due to:

- Erosion
- Looting
- Desecration
- War
- Development

Walter documenting a 58 Holes board in Azerbaijan

58 Holes:

- Originated in Egypt
- Found in Azerbaijan

Walter Crist (2013):

- Already documented one site
- Cancelled trip to another site after it had been bulldozed

Cultural Heritage

Games are an important part of our cultural heritage

"Any account of a race which omits to notice its amusements cannot be considered a complete or satisfactory one."
– Parker, Ancient Ceylon (1909)

Games reflect the cultures in which they're played

Can provide new lines of enquiry, new insights into past

Kevin Parker
Engineer, Ethnologist

State of the Field

What we have:

- **Tangible Cultural Heritage**
  - Archaeological evidence: *boards*, *pieces*, *dice*, *etc.*
  - Historical, anthropological, ethnological data

What we don't have:

- **Intangible Cultural Heritage**
  - Rules
  - Points of contact

Many gaps in our knowledge of early games

Can modern computational techniques help?

Digital Ludeme Project

Five-year research project
- Funded by the ERC (€2m)
- Maastricht University

Computational study of the world's traditional games

Games as mathematical entities:
- Evidence based
- Quantitative approach

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Approach

1. **Model**
   Full range of traditional strategy games
   in a single playable digital database

2. **Reconstruct**
   Missing knowledge about ancient games more reliably

3. **Map**
   Spread of games throughout history

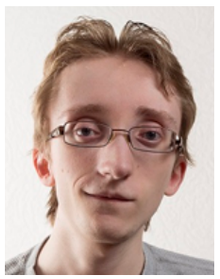
Aim: 1. To provide better reconstructions
2. To improve our understanding of traditional games,
   their development, impact on culture

Team

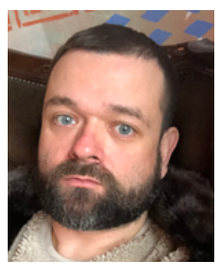
Cameron Browne (PI)
- Game AI (technical lead)

Eric Piette (Postdoctoral Researcher)
- Game AI (game engine development)

Matthew Stephenson (Postdoctoral Researcher)
- Game AI (GUI, networking, data mining)



Dennis Soemers (PhD Candidate)
- Game AI (feature learning)



Walter Crist (Postdoctoral Researcher)
- Anthropologist/archaeologist
- Middle East and Mediterranean specialist

Scope

Traditional games of strategy

Traditional

- No proprietary owner
- Some historical longevity
- Connection with local culture

XII Scripta board from Laodicaea, Turkey

Strategy

- Reward mental skill
- Good decisions beat bad decisions

  e.g. board, tile, card, dice, *etc.*

Methodology

We want to model the 1,000 most “important” traditional games:

- Documented, can be located and dated
- Impact on evolutionary record

Single playable database

[http://ludii.games]

How?

Ludemes

Game “memes” (Borvo, 1975)

- Units of game-related information
- Building blocks (DNA) of games
- Encapsulate key concepts

e.g.

```
(tiling square)
(size 3)
```

Ludemes

Game “memes”

- Units of game-related information
- Building blocks (DNA) of games
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e.g.

```
(tiling square)
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```
(size 3)
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```
(board
  (tiling square)
  (size 3)
)
```

Ludemes

Game “memes”
- Units of game-related information
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e.g.

```
(tiling square)
```

```
(size 3)
```

```
(board
  (tiling square)
  (size 3)
)
```

```
(game "?"
   (players White Black)
   (board
     (tiling square)
     (size 3)
   )
   (move (add Own Empty))
   (end (win All (in-a-row 3)))
)
```

Ludemes

Game “memes”
- Units of game-related information
- Building blocks (DNA) of games
- Encapsulate key concepts

e.g.

```
(tiling square)
```

```
(size 3)
```

```
(board
  (tiling square)
  (size 3)
)
```

```
(game “Tic-Tac-Toe”
  (players White Black)
  (board
    (tiling square)
    (size 3)
  )
  (move (add Own Empty))
  (end (win All (in-a-row 3)))
)
```

Stanford GDL

Academic standard
- 15 years

Programmer's view
- Low level instructions
- Not high level concepts

```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
    (true (control ?w)))
(<= (legal white noop) (true (control black)))
(<= (legal black noop) (true (control white)))
(<= (next (cell ?m ?n x)) (does white (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n o)) (does black (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n ?w)) (true (cell ?m ?n ?w))
    (distinct ?w b))
(<= (next (cell ?m ?n b)) (does ?w (mark ?j ?k))
    (true (cell ?m ?n b)) (or (distinct ?m ?j)
    (distinct ?n ?k)))
(<= (next (control white)) (true (control black)))
(<= (next (control black)) (true (control white)))
(<= (row ?m ?x) (true (cell ?m 1 ?x))
    (true (cell ?m 2 ?x)) (true (cell ?m 3 ?x)))
(<= (column ?n ?x) (true (cell 1 ?n ?x))
    (true (cell 2 ?n ?x)) (true (cell 3 ?n ?x)))
(<= (diagonal ?x) (true (cell 1 1 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 3 ?x)))
(<= (diagonal ?x) (true (cell 1 3 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 1 ?x)))
(<= (line ?x) (row ?m ?x))
(<= (line ?x) (column ?m ?x))
(<= (line ?x) (diagonal ?x))
(<= open (true (cell ?m ?n b))) (<= (goal white 100) (line x))
(<= (goal white 50) (not open) (not (line x)) (not (line o)))
(<= (goal white 0) open (not (line x)))
(<= (goal black 100) (line o))
(<= (goal black 50) (not open) (not (line x)) (not (line o)))
(<= (goal black 0) open (not (line o)))
(<= terminal (line x))
(<= terminal (line o))
(<= terminal (not open))
```

Ludemes vs GDL

```
(game "Tic-Tac-Toe"
  (players White Black)
  (board
    (tiling square)
    (size 3)
  )
  (move (add Own Empty))
  (end (win All (in-a-row 3)))
)
```

```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
    (true (control ?w)))
(<= (legal white noop) (true (control black)))
(<= (legal black noop) (true (control white)))
(<= (next (cell ?m ?n x)) (does white (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n o)) (does black (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n ?w)) (true (cell ?m ?n ?w))
    (distinct ?w b))
(<= (next (cell ?m ?n b)) (does ?w (mark ?j ?k))
    (true (cell ?m ?n b)) (or (distinct ?m ?j)
    (distinct ?n ?k)))
(<= (next (control white)) (true (control black)))
(<= (next (control black)) (true (control white)))
(<= (row ?m ?x) (true (cell ?m 1 ?x))
    (true (cell ?m 2 ?x)) (true (cell ?m 3 ?x)))
(<= (column ?n ?x) (true (cell 1 ?n ?x))
    (true (cell 2 ?n ?x)) (true (cell 3 ?n ?x)))
(<= (diagonal ?x) (true (cell 1 1 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 3 ?x)))
(<= (diagonal ?x) (true (cell 1 3 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 1 ?x)))
(<= (line ?x) (row ?m ?x))
(<= (line ?x) (column ?m ?x))
(<= (line ?x) (diagonal ?x))
(<= open (true (cell ?m ?n b))) (<= (goal white 100) (line x))
(<= (goal white 50) (not open) (not (line x)) (not (line o)))
(<= (goal white 0) open (not (line x)))
(<= (goal black 100) (line o))
(<= (goal black 50) (not open) (not (line x)) (not (line o)))
(<= (goal black 0) open (not (line o)))
(<= terminal (line x))
(<= terminal (line o))
(<= terminal (not open))
```

Ludemes vs GDL

```
(game "Tic-Tac-Toe"
  (players White Black)
  (board
    (tiling square)
    (size 7)
  )
  (move (add Own Empty))
  (end (win All (in-a-row 3)))
)
```

```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
    (true (control ?w)))
(<= (legal white noop) (true (control black)))
(<= (legal black noop) (true (control white)))
(<= (next (cell ?m ?n x)) (does white (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n o)) (does black (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n ?w)) (true (cell ?m ?n ?w))
    (distinct ?w b))
(<= (next (cell ?m ?n b)) (does ?w (mark ?j ?k))
    (true (cell ?m ?n b)) (or (distinct ?m ?j)
    (distinct ?n ?k)))
(<= (next (control white)) (true (control black)))
(<= (next (control black)) (true (control white)))
(<= (row ?m ?x) (true (cell ?m 1 ?x))
    (true (cell ?m 2 ?x)) (true (cell ?m 3 ?x)))
(<= (column ?n ?x) (true (cell 1 ?n ?x))
    (true (cell 2 ?n ?x)) (true (cell 3 ?n ?x)))
(<= (diagonal ?x) (true (cell 1 1 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 3 ?x)))
(<= (diagonal ?x) (true (cell 1 3 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 1 ?x)))
(<= (line ?x) (row ?m ?x))
(<= (line ?x) (column ?m ?x))
(<= (line ?x) (diagonal ?x))
(<= open (true (cell ?m ?n b))) (<= (goal white 100) (line x))
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(<= (goal black 0) open (not (line o)))
(<= terminal (line x))
(<= terminal (line o))
(<= terminal (not open))
```

Ludemes vs GDL

```
(game "Tic-Tac-Toe"
  (players White Black)
  (board
    (tiling hexagonal)
    (size 7)
  )
  (move (add Own Empty))
  (end (win All (in-a-row 3)))
)
```

```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
    (true (control ?w)))
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    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n o)) (does black (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n ?w)) (true (cell ?m ?n ?w))
    (distinct ?w b))
(<= (next (cell ?m ?n b)) (does ?w (mark ?j ?k))
    (true (cell ?m ?n b)) (or (distinct ?m ?j)
    (distinct ?n ?k)))
(<= (next (control white)) (true (control black)))
(<= (next (control black)) (true (control white)))
(<= (row ?m ?x) (true (cell ?m 1 ?x))
    (true (cell ?m 2 ?x)) (true (cell ?m 3 ?x)))
(<= (column ?n ?x) (true (cell 1 ?n ?x))
    (true (cell 2 ?n ?x)) (true (cell 3 ?n ?x)))
(<= (diagonal ?x) (true (cell 1 1 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 3 ?x)))
(<= (diagonal ?x) (true (cell 1 3 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 1 ?x)))
(<= (line ?x) (row ?m ?x))
(<= (line ?x) (column ?m ?x))
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(<= open (true (cell ?m ?n b))) (<= (goal white 100) (line x))
(<= (goal white 50) (not open) (not (line x)) (not (line o)))
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(<= (goal black 0) open (not (line o)))
(<= terminal (line x))
(<= terminal (line o))
(<= terminal (not open))
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Ludemes vs GDL

```
(game "Tic-Tac-Toe"
  (players White Black)
  (board
    (tiling hexagonal)
    (size 7)
  )
  (move (add Own Empty))
  (end (win All (no-moves)))
)
```

```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
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(<= terminal (line x))
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Ludemes vs GDL

```
(game "Tic-Tac-Toe"
  (players White Black)
  (board
    (tiling hexagonal)
    (size 7)
  )
  (move (add Own Empty))
  (end (win All (no-moves)))
)
```

Designer's view

- Encapsulates high level concepts
- Full range of games

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```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
    (true (control ?w)))
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    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n ?w)) (true (cell ?m ?n ?w))
    (distinct ?w b))
(<= (next (cell ?m ?n b)) (does ?w (mark ?j ?k))
    (true (cell ?m ?n b)) (or (distinct ?m ?j)
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(<= (goal black 0) open (not (line o)))
(<= terminal (line x))
(<= terminal (line o))
(<= terminal (not open))
```

How Many Ludemes?

Do we have to implement them all?
- Most of them

~340 so far:
- 50 equipment (*components*, *containers*)
- 80 rules (*play*, *start*, *end*)
- 180 functions (*integer*, *boolean*, *region*)
- plus control functions

~400 expected:
- Not that many – high reuse factor
- Very achievable!

System is fully extensible
- Just add more as needed

How To Improve Reconstructions?

Search for alternative rule sets that maximise:

1. **Historical Authenticity**

2. **Game Quality**

How To Improve Reconstructions?

Search for alternative rule sets that maximise:

1. Historical Authenticity

- Rules match: *location*, *period*, *cultural context*
- Based on historical data

2. Game Quality

- Run self-play trials between AI agents
- Look for obvious flaws
- Look for indications of quality

Game Quality

Previous work:

- *Evolutionary Game Design* (Browne, 2009)
- Two steps

1. Filter out obviously bad rule sets

2. Evaluate remaining games for potential to interest human players

Yavalath
by Ludi (2009)

Obvious Flaws

Basic indicators of bad games:

1. **Bias**
    - Games should be fair

2. **Drawishness**
    - Most games should produce a result

3. **Game Length**
    - Games shouldn’t be too short or too long

Easy to detect, can eliminate immediately

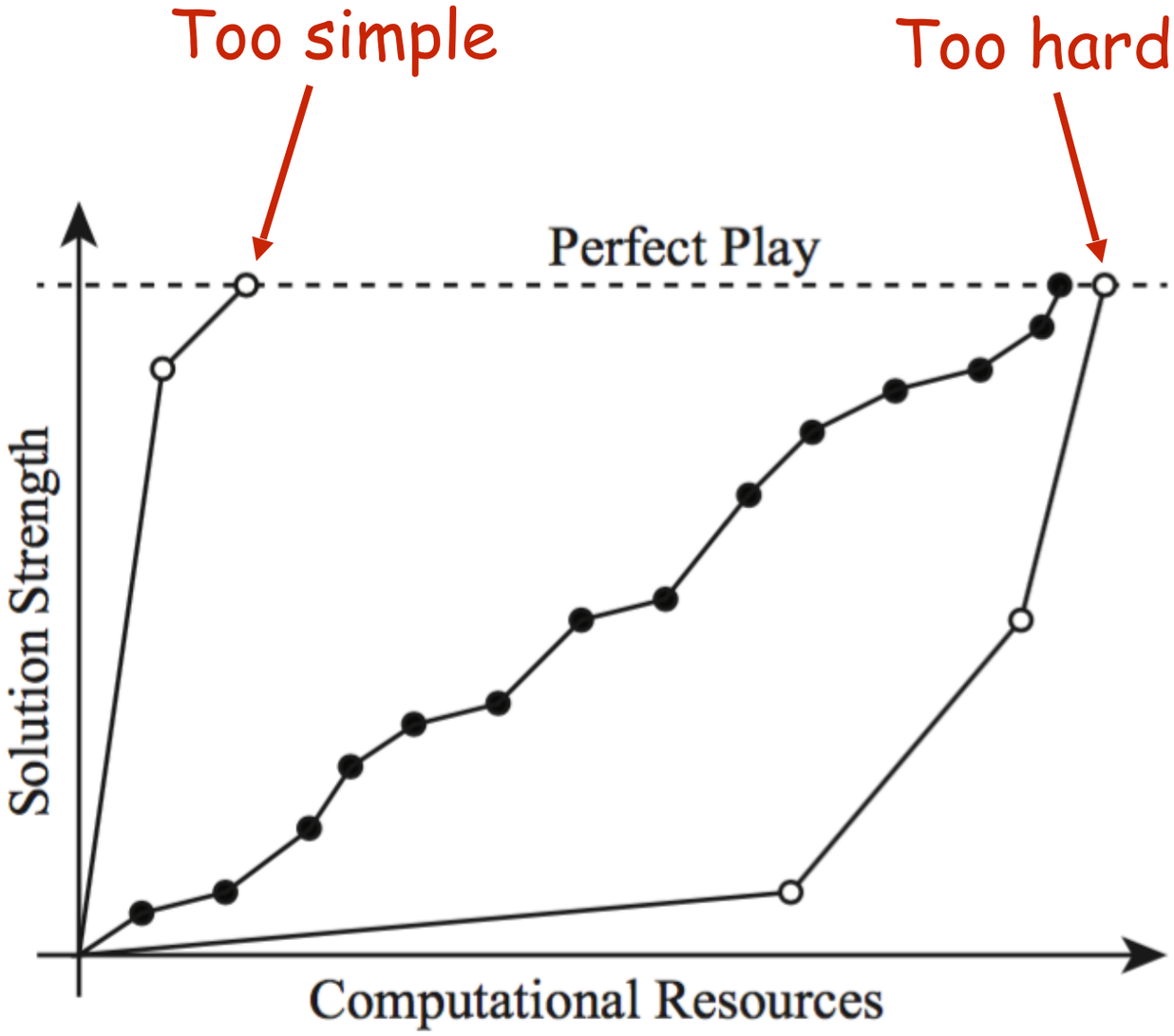
Strategic Potential

Potential to interest human players:

- Much harder to define and measure!
- Difficult to validate

Strategic Depth

- Potential for increasingly sophisticated strategies
- Universal quality metric?



Strategy Ladder
Lantz *et al.* (*AAAI'17*)

Hypotheses

Games with deeper* and more easily understood strategies are more likely to:

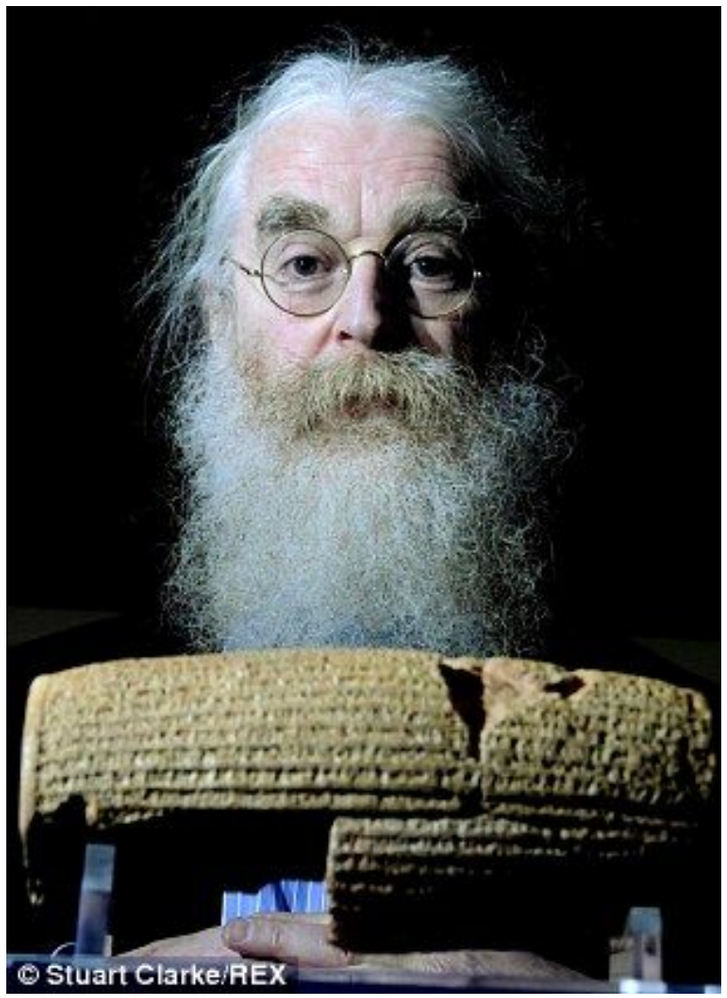
I. Be played
II. Be taught
III. Survive

* *Relative to complexity*

These are the “good” games

Irving Finkel (2012):

- “Good” games spread
- “Good” games cannot be stopped
- “Good” games survive for millennia



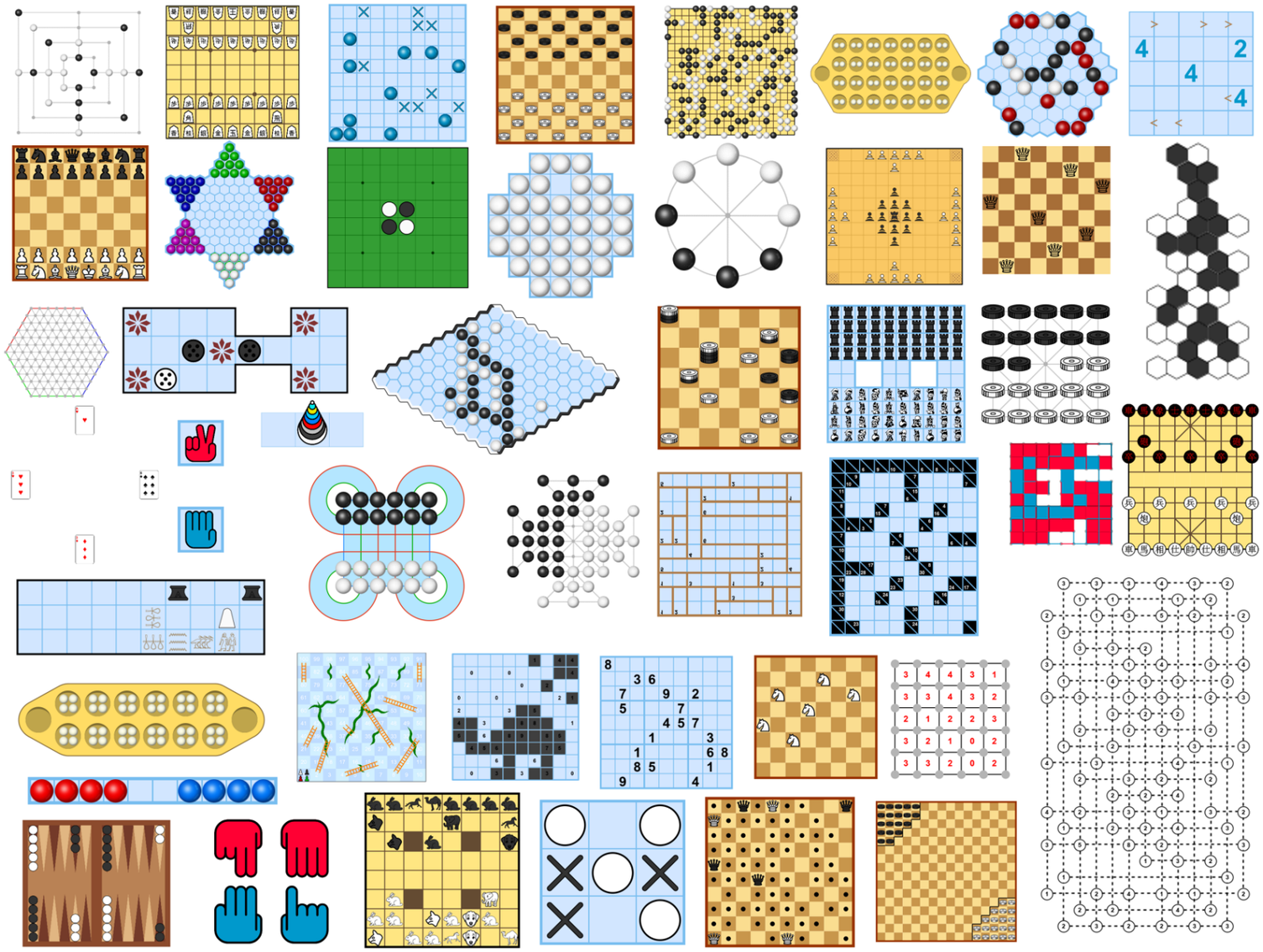
Irving Finkel
Curator, British Museum

Ludii

Software for performing the analysis

General game system:

- Modelling
- Playing
- Analysing
- Reconstructing



Currently ~200 games

Expected release:

- March 31

Beta version available:

- http://ludii.games

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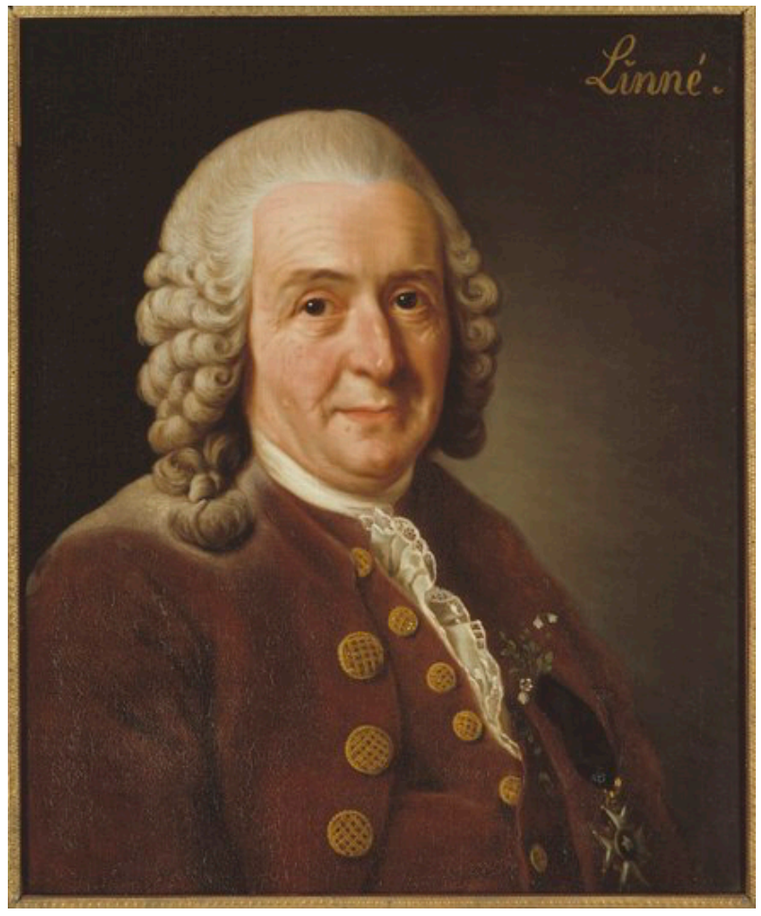
Case Study

Hnefatafl “Viking Chess”
- Scandinavia (c.800AD)
- No original rules found

Linnaeus (1732)
- Saw Tablut, transcribed rules (in Latin)

Smith (1811)
- Translated into English

Murray (1913) *History of Chess*
- Assumed same rules for Hnefatafl
- Published them
- Became de facto



Carl Linnaeus (1707–1778)

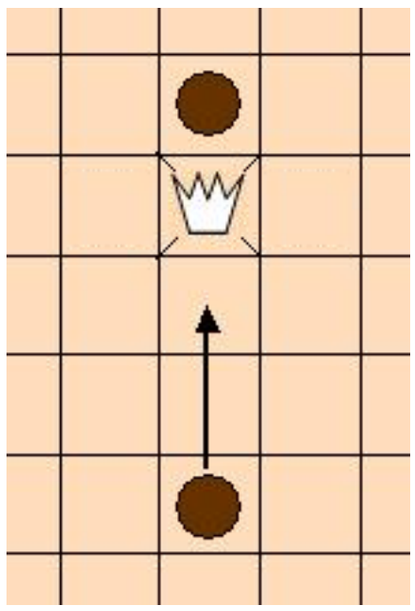
Case Study

BUT…

Smith made a
bad translation of
the king capture rule

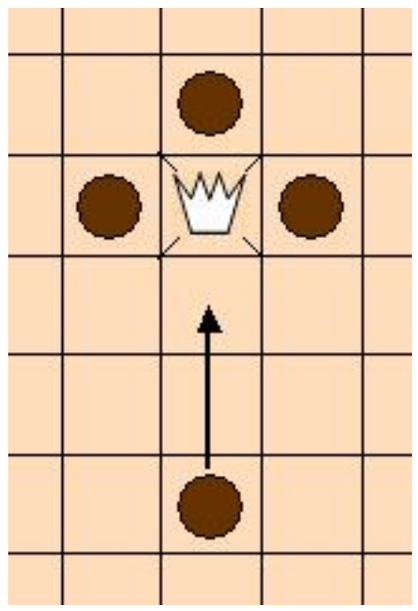
A. Original Latin:

- "… likewise the king…"
- Flanked
- Easy to capture



B. Smith's mistranslation:

- "… except the king…"
- Surrounded
- Hard to capture

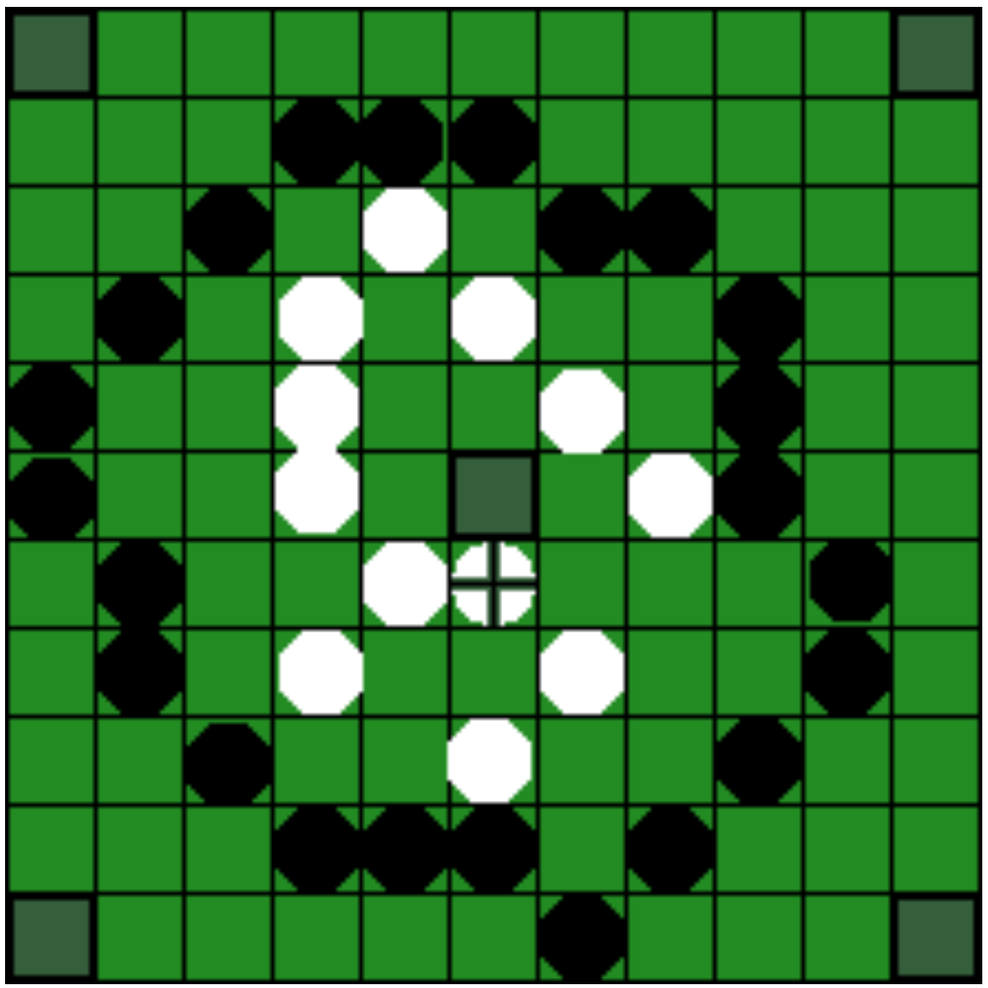


[DEMO]

But There's More…

Attackers have a winning(?) strategy:

- Form a wall
- Constrict
- King can't win

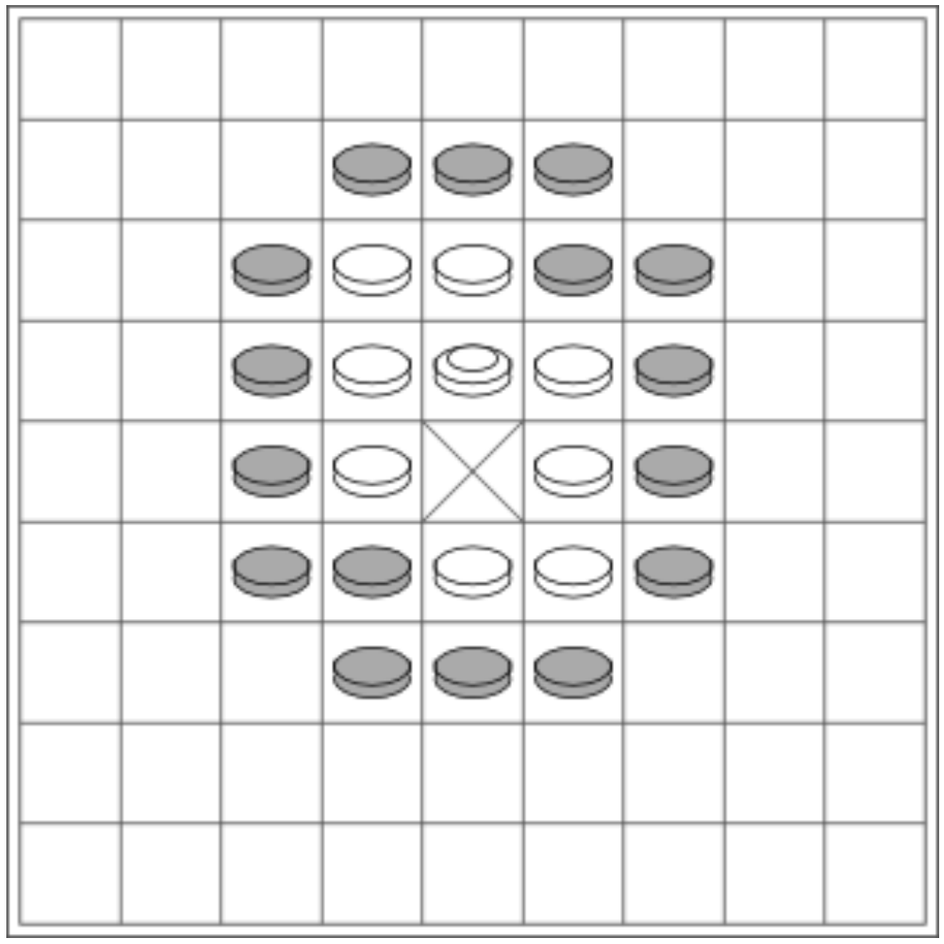


Strong AI should pick this up:

- Bias swings towards attackers
- Regardless of king capture rule

But There's Even More…

Defenders can form a fortress:
- King moves back and forth
- Avoid defeat indefinitely



Good AI should also pick this up
- Game is now drawish

Copenhagen Rules:
- Proposed 2011
- Solves these problems
- Quite complex and specific

AI Level

What AI level do we need to evaluate games?

- Random play:
  - Fast but unrealistic

- Competent “human level” play:
  - Achievable, experience of most human players

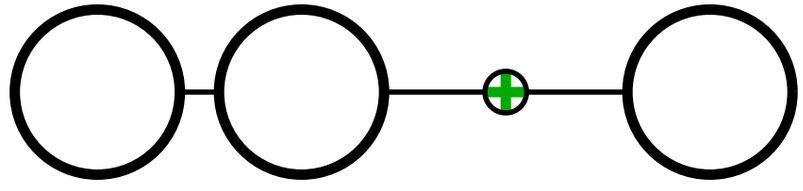
- Expert + Superhuman play:
  - Hard to achieve, not representative
    e.g. Chess and Draughts is drawish at World Champion level

We want AI smart enough to learn basic strategies

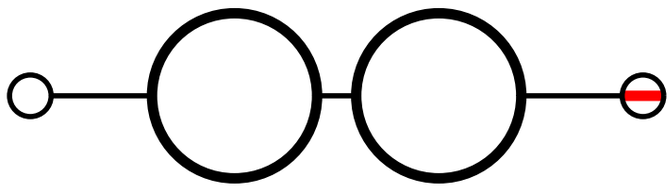
Strategy Learning

Learn features that indicate good/bad patterns:

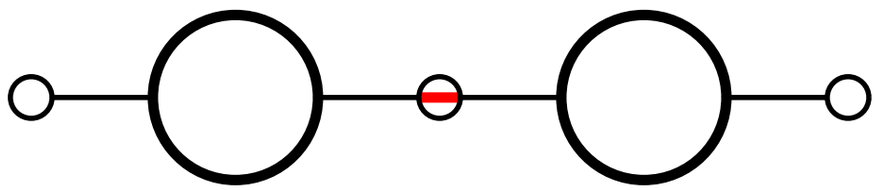
- Improve Monte Carlo (MC) simulations
- Represent simple strategies
  e.g. "Make line of 4"
  "Don't make line of 3"



- Number and complexity indicate strategic potential?



- Also allow us to explain learnt strategies in human comprehensible terms



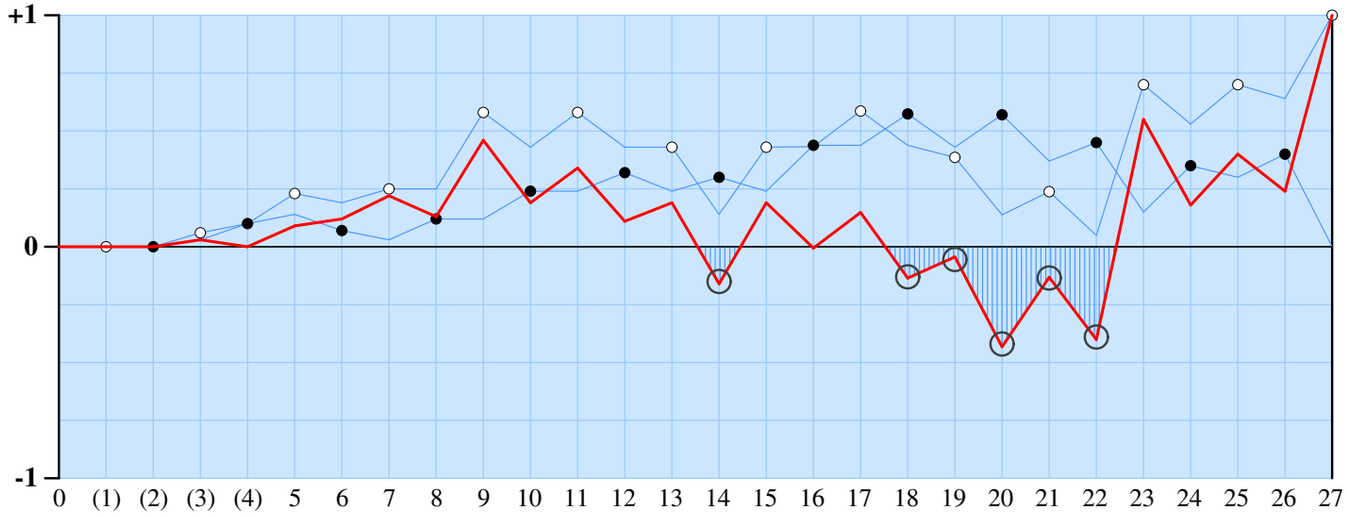
Ludemic Distance

"Distance" between games

1. **Genotypic Distance** (*form*)
   - How game is described
   - Edit distance between descriptions
   - Simple to measure

```
(game "Tic-Tac-Toe"
  (players White Black)
  (board
    (tiling square)
    (size 3)
  )
  (move (add Own Empty))
  (end (win All (in-a-row 3)))
)
```

2. **Phenotypic Distance** (*function*)
   - How the game plays
   - Trends that emerge during play
   - Hard to measure reliably



Computational Phylogenetics

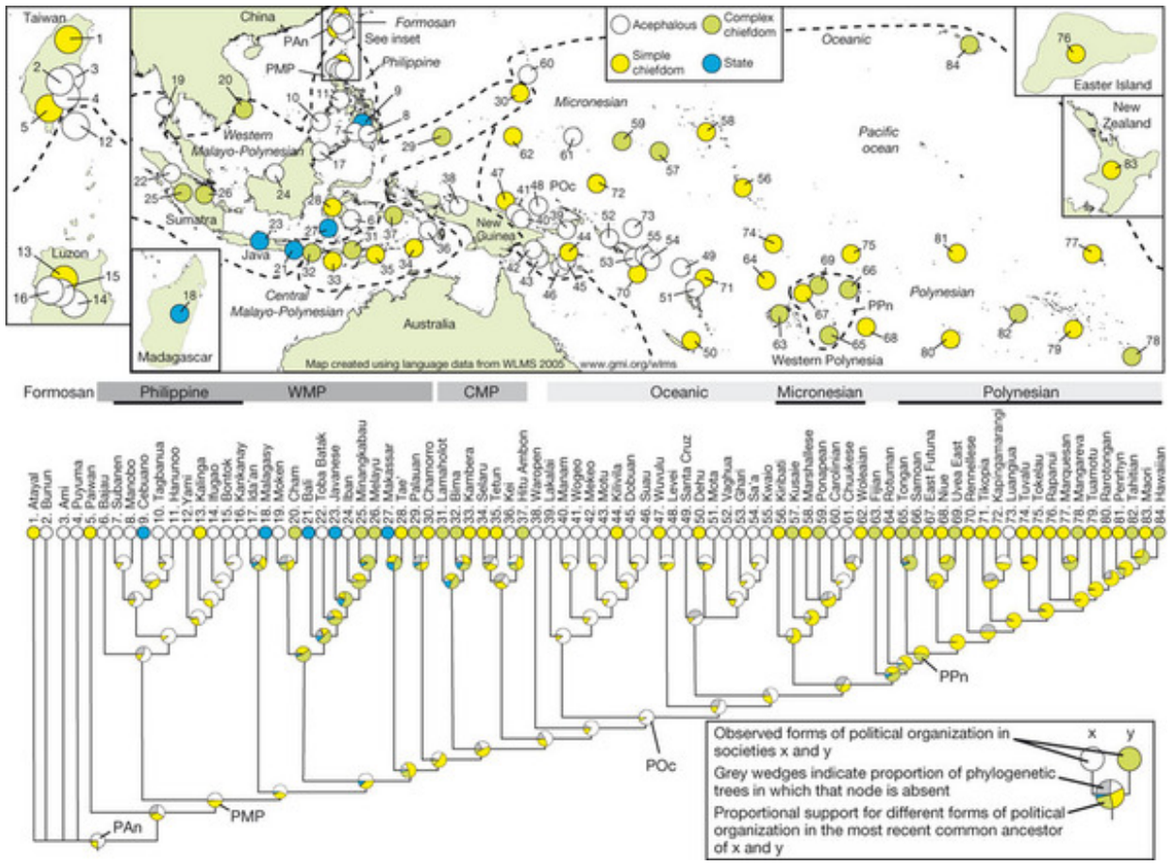
Ludemic distance:

- In lieu of actual genetic distance

1. **Family Trees**
   - Key game families

2. **Ancestral State Reconstruction**
   - Identify likely traits (i.e. ludeme structures) in ancestors

3. **Missing Links**
   - Games that explain gaps in the evolutionary record?

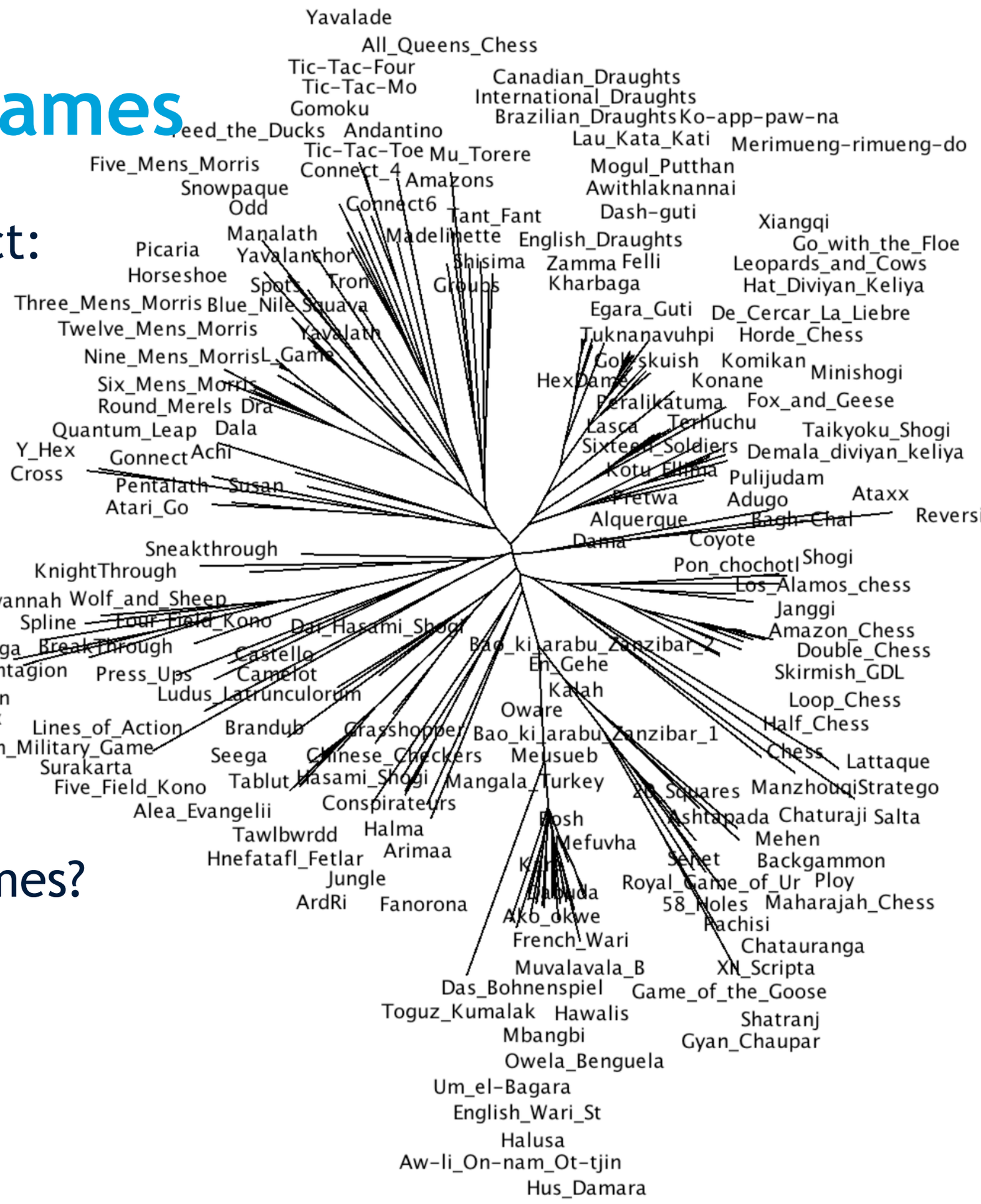


Phlyogenetic analysis of Austronesian societies
Currie (210) *Nature*

Phylogeny of Games

UM student group project:

- Phylogenetic analysis of 200 Ludii games
- “Bag of Words” approach



Meaningful clusters!

New ways to classify games?

- Based on underlying structure + function

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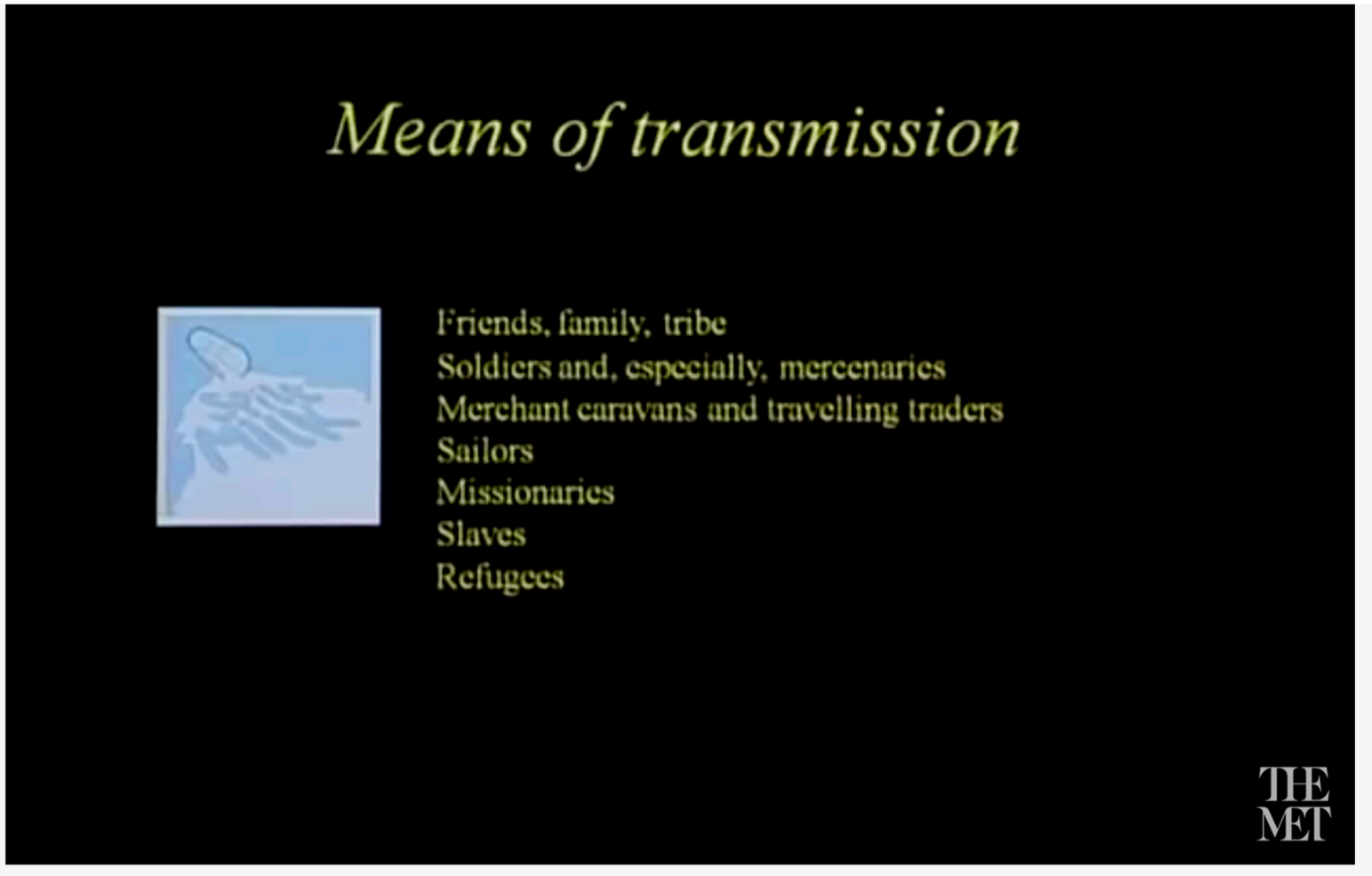
Transmission of Games

Games travel through human movement

Finkel (2012) identifies means of transmission

"Games can travel in somebody's head"



Games of the Ancient World

140,638 views • Mar 9, 2012 541 81 SHARE SAVE

Social Lubricants

Games are social lubricants:
- Ways of connecting people
- Meaningful contact between people

Cross boundaries:
- Culture
- Language

Can sit down with anyone and teach them a game:
- How to play
- How to play *well*

Traditionally passed verbally:
- Printed rule sets are a recent invention
- Source of variation

Examples

Ludus Latrunculorum:
- Traditional Roman game
- Travelled with Roman army

Hnefatafl/Tablut:
- Traditional Scandinavian game
- Played wherever the Vikings travelled

Ludus Latrunculorum
Hadrian's wall (UK)

Cultural Contact

Games are touchpoints between cultures:

- Evidence of contact?

e.g. Patolli and Pachisi

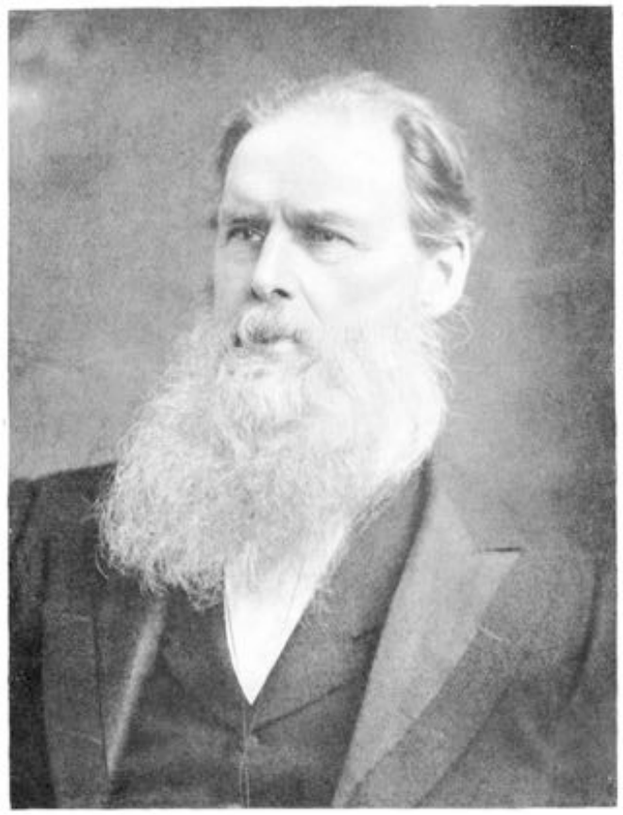
Patolli Mexico (200BC–1200)

Pachisi India (from 600-1600)

Cultural Contact

Tyler (1879)
- Evidence of early pre-Columbian contact

Erasmus (1950)
- Coincidence, “Limitation of Possibilities”



E. B. Tyler (1832–1917)

Patolli Mexico (200BC–1200)

Pachisi India (from 600-1600)

GeaCron

Geo-temporal database:

- Yearly maps
- Last 5,000 years
- 2,000 cultures

IN:

- GPS + date

OUT:

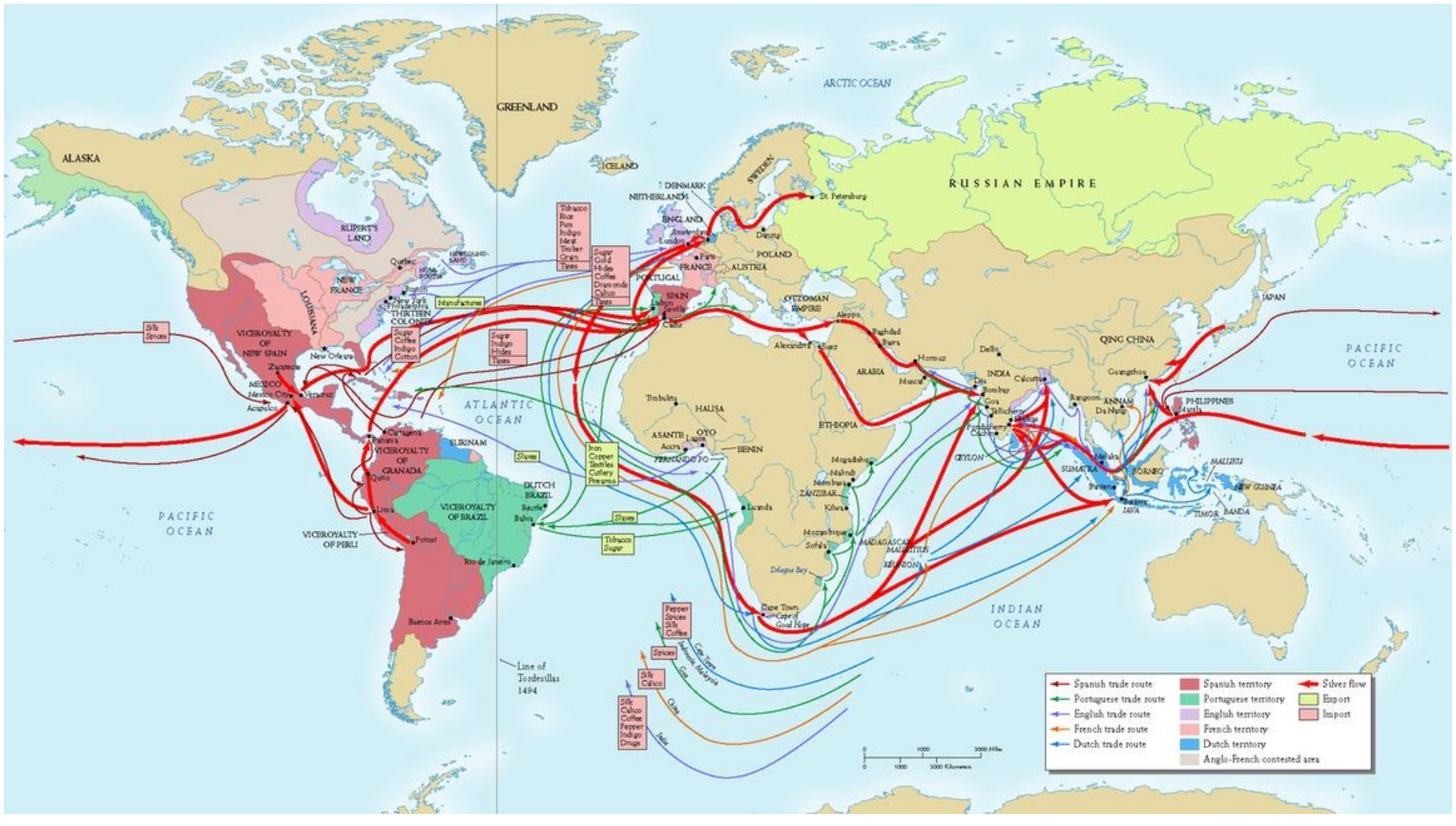
- Civilisation/nation
- Historial landmarks, events, routes, etc.

Viking route from Norway to Paris (845)

Spread of Games

We have 275 historical routes:

- Correlate spread of games/ludemes with spread of humans throughout history



Colonial trade routes (1890s)

Silk Road Trade Routes

Very important in the history of games

- Fertile crescent to far Asia

Next steps for project…

Map 12.1 The silk roads,

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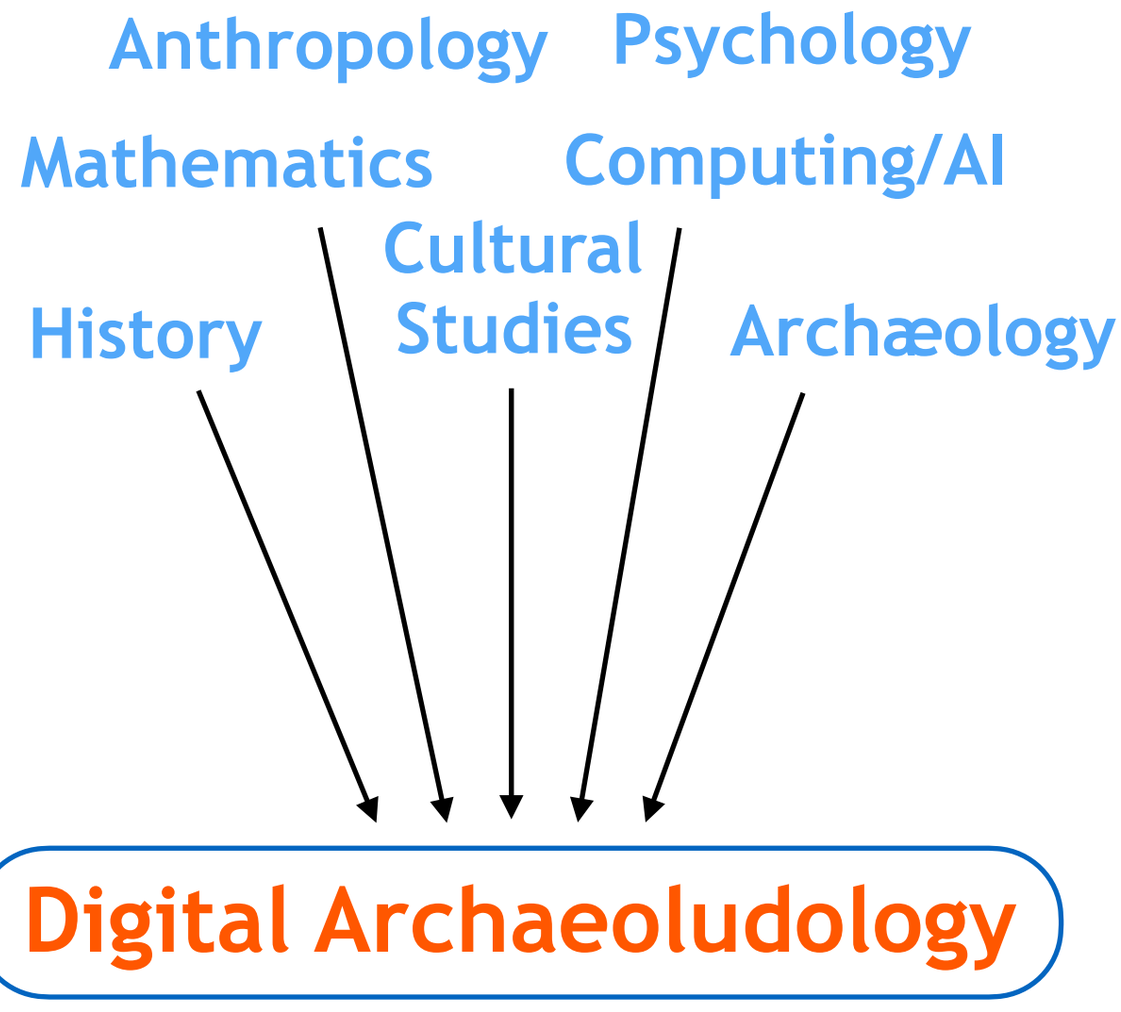
Digital Archaeoludology

Traditional game studies:
- Historical analysis
- Less mathematical

Modern game AI studies:
- Technical analysis
- No historical context

New research field:
- Bridges this gap



DAL: *Use of modern computational techniques to harness the available evidence and improve our understanding of ancient games*

Conclusion

- Lots of evidence to work with
- New approaches to try
- Results coming soon…

European Research Council
Established by the European Commission

Thank You!

Questions?

Digital Ludeme Project

http://ludeme.eu

Please take a postcard or two

http://ludii.games

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