Cultural Heritage Network: Games as Heritage

Artificial Intelligence and the Heritage of Games

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Maastricht University

Context

Games are ubiquitous
- All humans play games
- All human cultures have their own games
- Games reflect the culture(s) in which they're played

Games offer a window of insight into cultural past

Ancient games rarely recorded
- Passed on by oral tradition
- Huge variety today
- Very little knowledge

Cultural Contact

Games are cultural artefacts
- Touchpoints between cultures
- Evidence of contact

e.g. Patolli and Pachisi

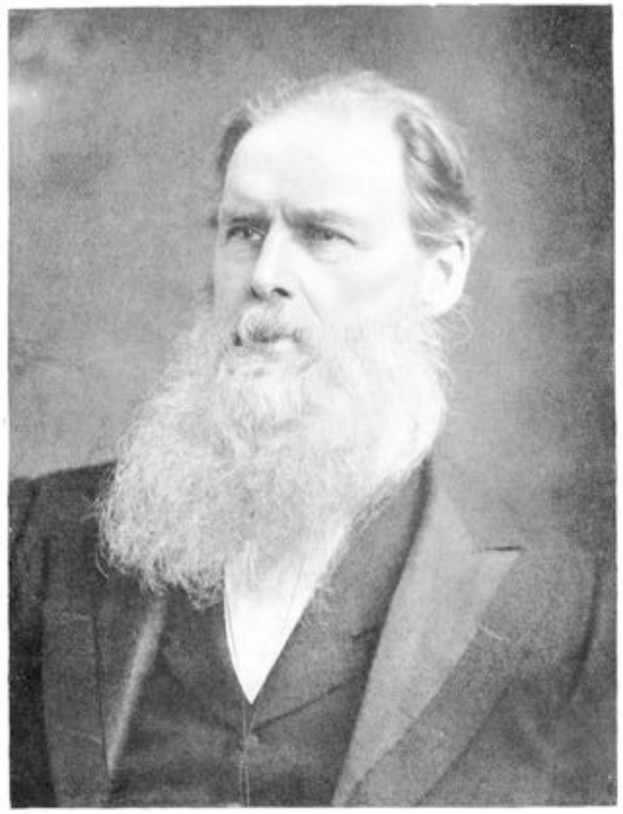
Patolli Mexico (200BC–1200AD)

Pachisi India (600-1600 AD)

Cultural Contact

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

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



E. B. Tyler (1832–1917)

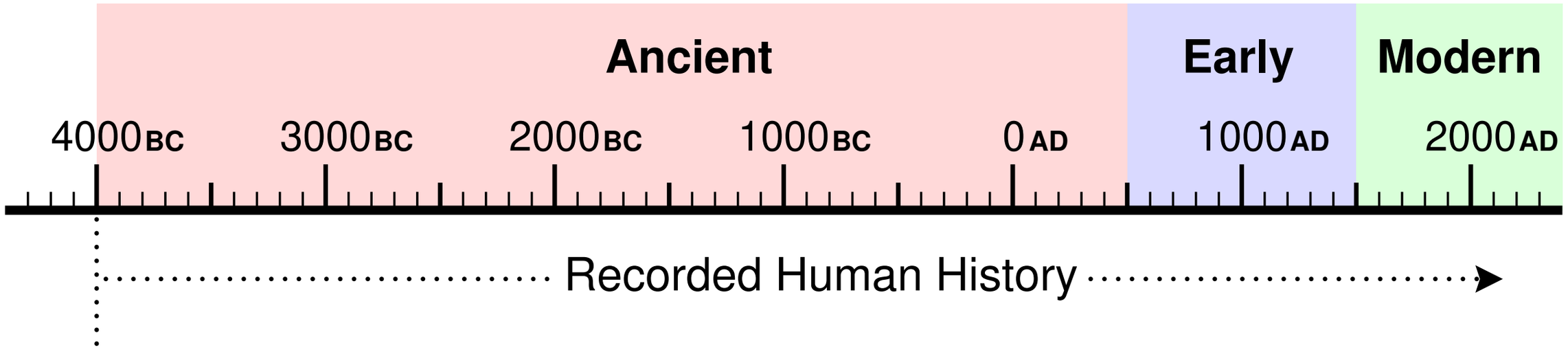
Patolli Mexico (200BC–1200AD)

Pachisi India (600-1600 AD)

Games in Human History

Archaeological evidence of games
- Found worldwide
- Throughout recorded history

Provides clues
- Reconstruction is a subjective endeavour



Lack of evidence, cultural context and anthropological theory
- Little work done on the cultural diffusion of games

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

New perspective
New lines of enquiry

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Objectives

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

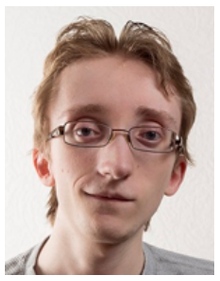
Aim: To improve our understanding of traditional games
using available evidence and modern AI techniques

Team

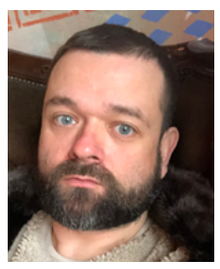
Cameron Browne (PI)
Game AI researcher
Technical lead

Eric Piette (Postdoctoral Researcher)
Game AI researcher (GGP world champion)
Game engine development

Matthew Stephenson (Postdoctoral Researcher)
Game AI researcher
Data mining, systems integration



Dennis Soemers (PhD Candidate)
AI, feature learning, external collaborations (Google, etc.)



Walter Crist (Postdoctoral Researcher)
Anthropologist/archaeologist
Ancient Egypt and Mediterranean specialist

Scope

Traditional games of strategy

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

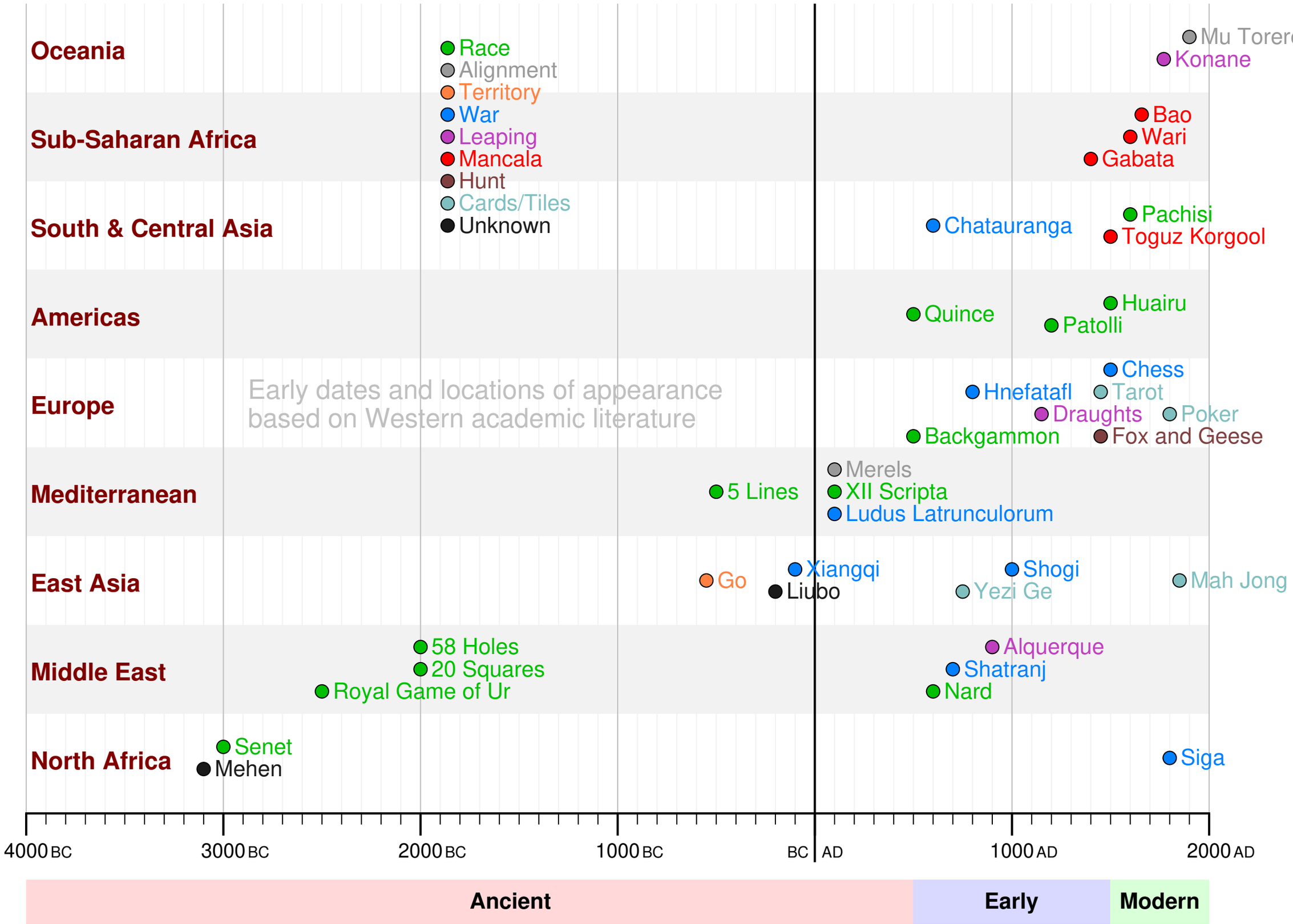
XII Scripta board from Laodicaea, Turkey

Strategy
- Reward mental skill
- Good decisions beat bad decisions

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

Model the 1,000 most “important” traditional games
- Documented, can be located and dated
- Impact on evolutionary record

Timeline


Oceania
Sub-Saharan Africa
South & Central Asia
Americas
Europe
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
Bao
Wari
Gabata
Chatauranga
Pachisi
Toguz Korgool
Quince
Huairu
Patolli
Chess
Hnefatafl
Tarot
Draughts
Poker
Backgammon
Fox and Geese
Merels
5 Lines
XII Scripta
Ludus Latrunculorum
Go
Xiangqi
Liubo
Shogi
Yezi Ge
Mah Jong
58 Holes
20 Squares
Royal Game of Ur
Alquerque
Shatranj
Nard
Senet
Mehen
Siga
4000 BC
3000 BC
2000 BC
1000 BC
BC
AD
1000 AD
2000 AD
Ancient
Early
Modern

Games as Cultural Heritage

Tangible cultural heritage
- Physical evidence
  e.g. boards, pieces, components, *etc.*

Intangible cultural heritage
- Rules
- Social/cultural context
- Restore and preserve

What is the available evidence?

Ancient Egypt

Earliest known games

Mehen (c.3100BC)
- No rules
- No clues to how it was played

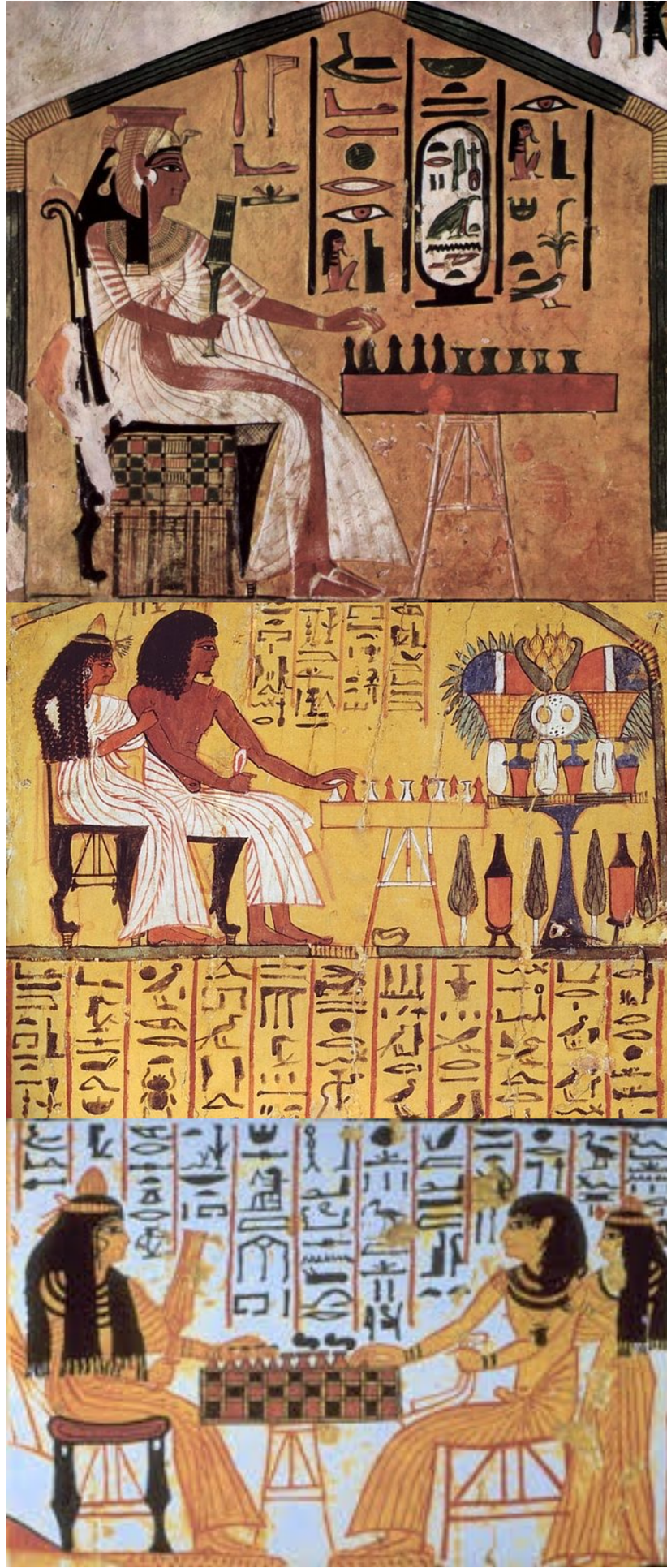
Senet (c.3000BC)
- Hundreds of sets found
- No rules
- Hieroglyphic art

Senet

From hieroglyphs
- Two players
- Some starting positions

From evidence
- Two piece types
- Special symbols on board
  - Entry points? Exit points?

About a dozen plausible reconstructions

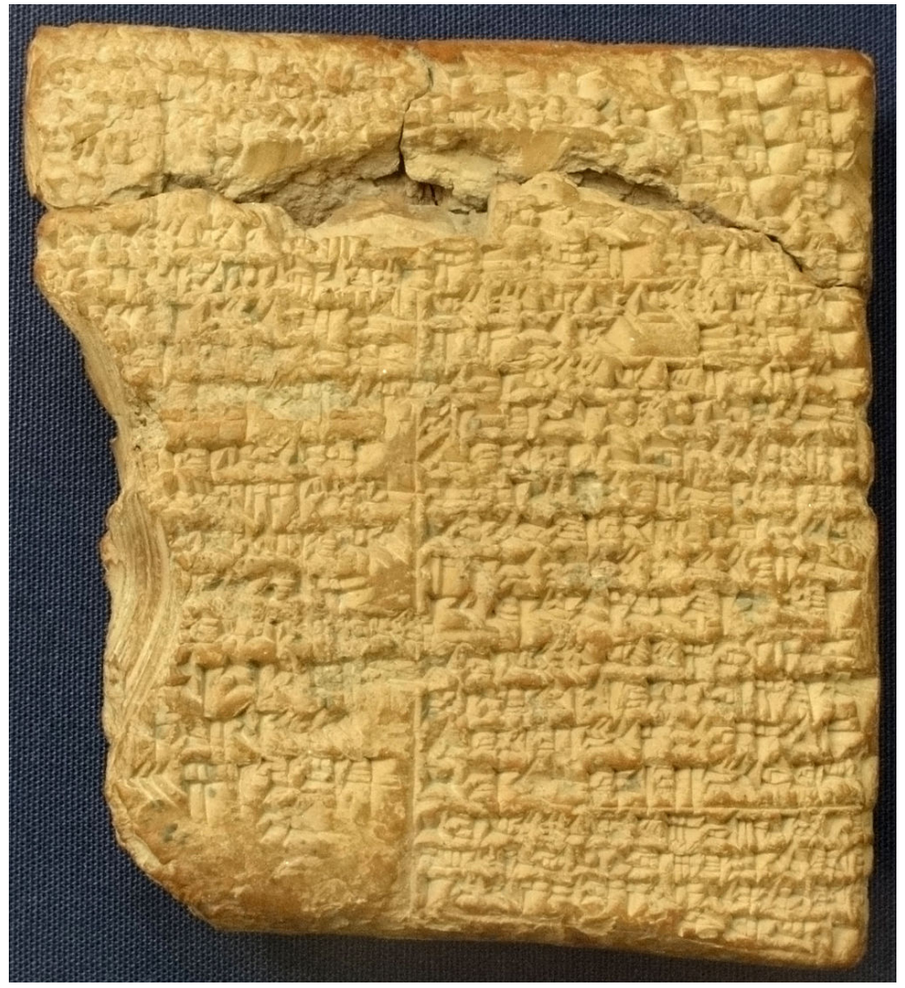


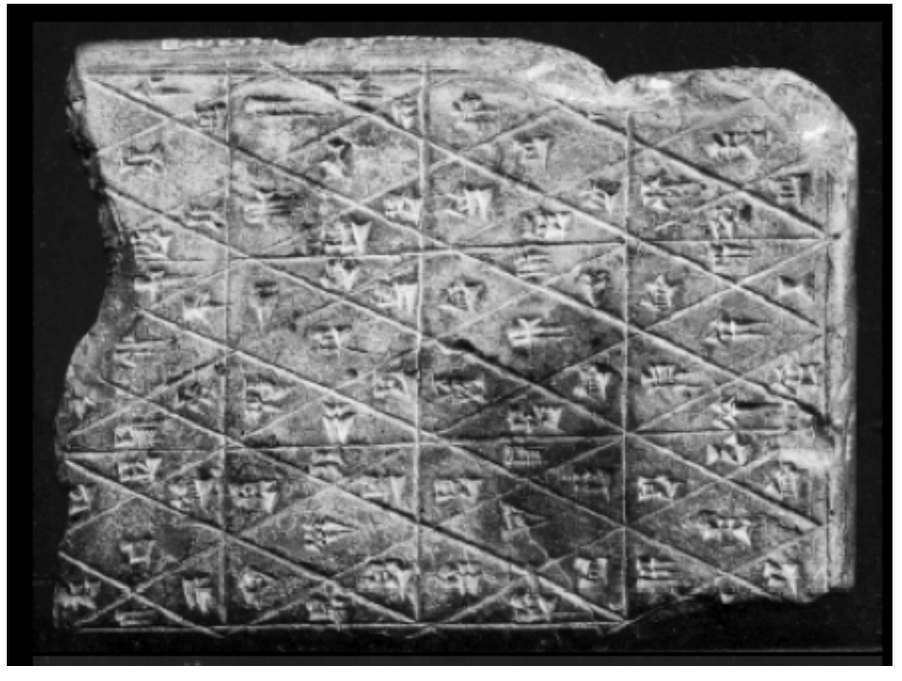
First Known Rules

Sumerian cuneiform tablets
- Mesopotamia, 177BC

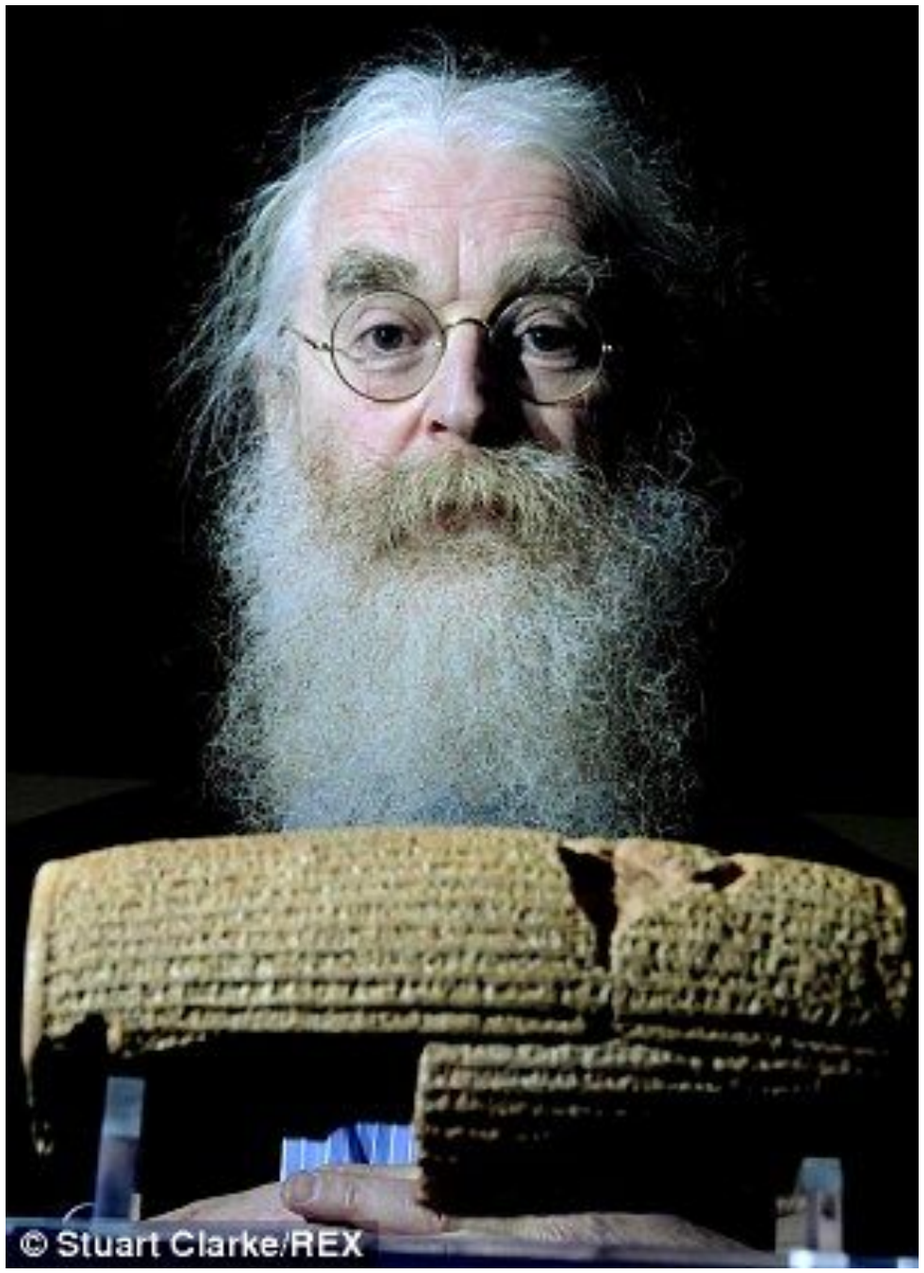
British Museum (top)
- One of 130,000

Parisian (bottom)
- Destroyed 1940s
- Photo survived

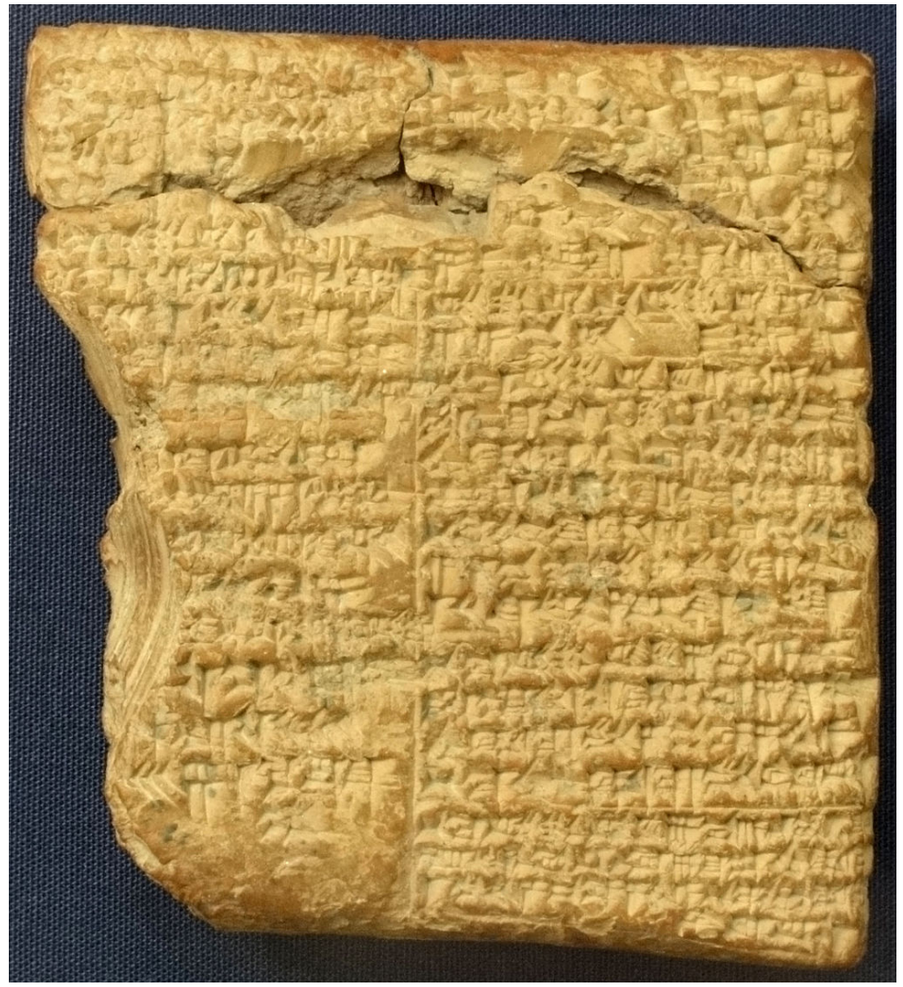


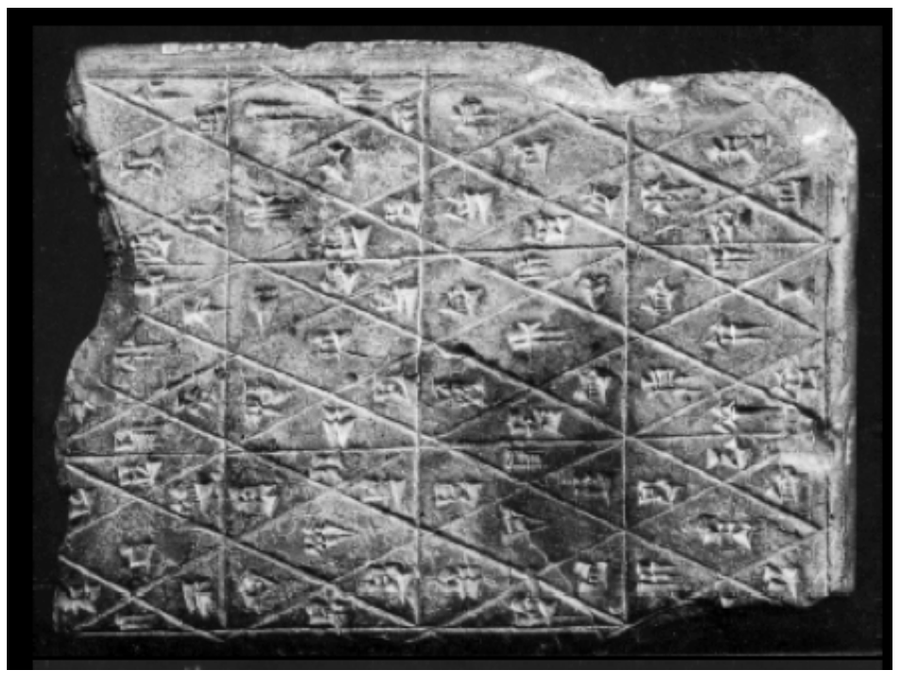


First Known Rules



Irving Finkel (1990)
Curator, British Museum





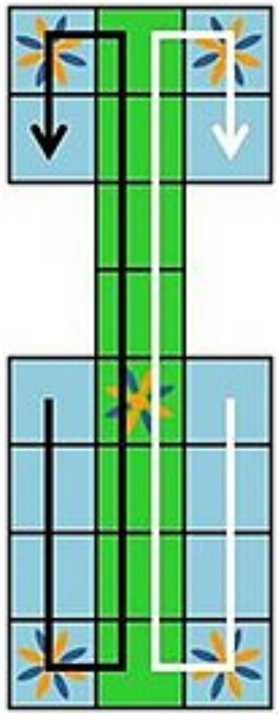
Royal Game of Ur

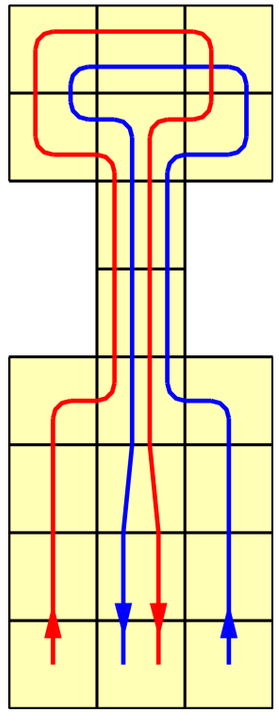
Played in Mesopotamia
- c.2600BC

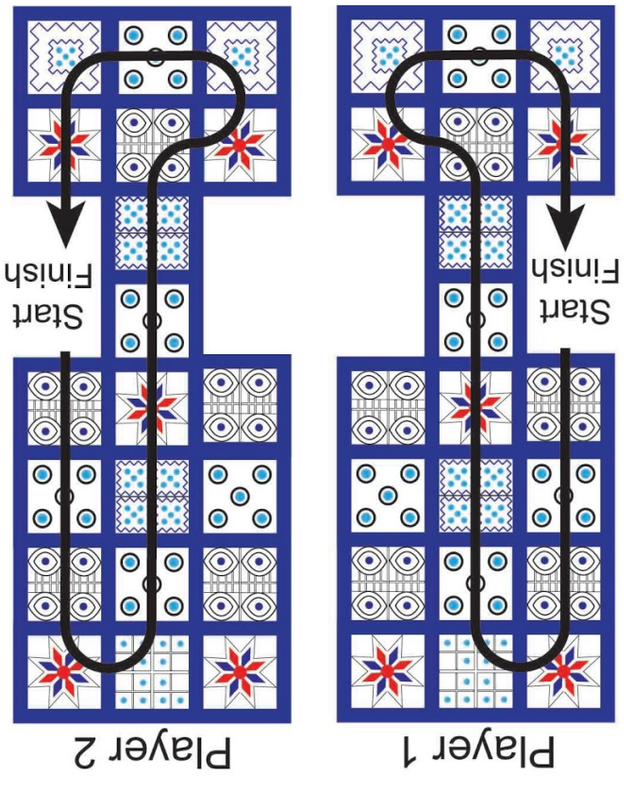
Tablets written
- c.177BC

Reconstruction by Irving
- 1990AD

Still some questions
- Same game? Probably
- Which track?







Transcription Errors

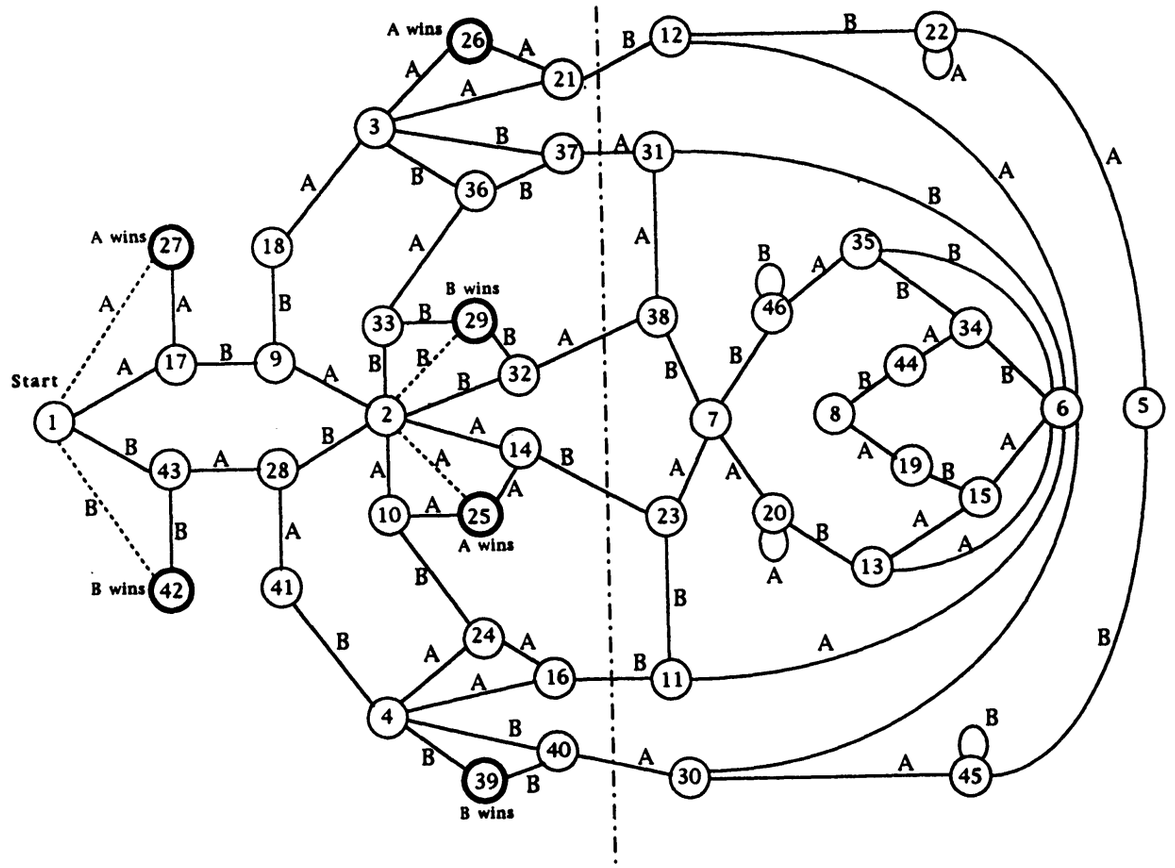
Mu Torere (New Zealand, 18thC)
- Full knowledge
- Living players

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?

Approach

How to handle this incomplete, unreliable evidence?

- Quantify where possible
- Encode in single consistent format
- Establish historical/cultural context
- Find relationships within data

Ludemes

Game “memes”

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

e.g.

```
(tiling square)
```

```
(size 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)
)
```

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 "?"
   (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)))
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(<= (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))
(<= (goal white 50) (not open) (not (line x)) (not (line o)))
(<= (goal white 0) open (not (line x)))
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(<= (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 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)))
(<= (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))
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(<= (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 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))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
    (true (control ?w)))
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(<= (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)
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(<= (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))
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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)))
(<= (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))
```

How Many Ludemes?

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

About 400 so far
- About 600 expected
- Not actually that many
- High reuse among games

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

Obvious Flaws

Basic indicators of bad games:

1. **Bias**
    - All players should have chance of winning

2. **Drawishness**
    - Most games should produce a result, not a draw

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

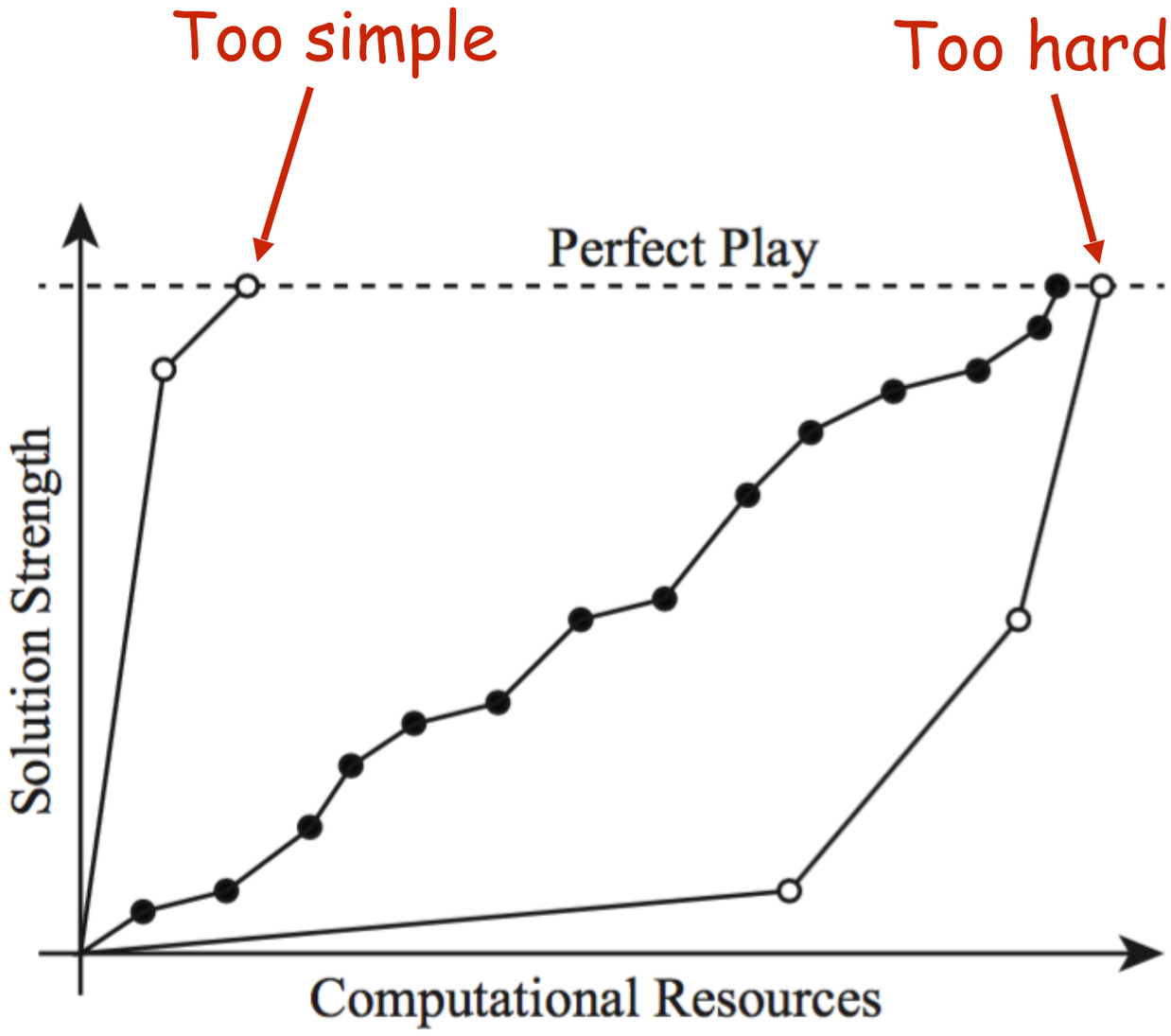
Easy to detect, can eliminate immediately

Game Quality

Potential to interest human players
- Much harder to define and measure!
- Can't validate

Strategic Depth
- Potential for increasingly sophisticated strategies
- Universal metric?

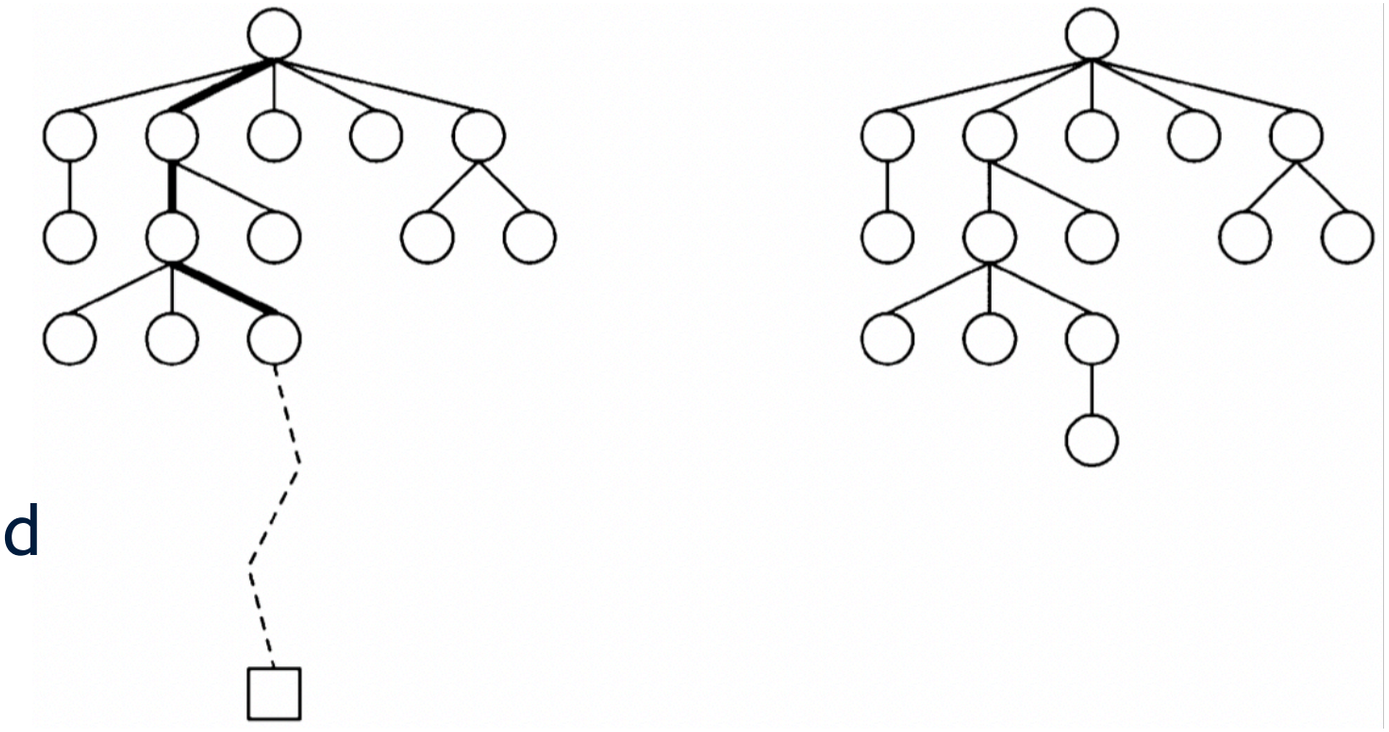
The games that survive
- Essence of strategy games
- Easier to teach?



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

AI Players

Monte Carlo tree search (MCTS)
- Run many (semi)random simulations
- Build search tree from results
- Works well for many games
  …but not all



Bias playouts with features
- Geometric piece patterns
- Encourage good/discourage bad
- Generalise to arbitrary grids

Benefits
- Improve player strength
- Encode strategies = depth
- Explain strategies?

“Make-line-of-4” features

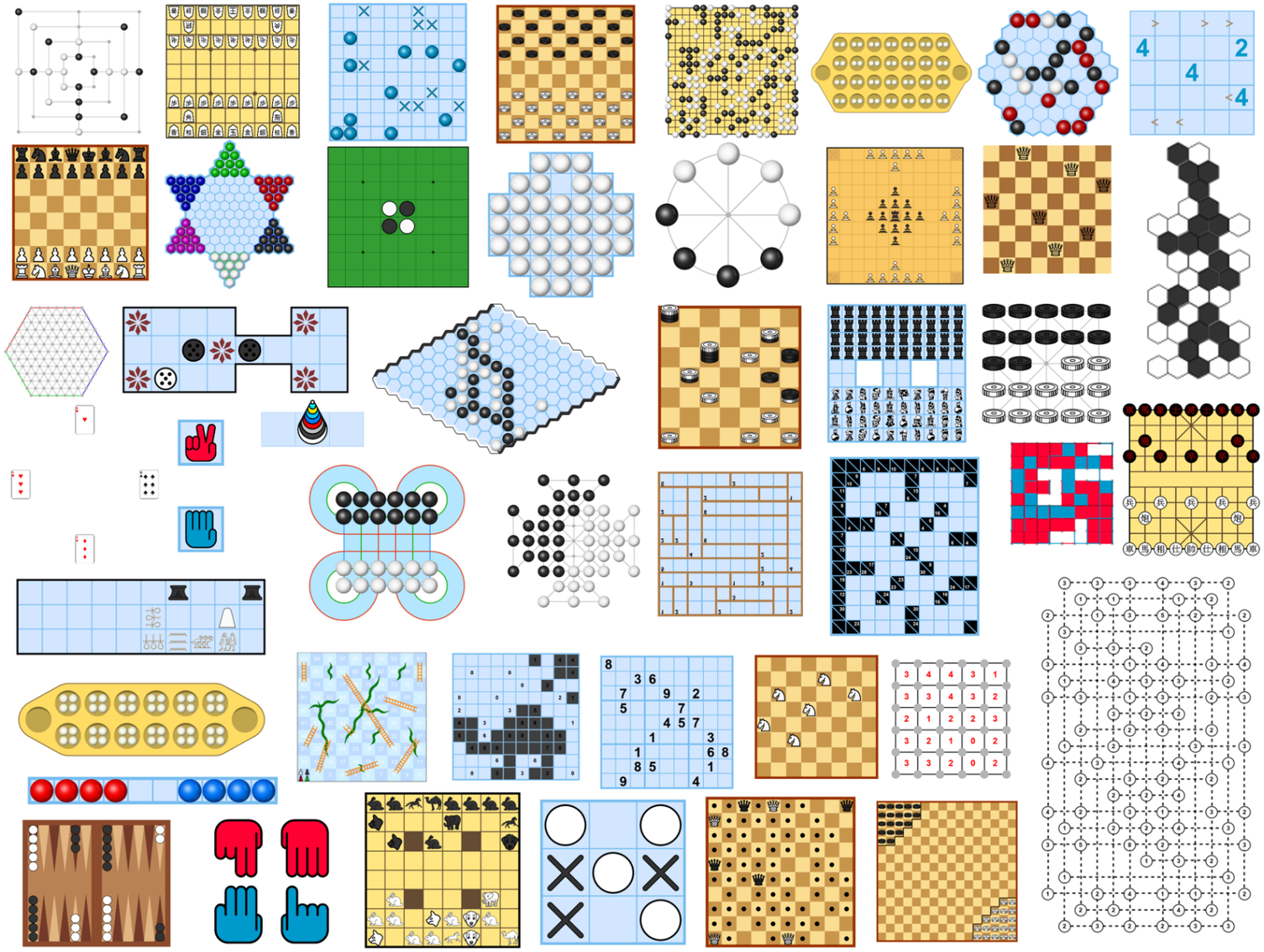
Ludii

General game system
- Playing, analysing, designing, reconstructing

Early stages
- 100 games

Beta version available
- http://ludii.games

Official release
- January 2020



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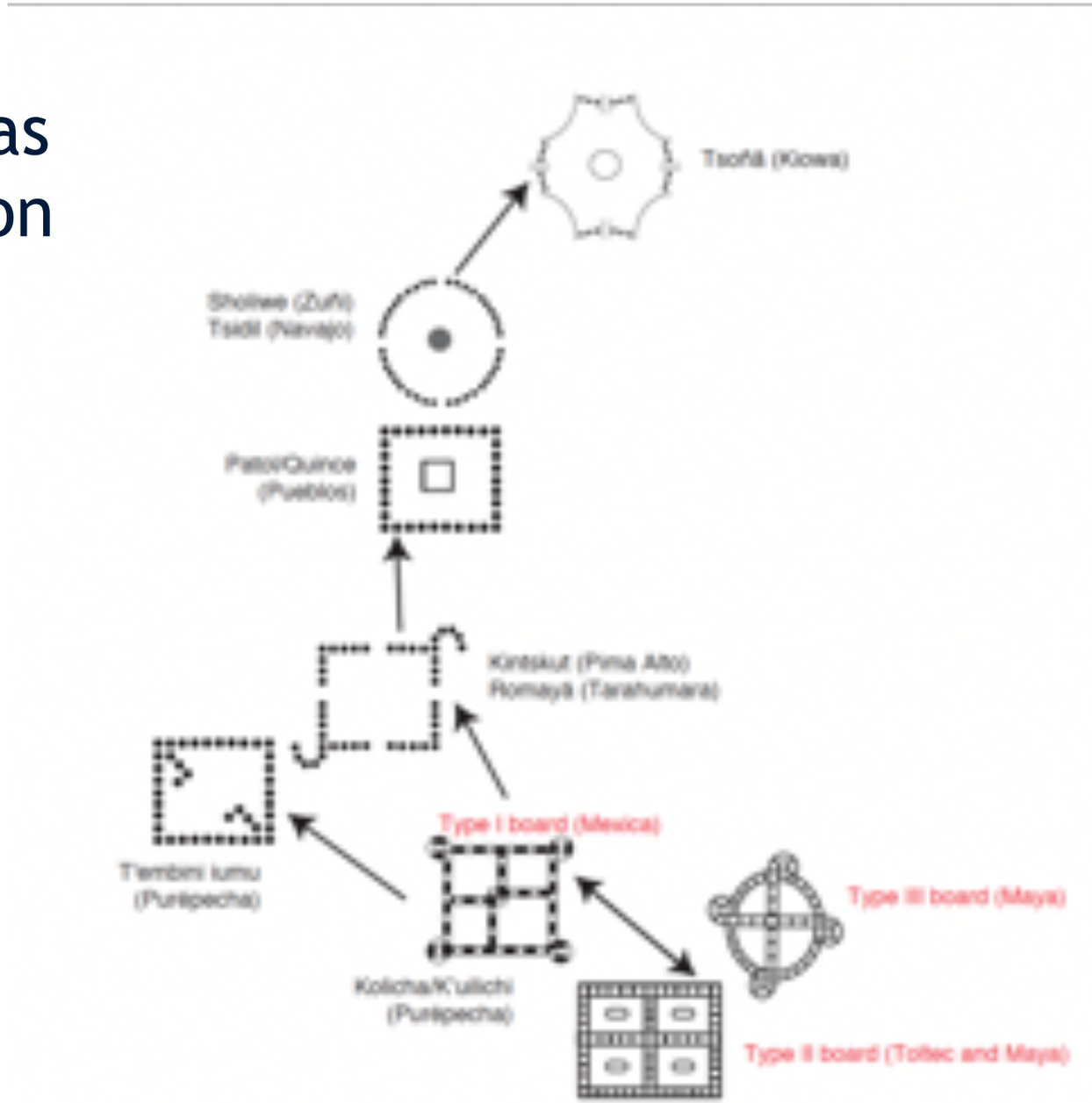
Cultural Transmission Theory

Games
- Vehicles for transmission of ideas
- Transerred from person to person

Ludemes
- Packages which are transmitted
- DNA of games

Ludemic Distance
- Number of steps required to change one game into another



Evolution of Mesoamerican board games
(after Depaulis 2018)

Computational Phylogenetics

Ludemic distance allows phylogenetic analysis
- Horizontal rule transmission

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

2. **Ancestral State Reconstruction**
   - Identify likely traits in ancestors

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

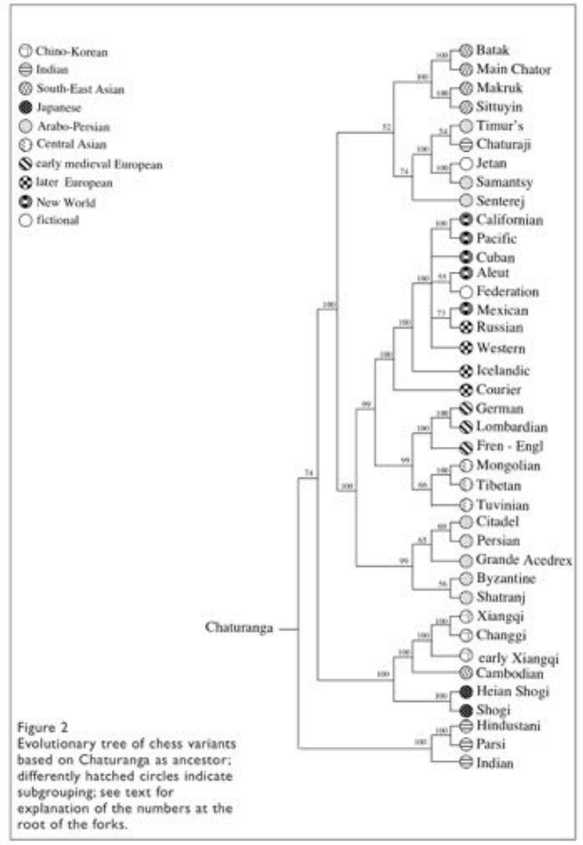
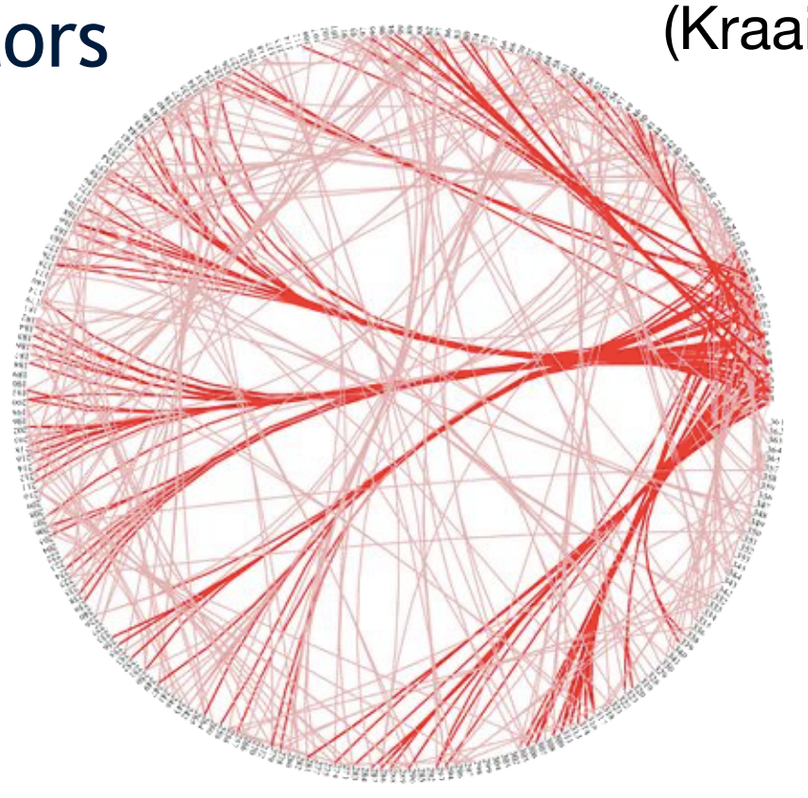


Figure 2
Evolutionary tree of chess variants based on Chaturanga as ancestor; differently hatched circles indicate subgrouping; see text for explanation of the numbers at the root of the forks.

Phylogeny of Chess

(Kraaijeveld 2000)



Horizontal Influence Map

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Data Gathering

Sources:
- Artifacts
- Rules texts
- Artwork depictions
- Ethnography
- Historical accounts

Ludus Latrunculorum board (Sabratha)

Walter documenting a **58 Holes** board (Azerbaijan)

Two men playing **Bao** (Malawi)

Data to be Gathered

Data per piece of evidence:

- Name
- Location
- Date
- Game rules
- Social status
- Gender of players
- Age of players
- Spaces in which people played
- Source
- **Confidence**

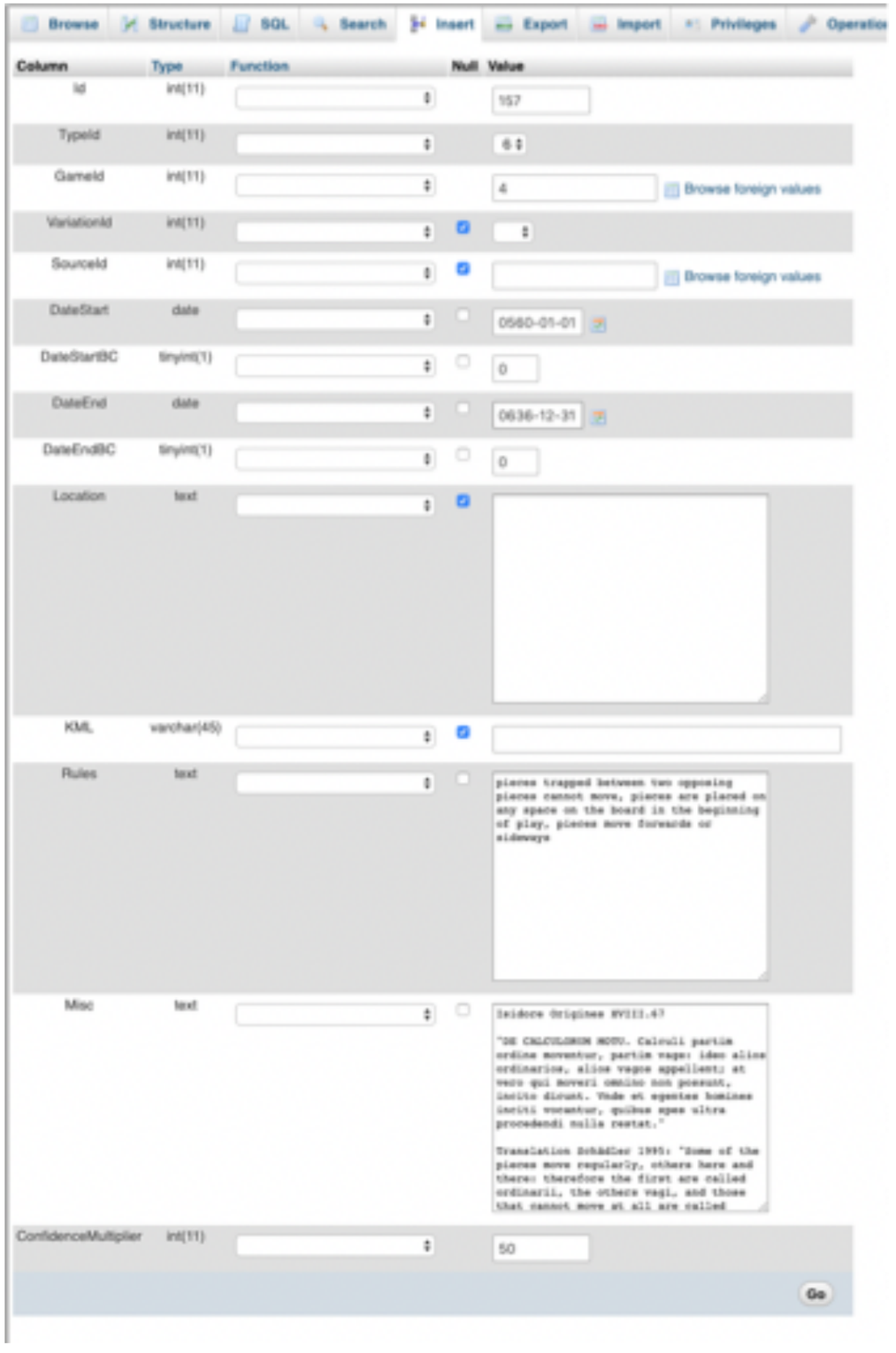
Data to be Gathered

Data per game:

- Name
- Ludemic descriptions of variants and reconstructions (*.lud files)
- Period
- Region
- Cross-reference known evidence
- Source(s)
- **Confidence** (incorporates evidential confidence)

Historical/cultural profile per game

- Also for component ludemes



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What Can We Do With This?

Derive historical/cultural context for each
- Game
- Ludeme

Evaluate known reconstructions for
- Plausibility
- Quality

Generate own reconstructions, maximising for
- Plausibility
- Quality

Provide a distribution of reconstructions per game,
ranked by plausibility and quality

GeaCron

Geo-temporal database
- Project partners

Yearly maps:
- 3,000BC — today
- 2,000 cultures

Viking route from Norway to Paris (845AD)

IN: GPS + date:

OUT: Civilisation + nation + landmarks + events + routes

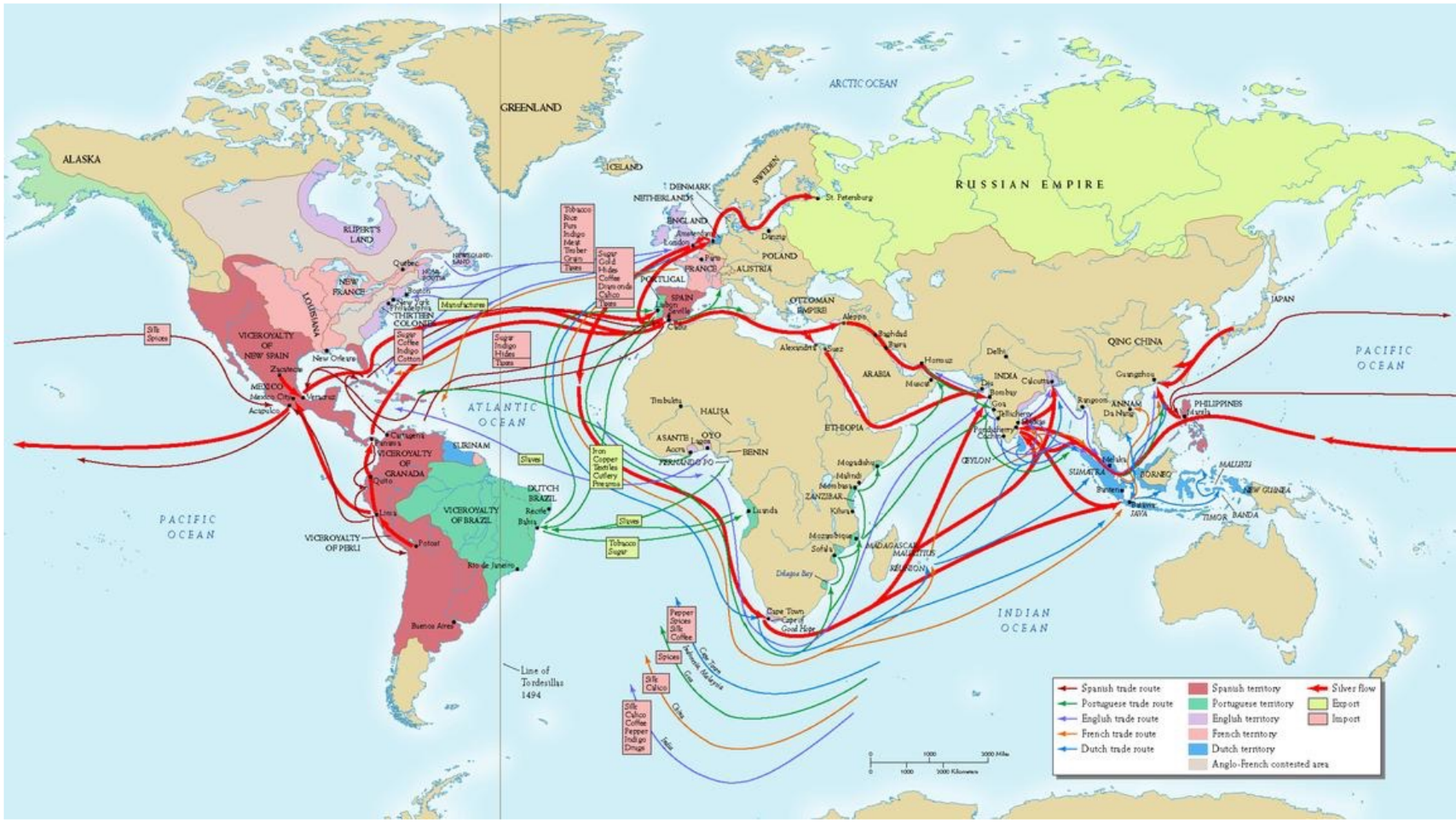
Spread of Games

Chart spread of games/ludemes throughout human history

Correlate with:

- Trade routes
- Explor. routes
- Military camp.ns
- Crusades
- Diasporas
- *etc.*

GeaCron have provided 275 known routes



Colonial trade routes (1890s)

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Silk Road Trade Routes

Very important in the history of games

- Fertile crescent:
  - Egypt
  - Sumeria
- Middle East
- India
- Asia

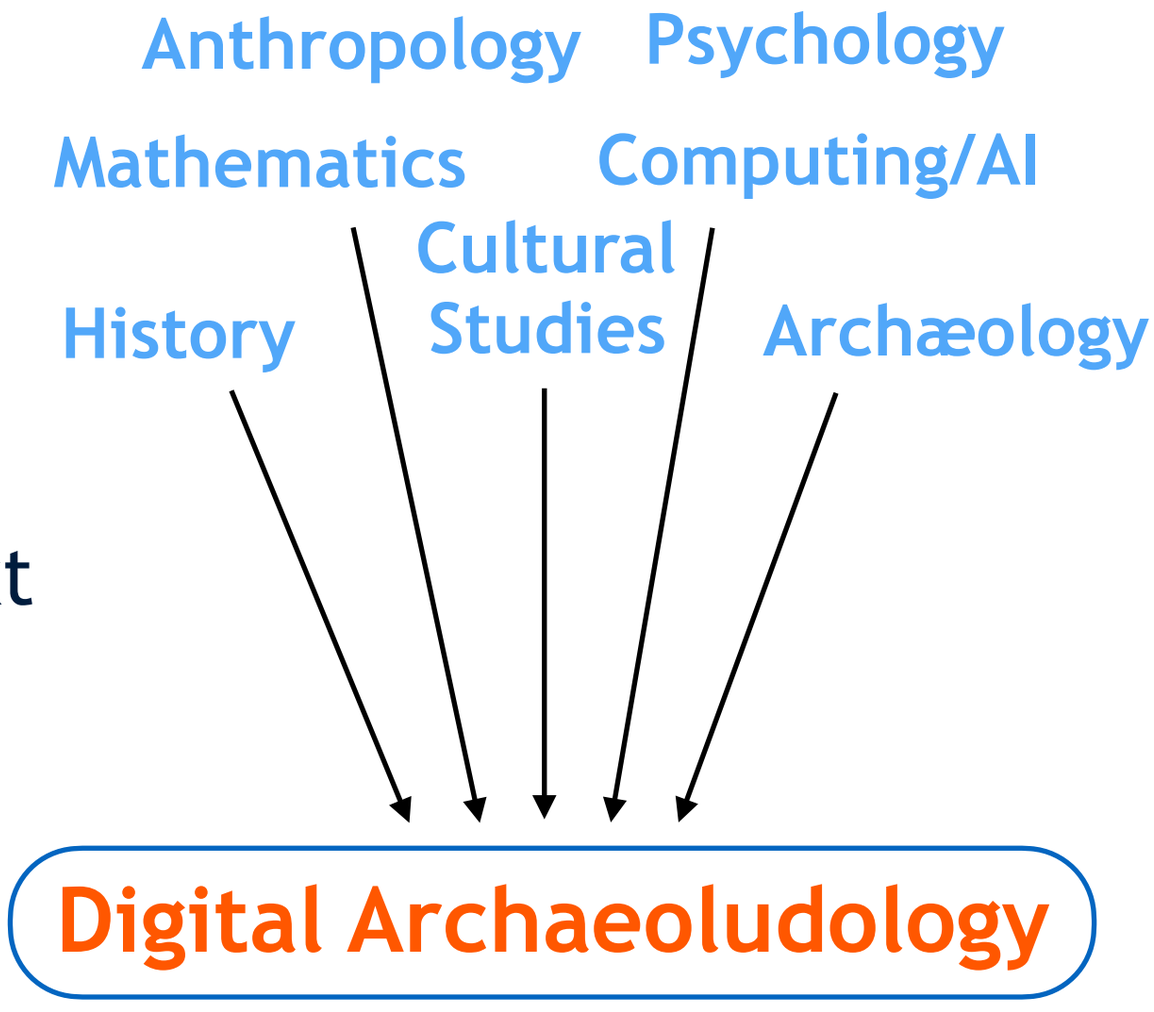
Map 12.1 The silk roads,

Digital Archaeoludology

Traditional game studies:
- Wealth of historical analysis
- Little mathematical analysis

Modern game AI studies:
- Huge surge in recent research
- Maths based, no historical context

Seek to bridge this gap
- Single unified research field

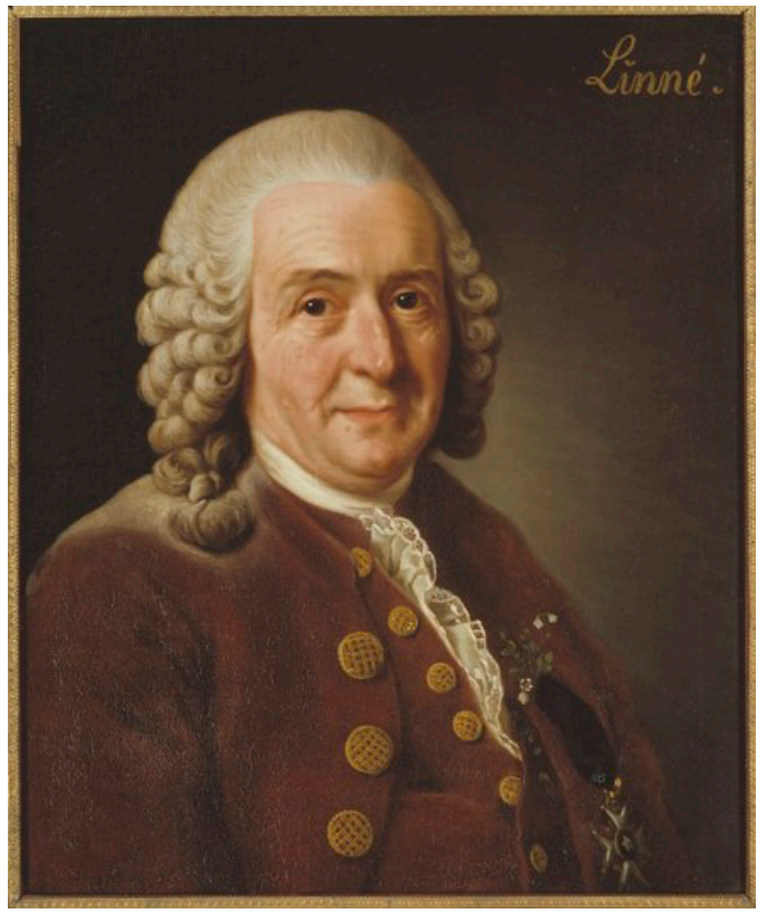


DAL: *Use of modern computational techniques to harness the available evidence and improve our understanding of ancient games*

Case Study

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

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



Carl Linnaeus (1707–1778)

Smith (1811)
- Translated into English

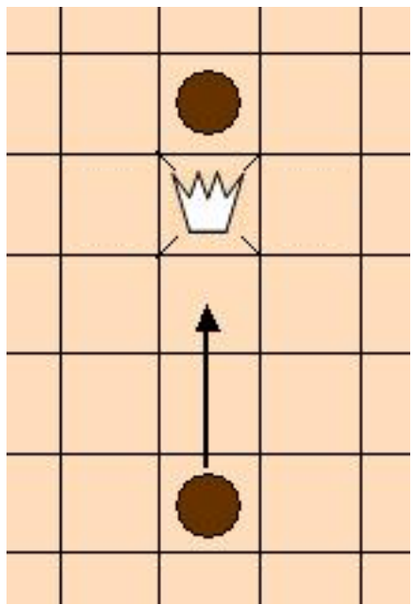
Murray (1913) *History of Chess*
- Published rules, became de facto

Case Study

BUT…

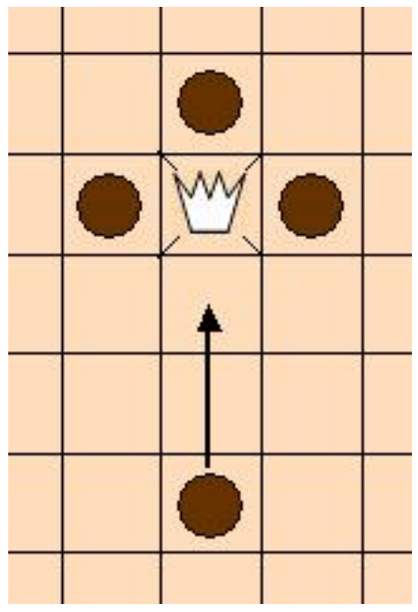
Smith made a
bad translation of
the king capture rule

A. “likewise the king”
   - Flanked
   - Easy to capture



B. “except the king”
   - Surrounded
   - Hard to capture

[DEMO]



Forensic Game Reconstruction

Given partial evidence, reconstruct the rules

e.g. Poprad Game (Slovakia)
- Tomb dated to 375AD
- Germanic chieftain

Equipment
- 17x15/16 grid
- 2 x Colours
- 1 or 2 x Sizes?

Ulrich Schadler (2018)
- “An impossible task”
- Ludii could help

Forensic Game Reconstruction

(players White Black)
(board (rect 17 16)) or (board (rect 17 15))
(pieces (disc White)(disc Black)) or
(pieces (disc White)(disc Black 1)(disc Black 2)) or
(pieces (disc White 1)(disc White 2)(disc Black 1)(disc Black 2))

(start *)
(play *)
(end *)

Use historical context

- Prioritise plausible rules
- Maximise game quality

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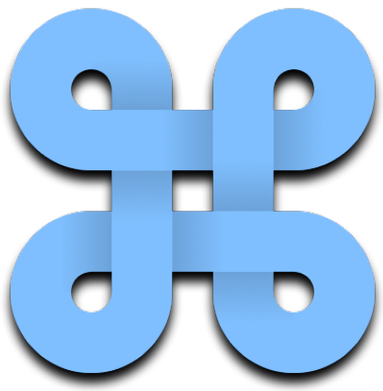
Conclusion

Thank You!

Questions?



http://ludii.games

Digital Ludeme Project

http://ludeme.eu

European Research Council

Established by the European Commission

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