

# Systems Theory in Design

## Nodes, links, and networks

A key aspect of systems is the relationship between elements — the system's structure.

Today, we will look at three related topics:

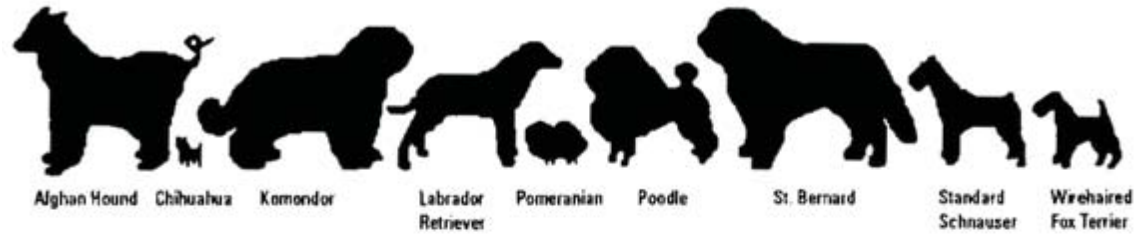
- **Information structures**
- **Communications within networks**
- **Counting and measuring**

# Information Structures

# Wurman offers “LATCH” as a set of organizing principles

## Location, Alphabet, Time, Category, or Hierarchy — a mixed list

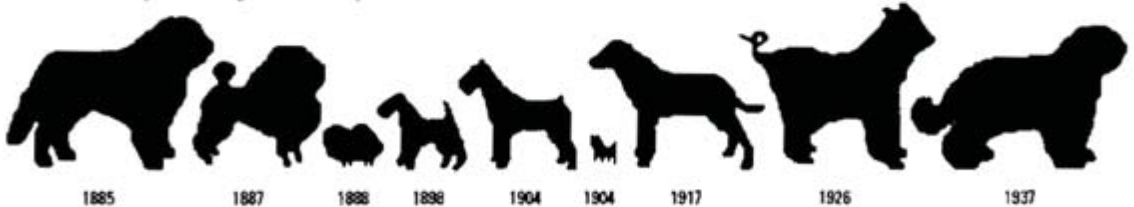
I could organize these dogs alphabetically...



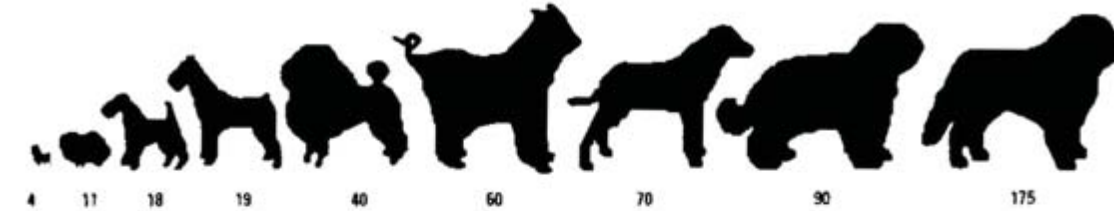
or by category (country of origin, for example)



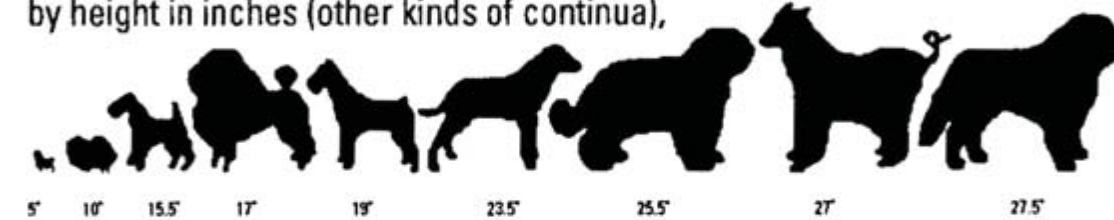
or by time (for instance, according to the year in which the breed was officially recognized by the American Kennel Club).



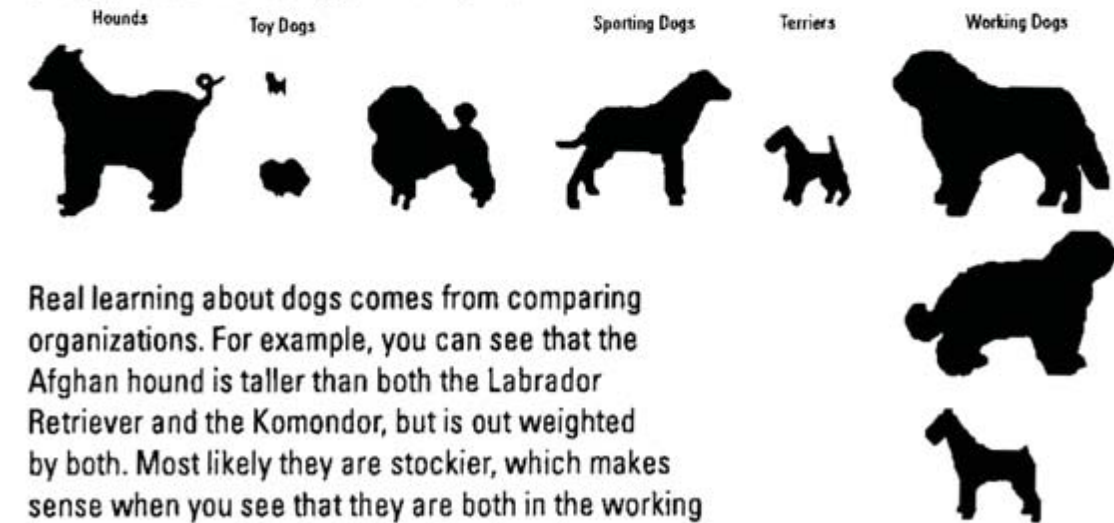
Then again, I might arrange them by weight in pounds,



by height in inches (other kinds of continua),



or by breeds as categorized by the American Kennel Club.



Real learning about dogs comes from comparing organizations. For example, you can see that the Afghan hound is taller than both the Labrador Retriever and the Komondor, but is out weighted by both. Most likely they are stockier, which makes sense when you see that they are both in the working dogs category while the Afghan is a hound.

Wurman, Richard Saul, *Information Anxiety*, Double Day, New York NY (1989) pg.71-72

# Ethnographic Frameworks suggest ways of cataloging systems.

## **AEIOU**

Activity

Environment

Interaction

Object

User

## **POEMS**

People

Objects

Environment

Messages

Services

## **Ax4**

Actors

Activities

Artifacts

Atmosphere

# Information structures decompose into half-a-dozen basic forms —

**“primitives”:**

- **Name-Value Pairs**
- **Nodes + Links**
- **Array**
- **Matrix**
- **Tree**
- **Web**

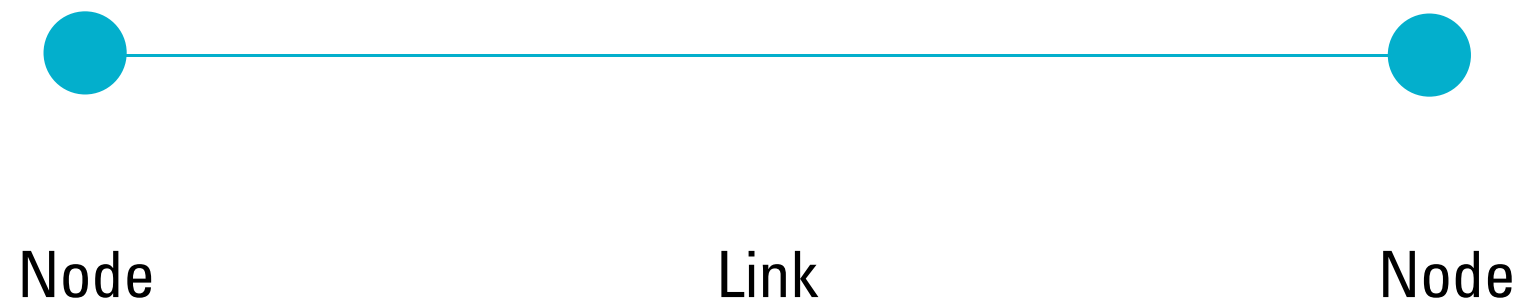
**Points or name-value pairs —**  
 **$x = 3.1415$**

# Name-Value Pairs — variable + the current instance

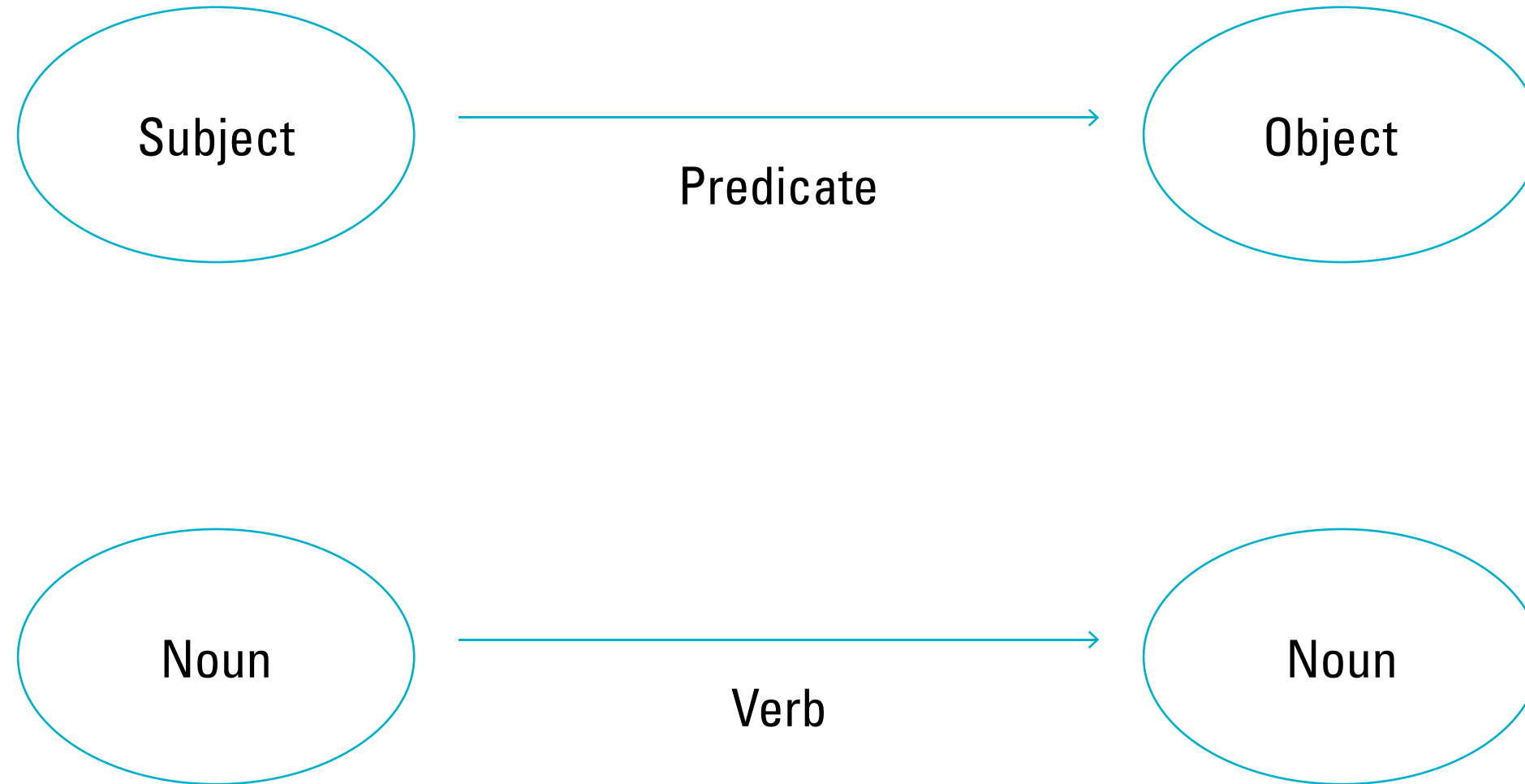
Key	Value
firstName	Bugs
lastName	Bunny
location	Earth



# Nodes + Links — also entities + relationships

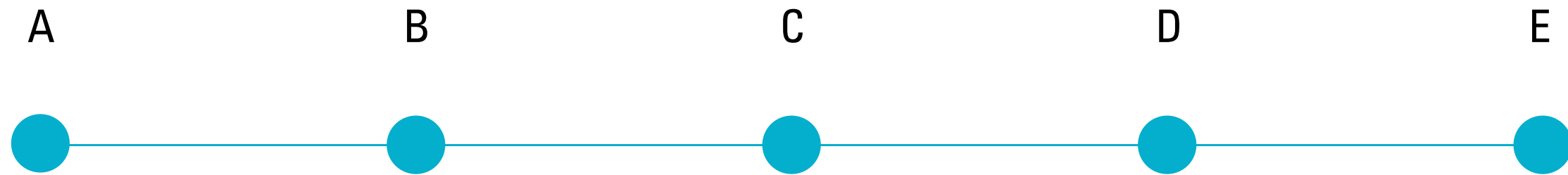


# RDF example — Resource Description Framework, an internet standard

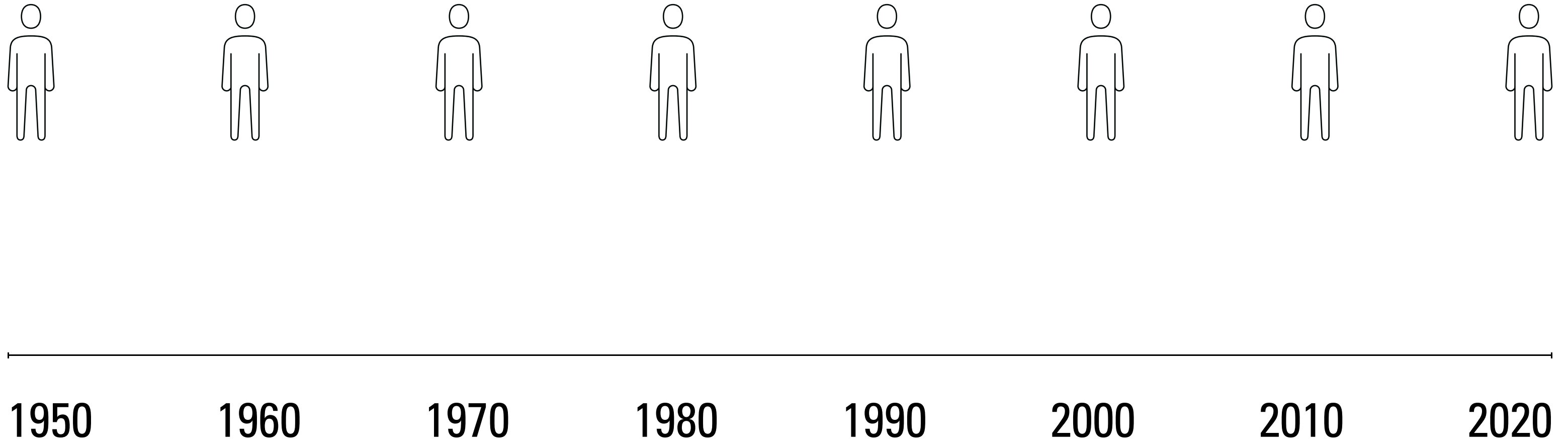


# Lines or arrays

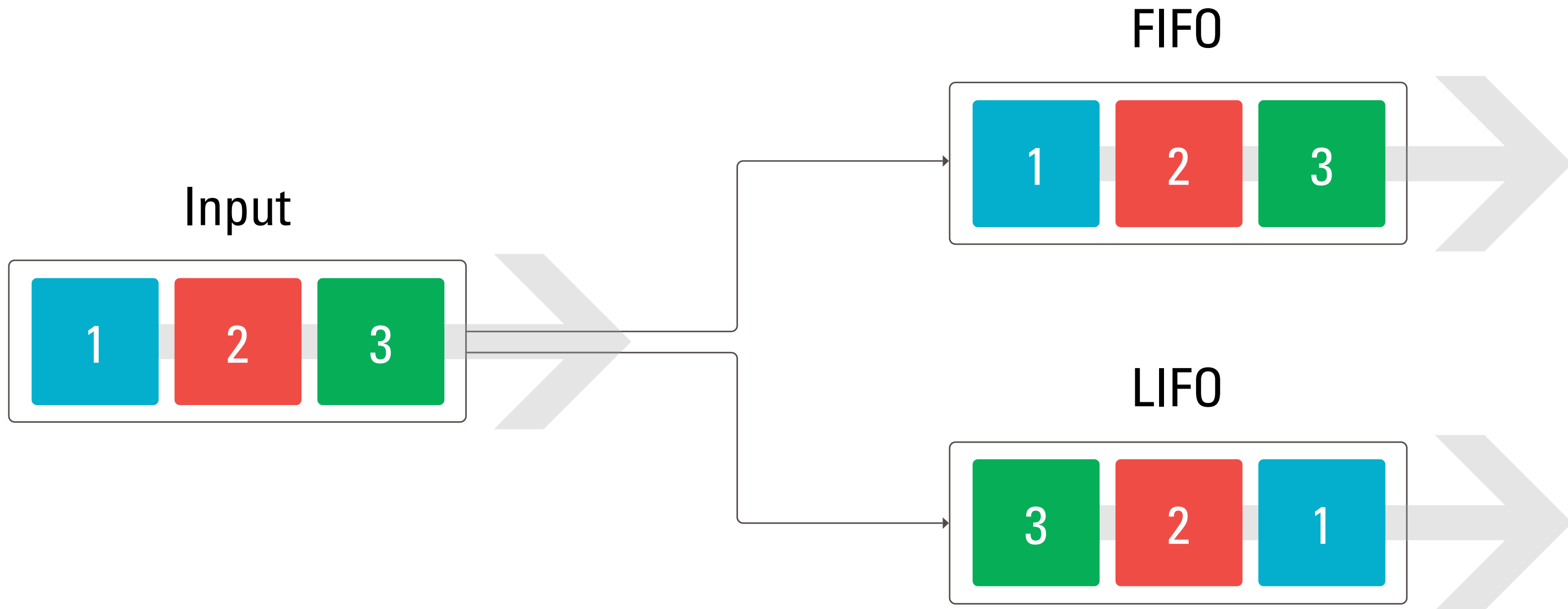
# Array — a “string” or list — may be a process, journey, or path



# A queue or timeline may also be thought of as an array.

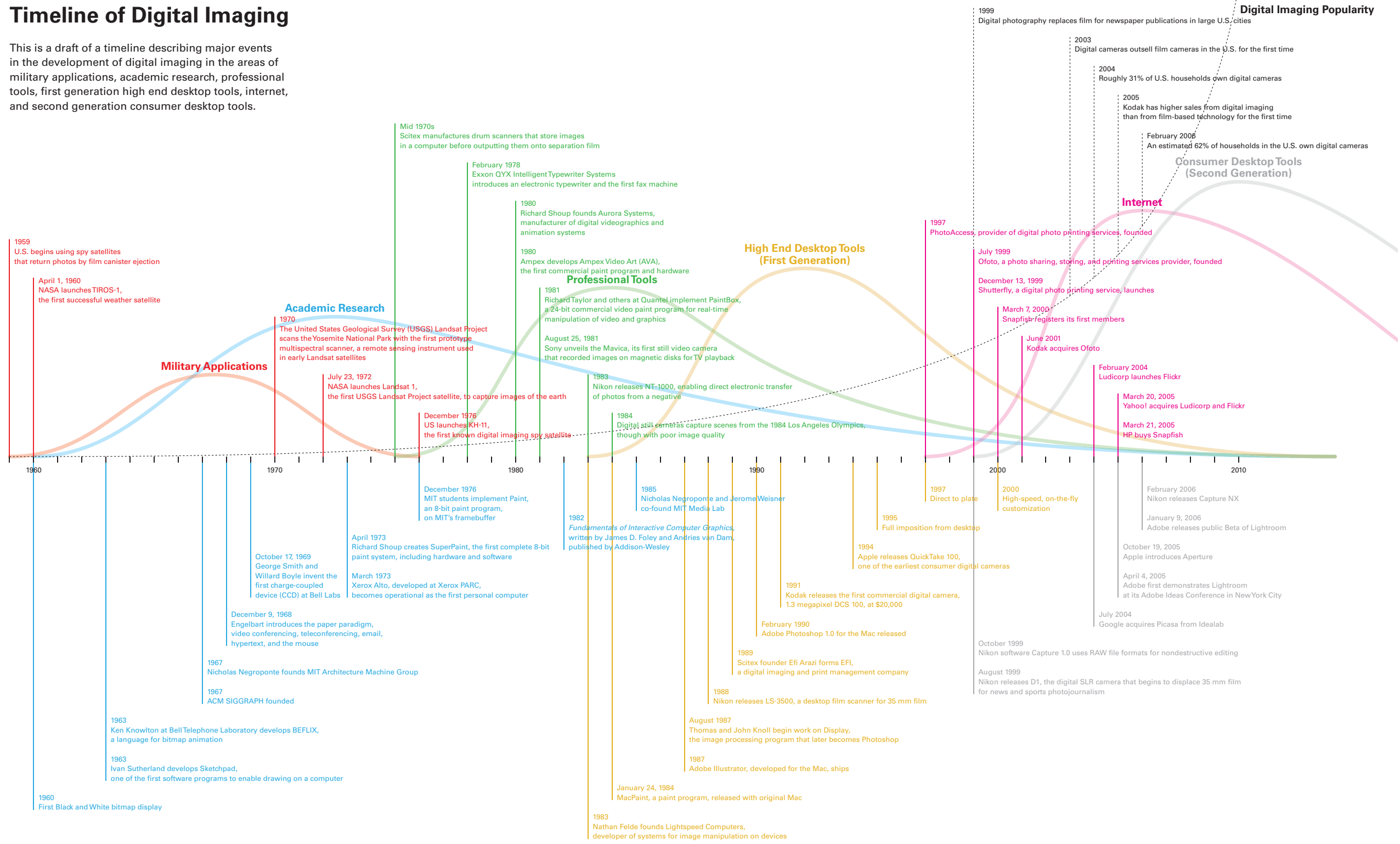


# In programming, “the stack” is also an array, which may be organized FIFO, First In, First Out LIFO, Last In, First Out



# Timeline of Digital Imaging

This is a draft of a timeline describing major events in the development of digital imaging in the areas of military applications, academic research, professional tools, first generation high end desktop tools, internet, and second generation consumer desktop tools.



Version 1.3  
Dubberly Design Office  
March 9, 2006

# Cybernetics and Systems Design Timeline

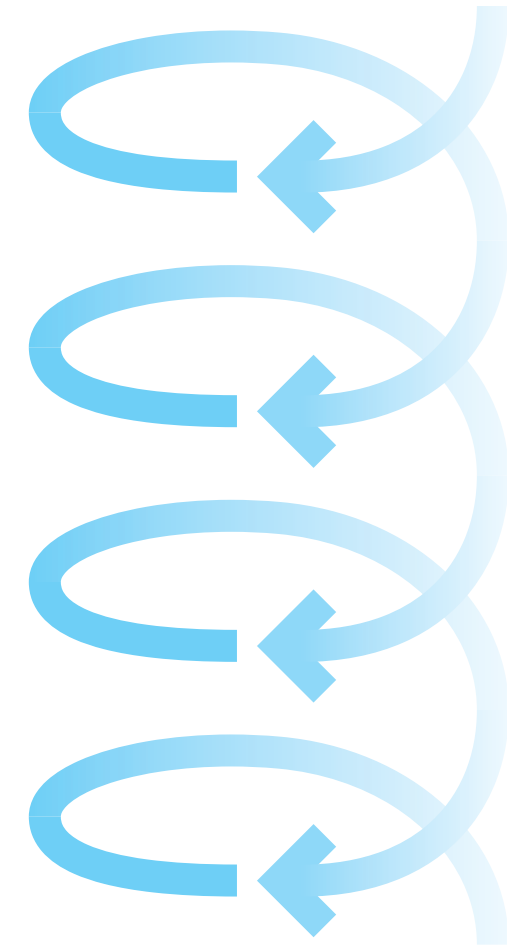
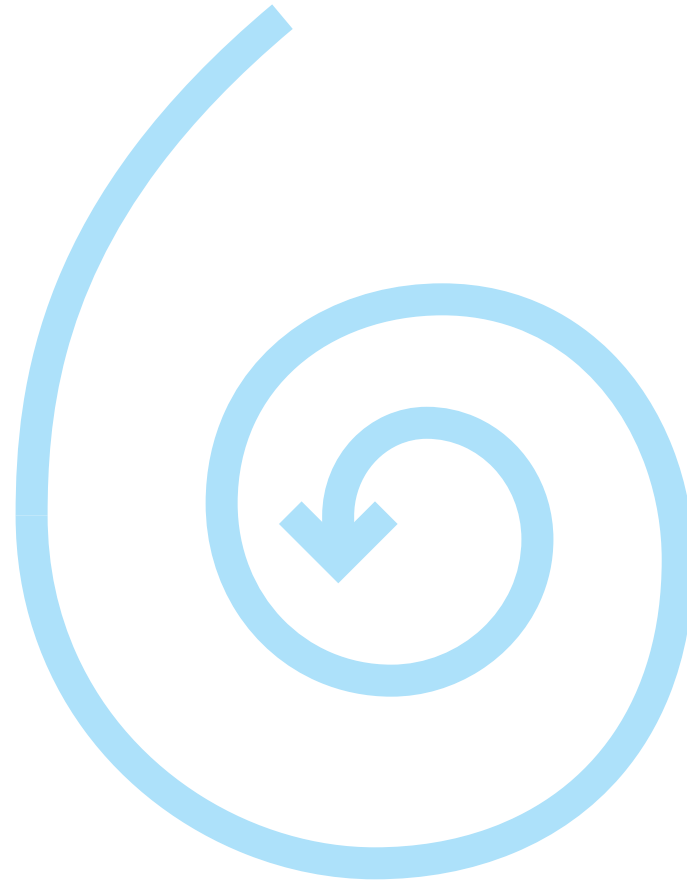
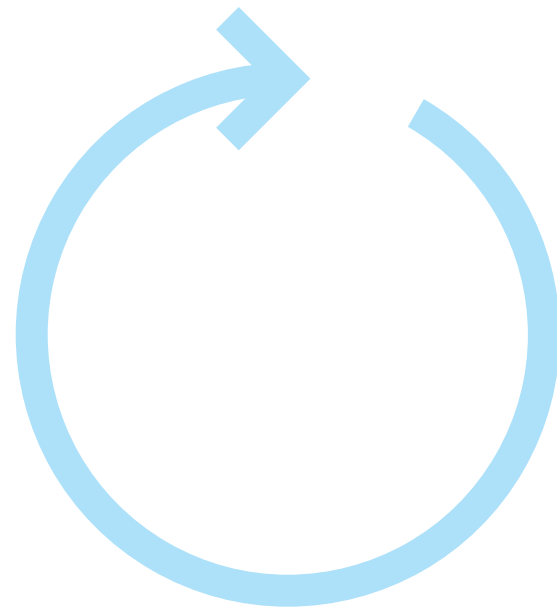
This timeline describes major events in the development of cybernetics, operations research, systems analysis, systems engineering, and systems design (compiled in 2002).





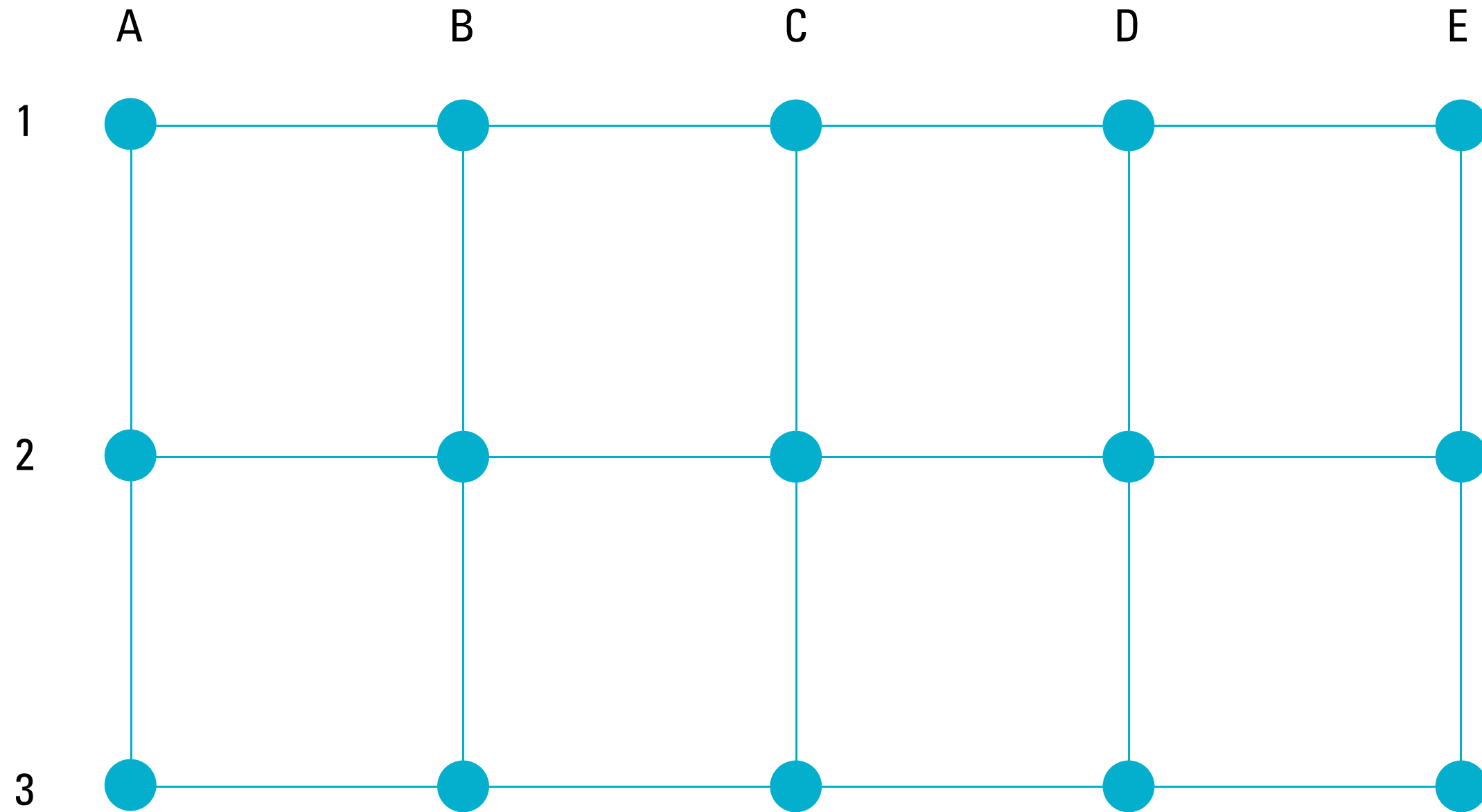


# A process may also be represented as a loop, spiral, or helix.



# Plane or Matrices

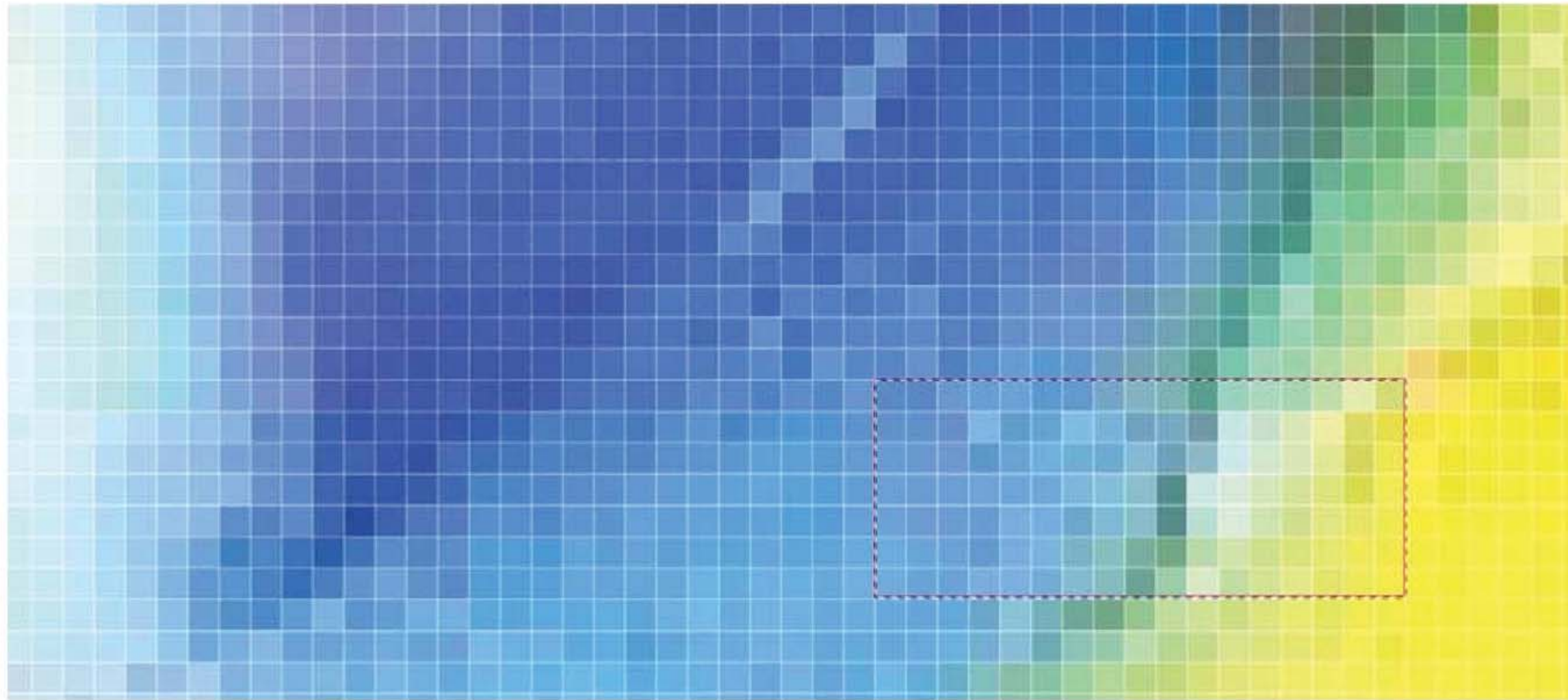
# Matrix — also table or “flat file”



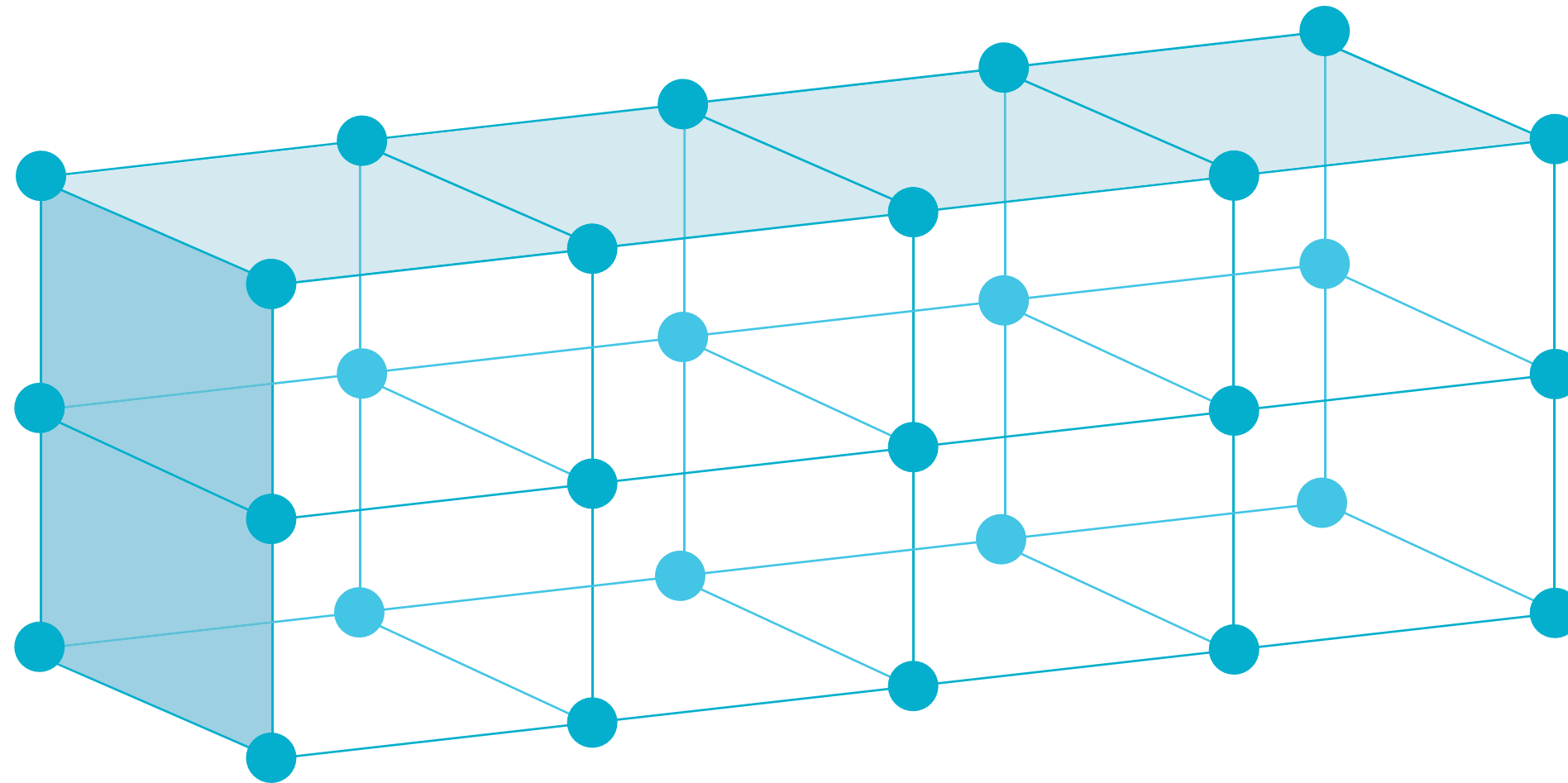
# A spreadsheet is a classic matrix structure: rows and columns.

◇	A	B	C	D
1		<b>FY 10</b>	<b>FY 11</b>	
2	Jan	1	2	
3	Feb	3	4	
4	March	5	6	
5	April	7	8	
6				
7	<b>Totals</b>	16	=SUM(C2:C5)	
8				
9				
10				

**A digital image also has a matrix structure; the file header defines the number of rows + columns.**



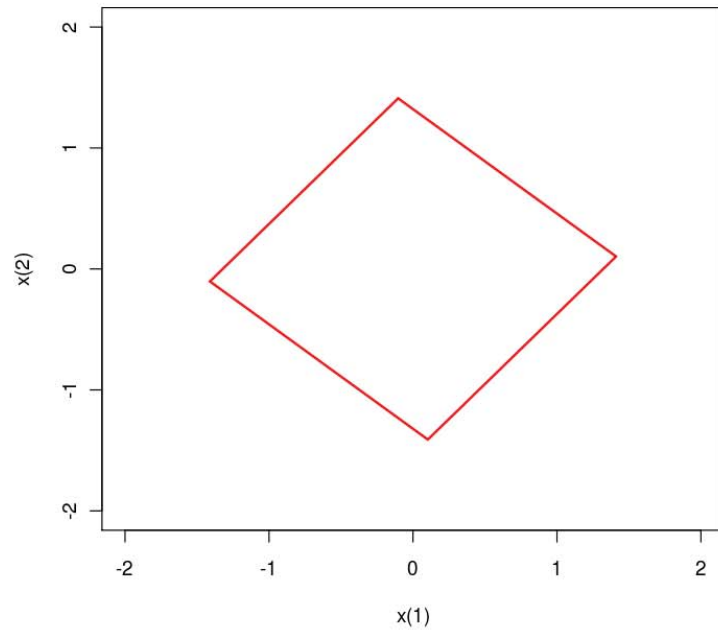
# A matrix may be 3D.



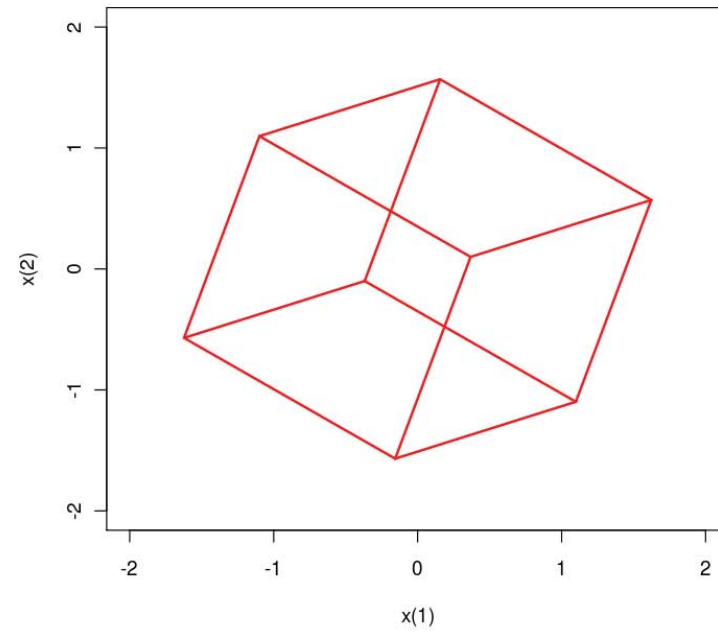


# Or 4D or more dimensions.

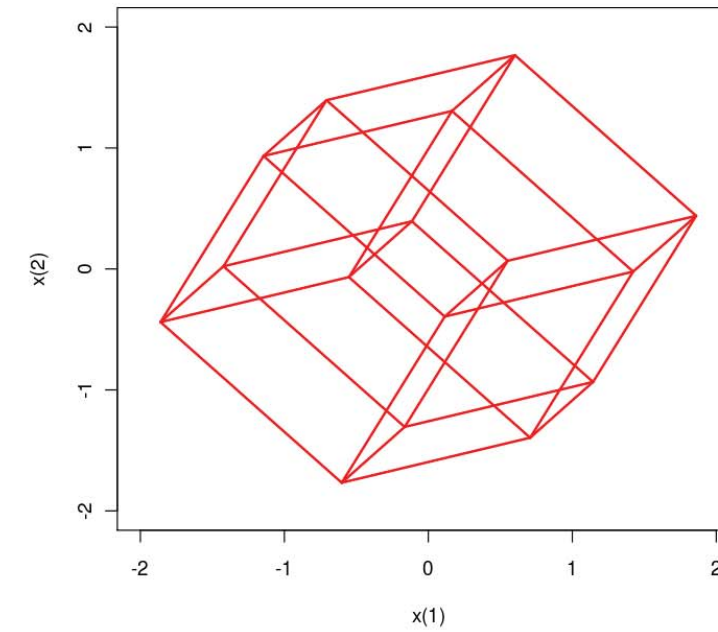
2-d hypercube



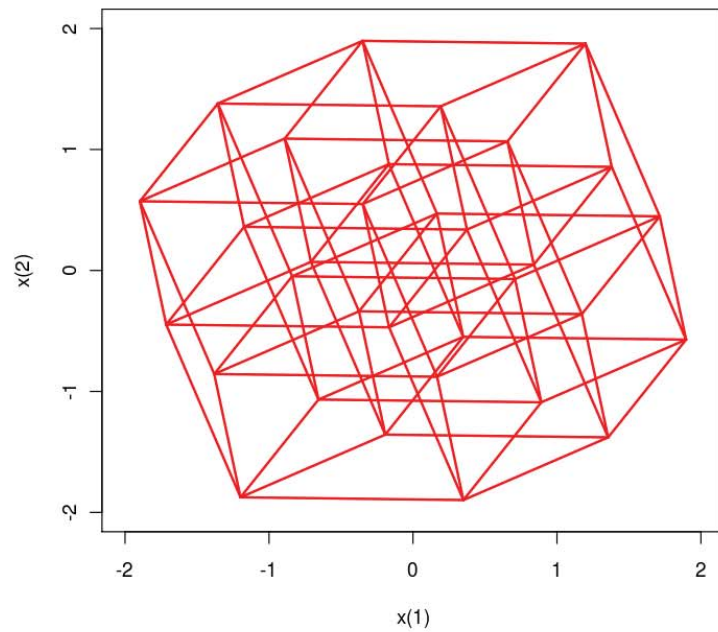
3-d hypercube



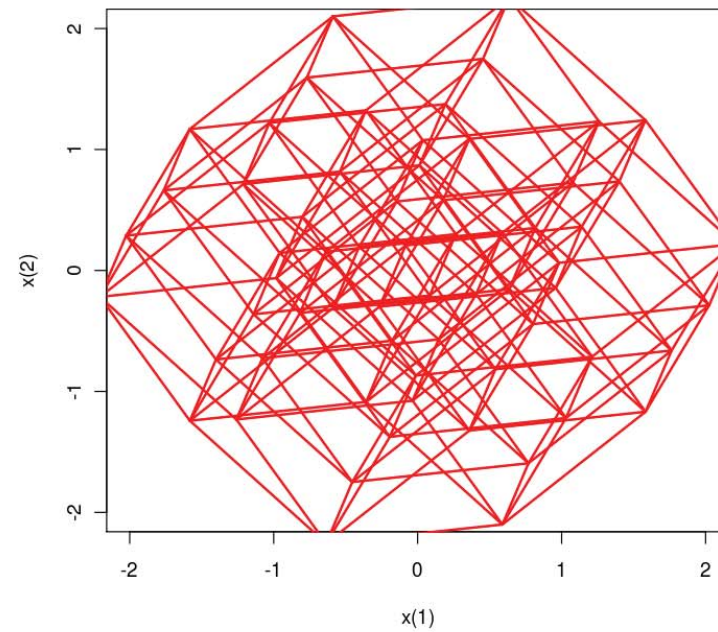
4-d hypercube



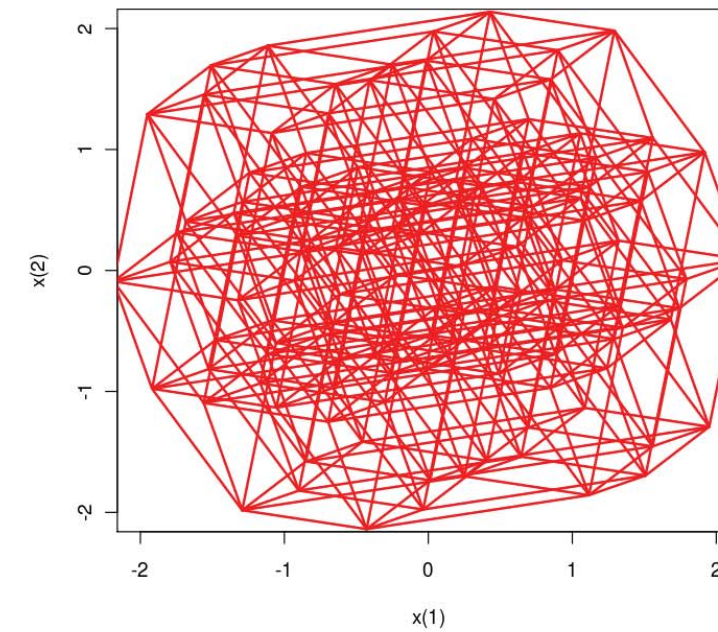
5-d hypercube



6-d hypercube



7-d hypercube





**E.g., A well organized stockroom is a “walk-in matrix”.**



# Pivot tables

A tool that allows you to summarize and explore large sets of data into a meaningful report.

	A	B	C	D	E	F	G	H	I
1	<b>Source Data for Pivot Table</b>								
2	Date	Qtr	Year	Customer	Region	Product	Quantity	Revenue	
3	01/05/13	Q1	2013	Customer 4	West	Product 9	15	270	
4	03/12/13	Q1	2013	Customer 1	Midwest	Product 3	20	200	
5	03/14/13	Q1	2013	Customer 6	West	Product 8	25	1,150	
6	03/27/13	Q1	2013	Customer 3	West	Product 1	14	100	
7	04/14/13	Q2	2013	Customer 6	Northeast	Product 7	16	400	
8	04/16/13	Q2	2013	Customer 7	Midwest	Product 5	40	510	
9	04/25/13	Q2	2013	Customer 6	South	Product 3	20	70	
10	04/28/13	Q2	2013	Customer 6	Midwest	Product 6	10	92	
11	07/03/13	Q3	2013	Customer 2	West	Product 7	29	350	
12	07/06/13	Q3	2013	Customer 6	Midwest	Product 7	10	128	
13	07/06/13	Q3	2013	Customer 1	Midwest	Product 7	30	660	



**Pivot Table**

Year: 2014

Sum of Revenue	Q1	Q2	Q3	Q4	Grand Total
Midwest		1,590	2,000	5,170	8,760
Northeast	35	184	660		879
South	483	1,702	15,879		18,064
West	19,263	3,292	2,212	1,740	26,507
<b>Grand Total</b>	<b>19,780</b>	<b>6,768</b>	<b>20,751</b>	<b>6,910</b>	<b>54,209</b>

**PivotTable Fields**

Choose fields to add to report:

- Date
- Qtr
- Year
- Customer
- Region
- Product
- Quantity
- Revenue

MORE TABLES...

Drag fields between areas below:

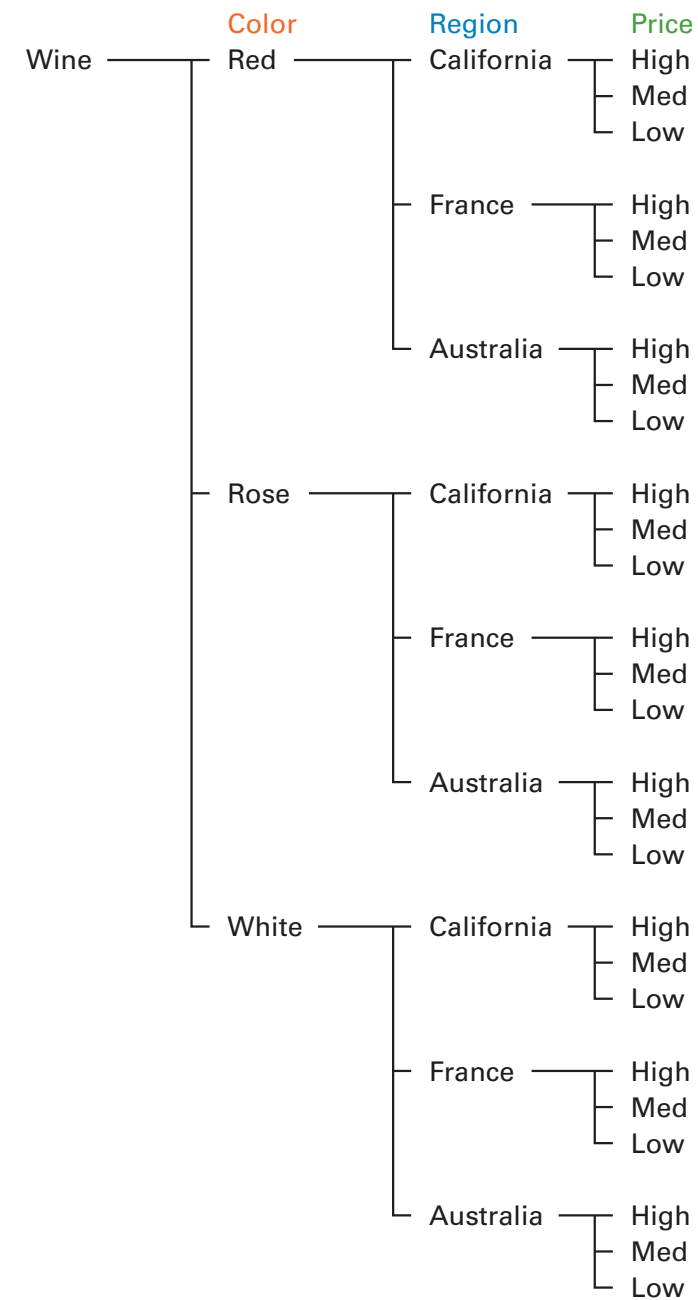
FILTERS	COLUMNS
Year	Qtr

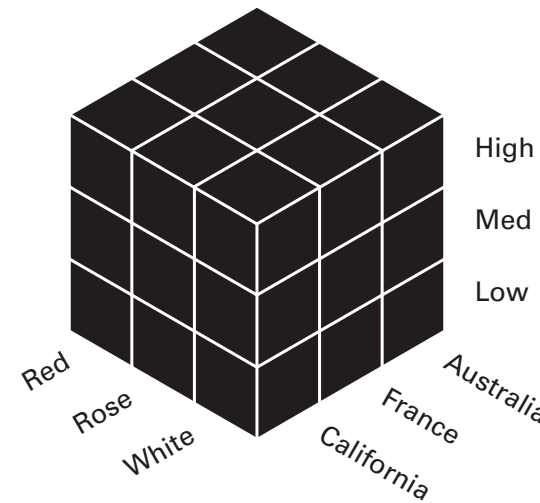
ROWS	VALUES
Region	Sum of Revenue

# A matrix may be represented as a tree (and vice versa), e.g., “all wine”

Tree



Cube



Interface

Criteria:

<input checked="" type="checkbox"/> Red	<input checked="" type="checkbox"/> California	<input checked="" type="checkbox"/> High
<input checked="" type="checkbox"/> Rose	<input checked="" type="checkbox"/> France	<input checked="" type="checkbox"/> Med
<input checked="" type="checkbox"/> White	<input checked="" type="checkbox"/> Australia	<input checked="" type="checkbox"/> Low

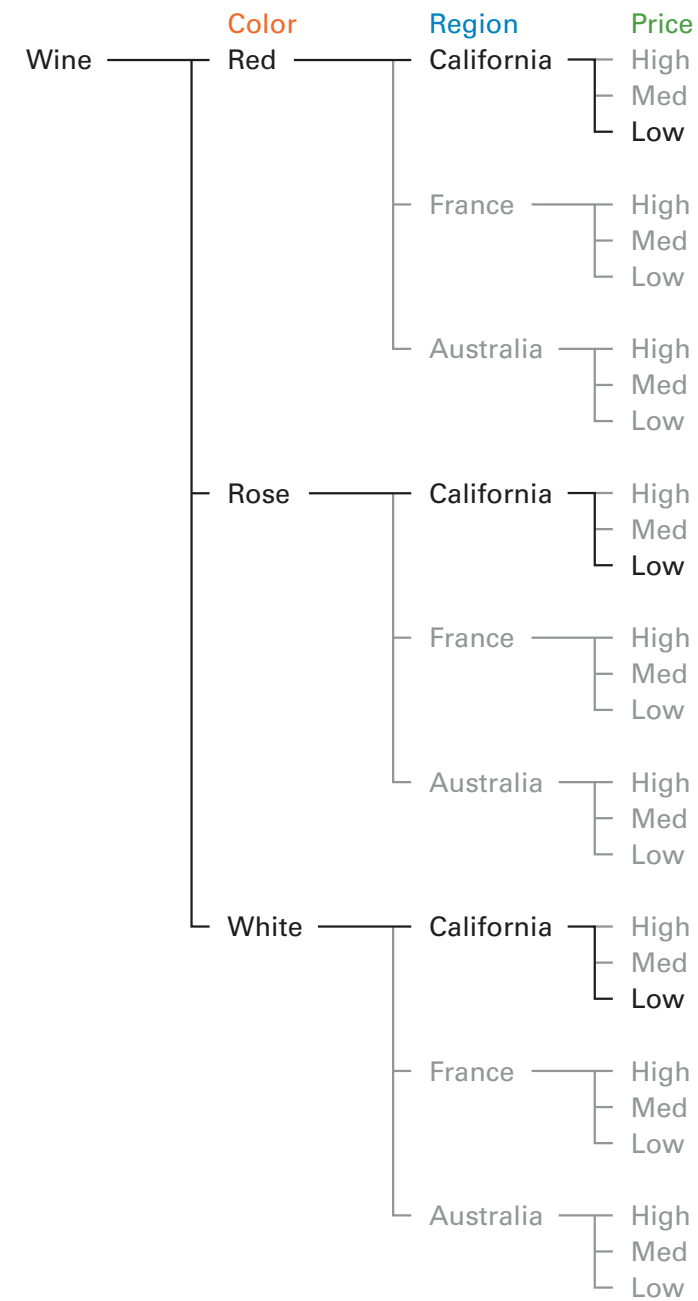
Result:

**27 Bottles**

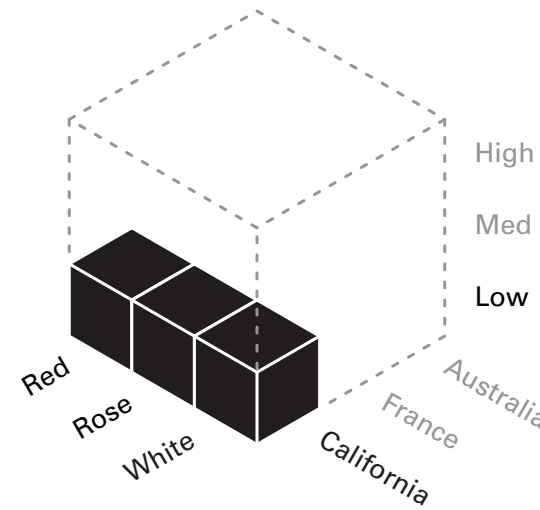
- 1) [Joseph Phelps Insignia](#)
- 2) [Chateau St. Jean Cabernet Sauvignon Sonoma](#)
- 3) [Beaulieu Vineyards Cabernet Sauvignon](#)
- 4) [Chateau Lafite Rothschild](#)
- 5) [Chateau Leoville Barton](#)
- 6) [E. Guigal Cotes du Rhone](#)
- 7) [Penfold's Grange](#)
- 8) [Hewitson L'Oizeau Shiraz](#)
- 9) [Thorne Clarke Shotfire Ridge Shiraz](#)
- 10) [Palmina "Botasea" Rosato](#)

# Filtering narrows selection, e.g., “California, low cost”

Tree



Cube



Interface

Criteria:

<input checked="" type="checkbox"/> Red	<input checked="" type="checkbox"/> California	<input type="checkbox"/> High
<input checked="" type="checkbox"/> Rose	<input type="checkbox"/> France	<input type="checkbox"/> Med
<input checked="" type="checkbox"/> White	<input type="checkbox"/> Australia	<input checked="" type="checkbox"/> Low

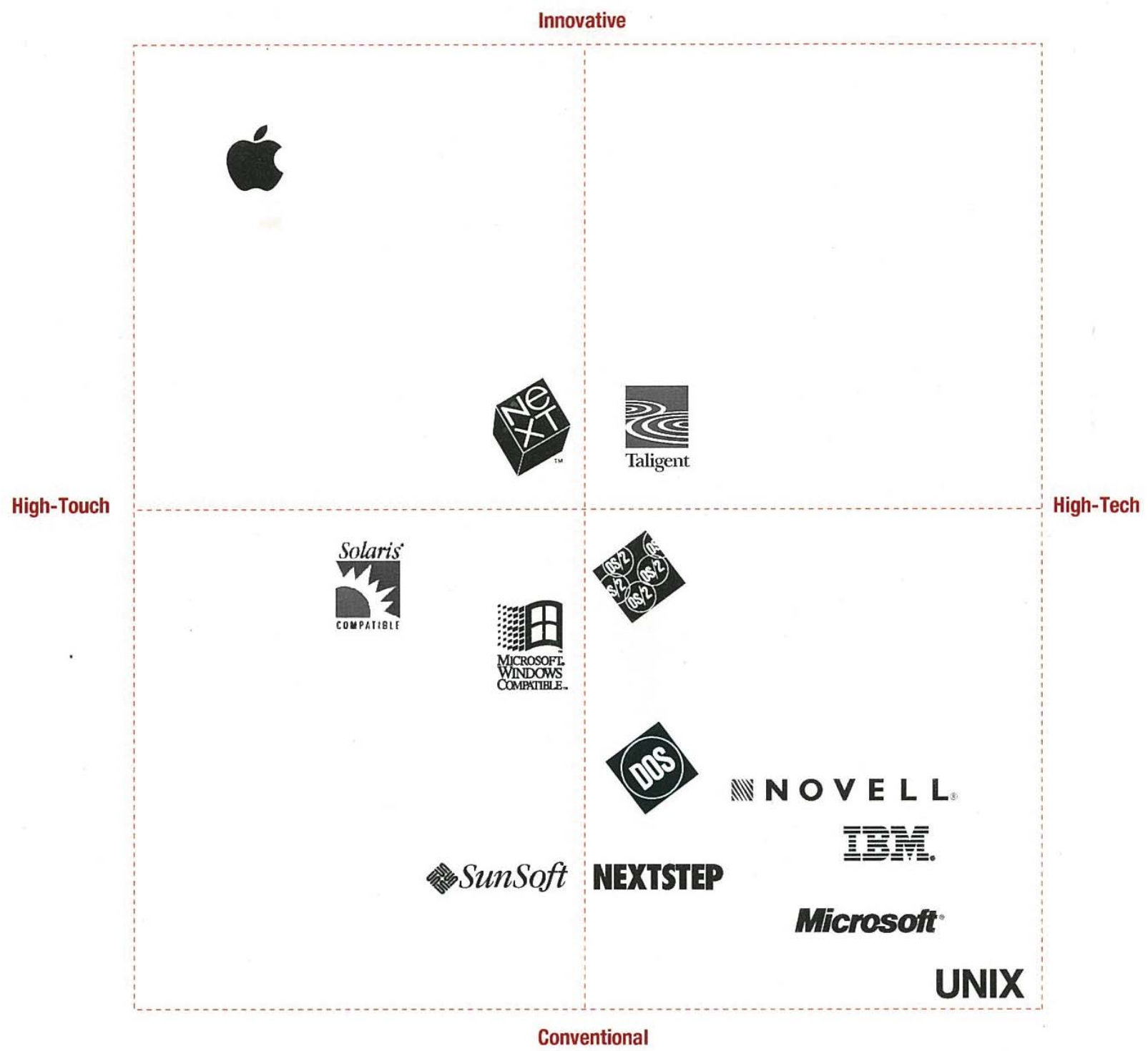
Result:

**3 Bottles**

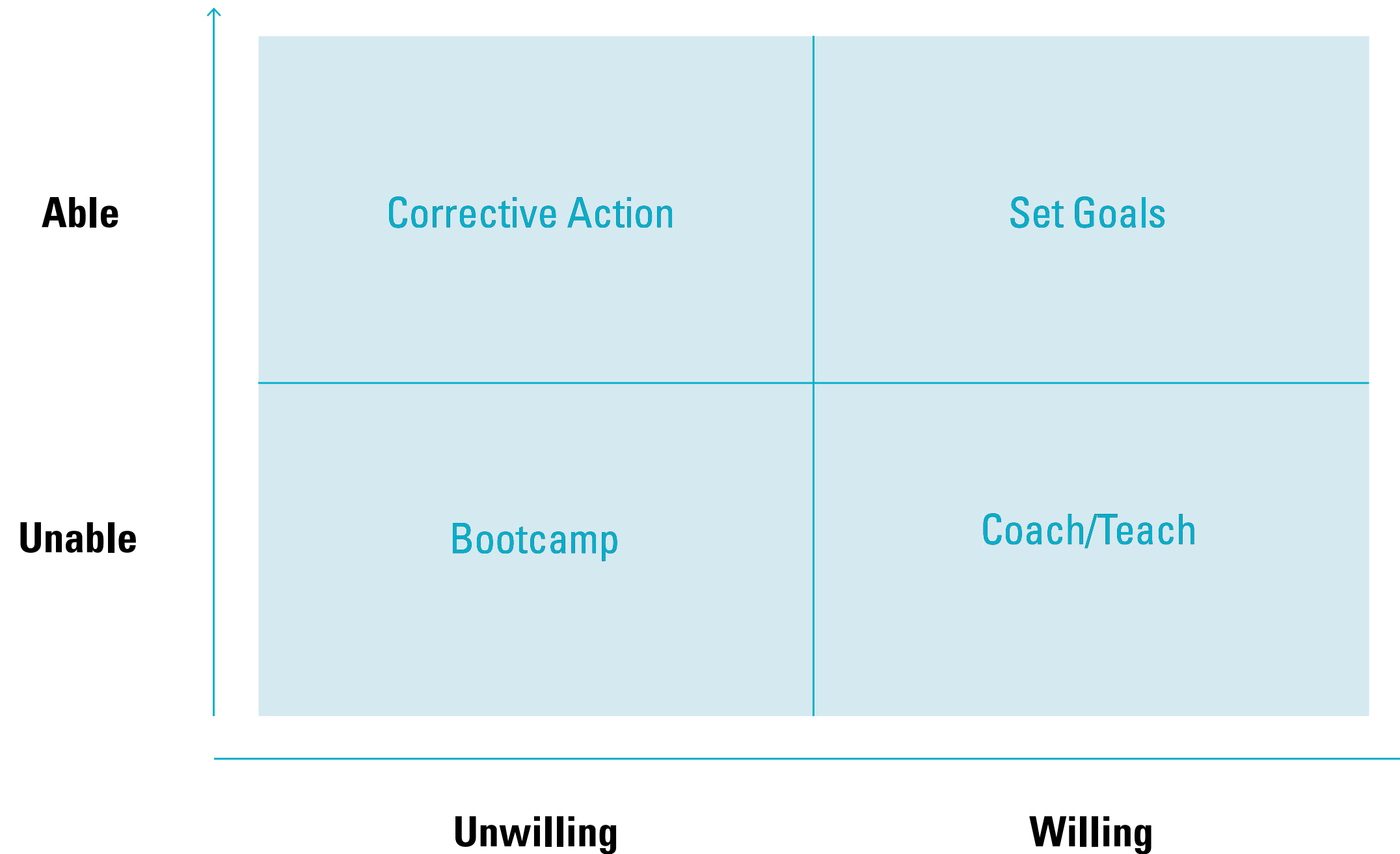
- 1) [La Crema Chardonnay](#)
- 2) [Bonny Doon “Vin Gris de Cigare”](#)
- 3) [Beaulieu Vineyards Cabernet Sauvignon](#)

# 2 x 2s are a type of matrix

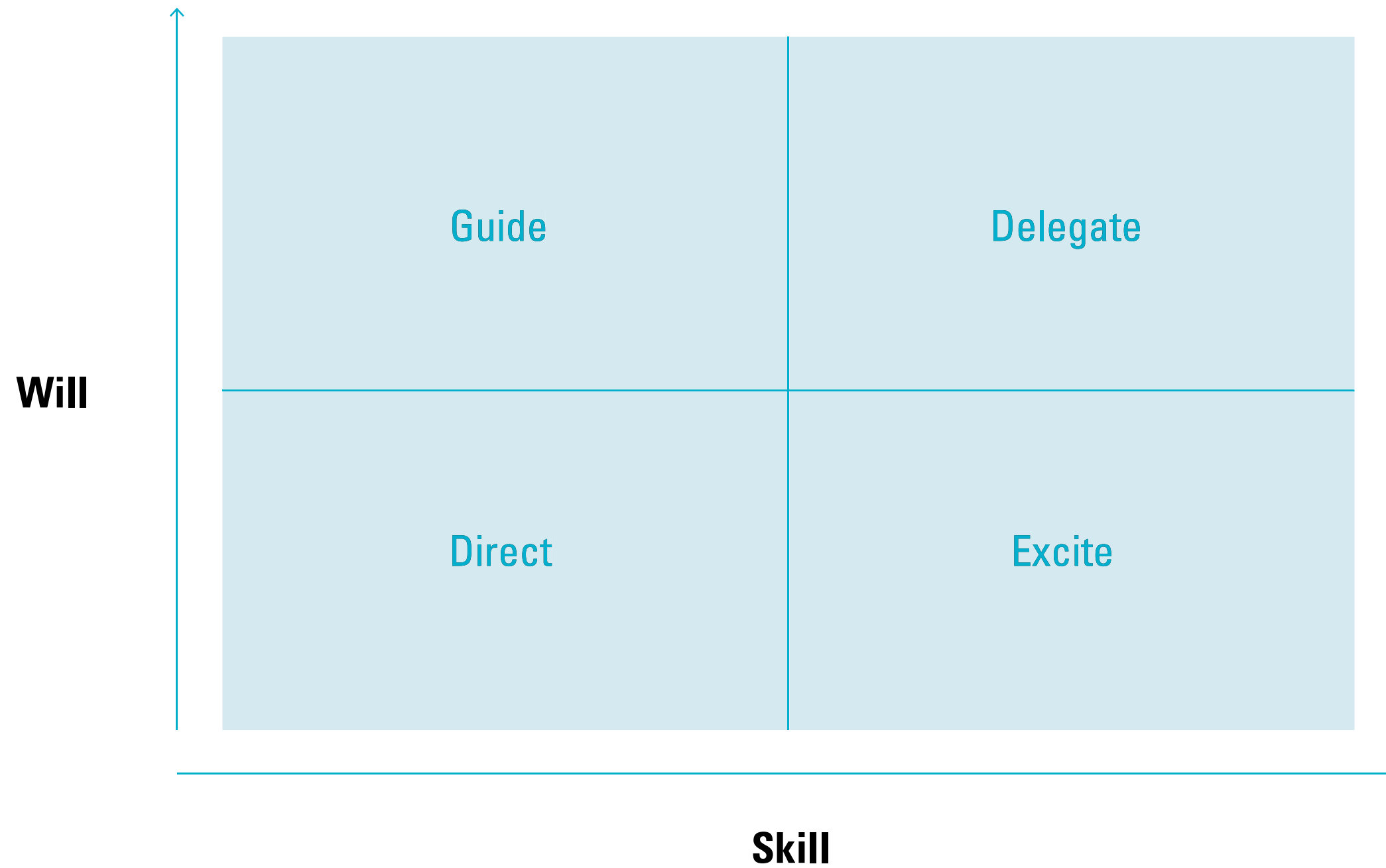
# Perceptual Mapping / Position Map



# Willingness vs Ability — Managerial Responses

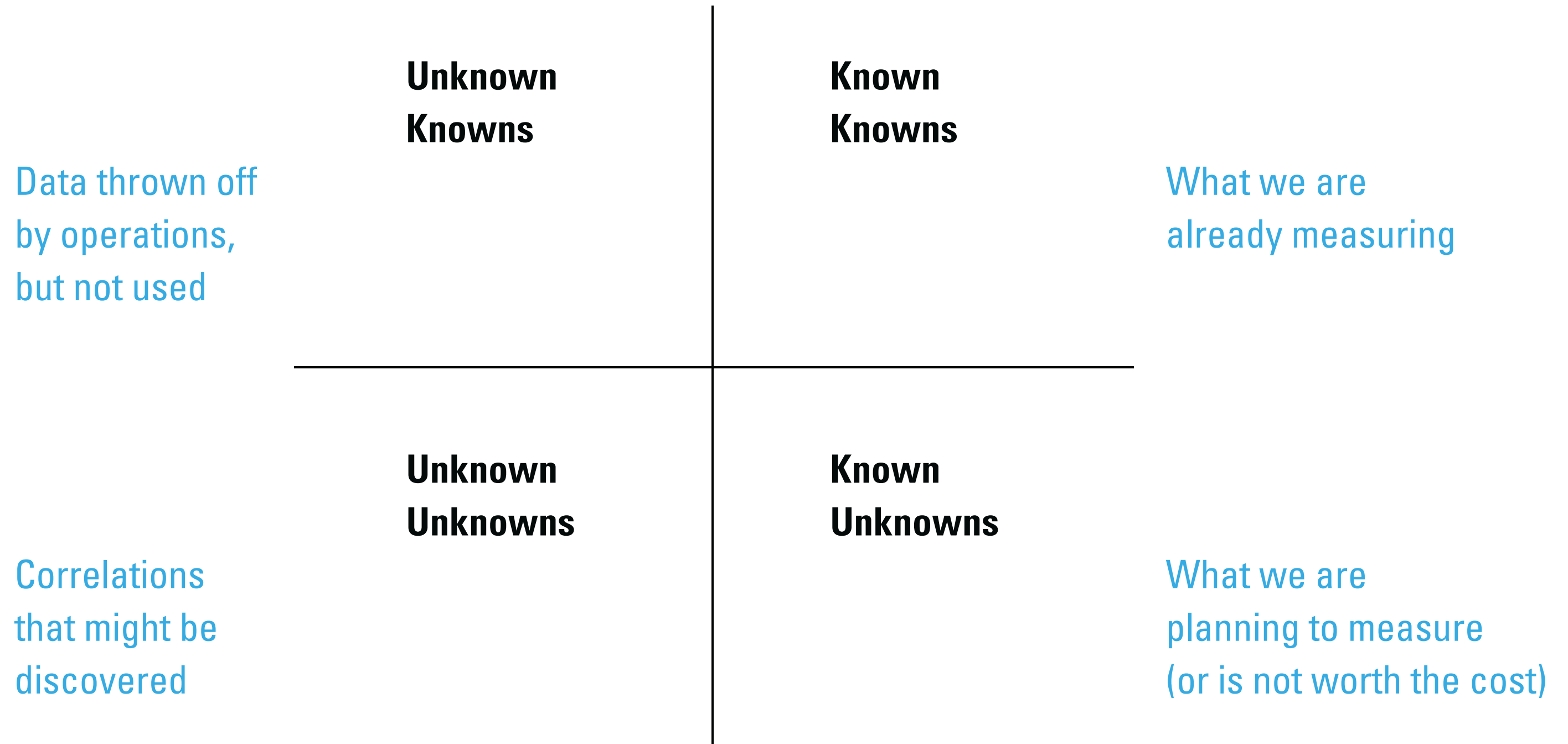


# Skill vs Will — Managerial Responses

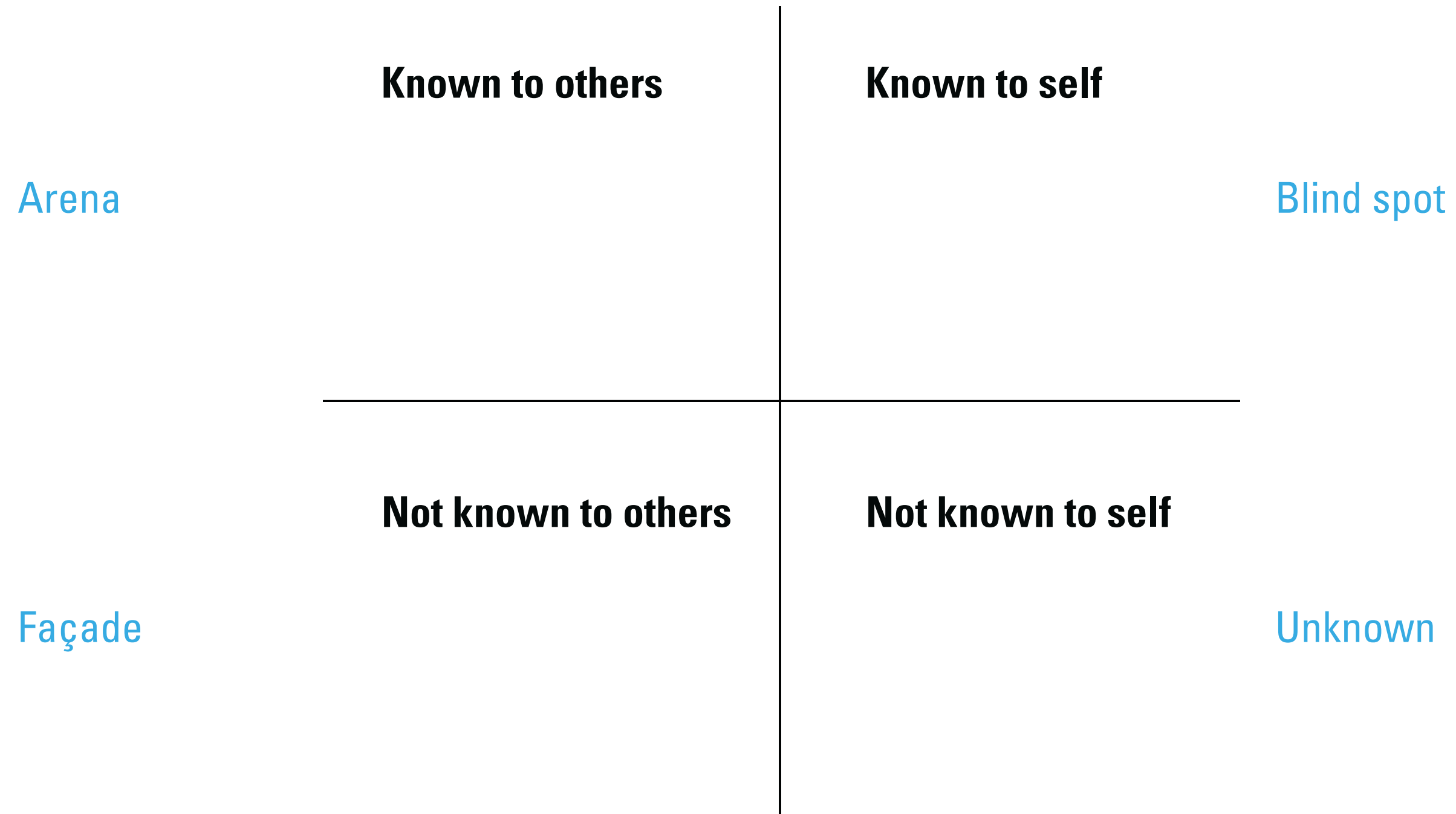




# Known vs Unknown



# Johari window, Joseph Luft & Harrington Ingham, 1955



# Doxa, Pierre Bourdieu, 1972

The universe of discourse

**Discussed  
Heterodoxy**

**Discussed  
Orthodoxy**

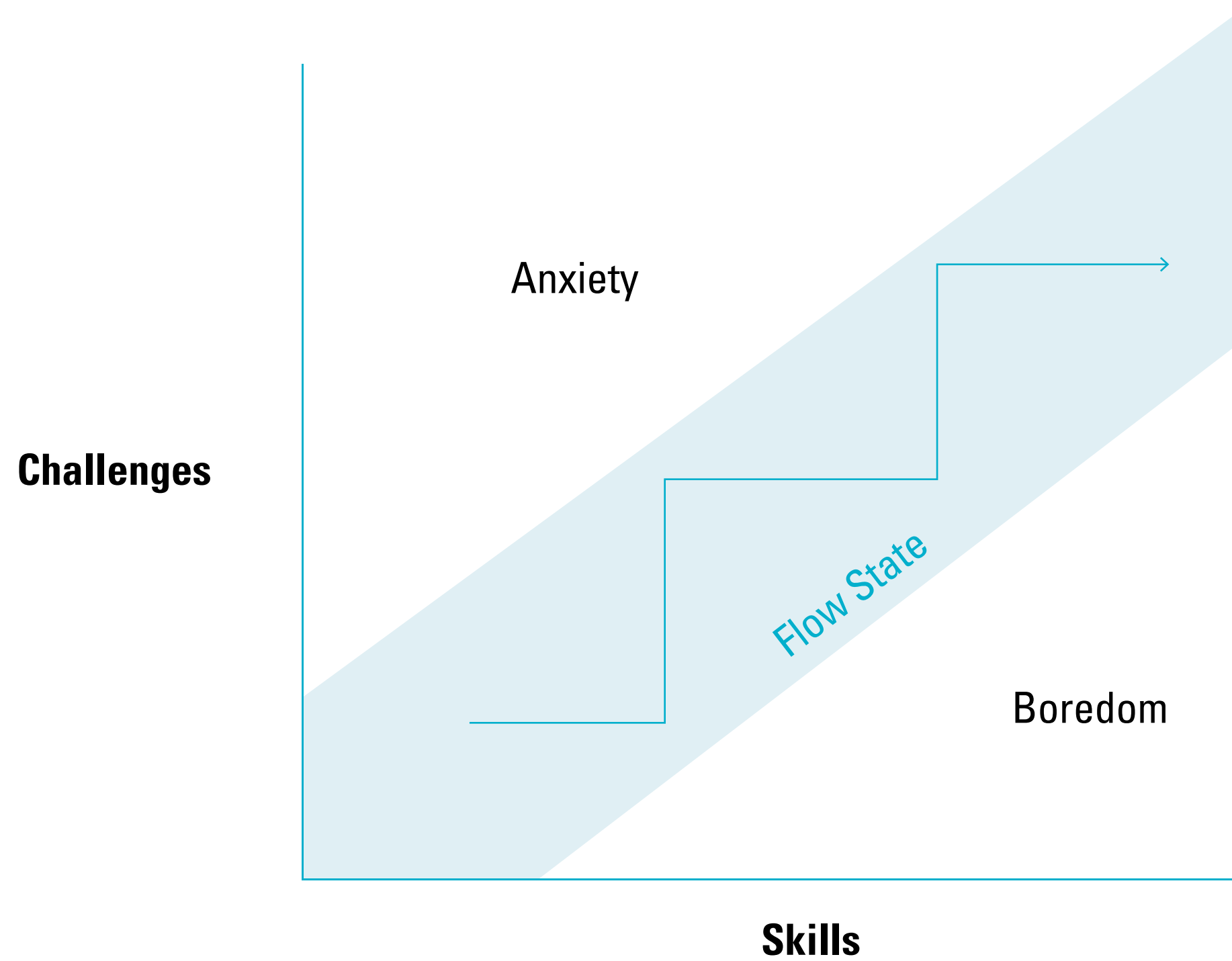
What we see  
in the press;  
what's taught  
in schools

**Undiscussed  
Heterodoxy**

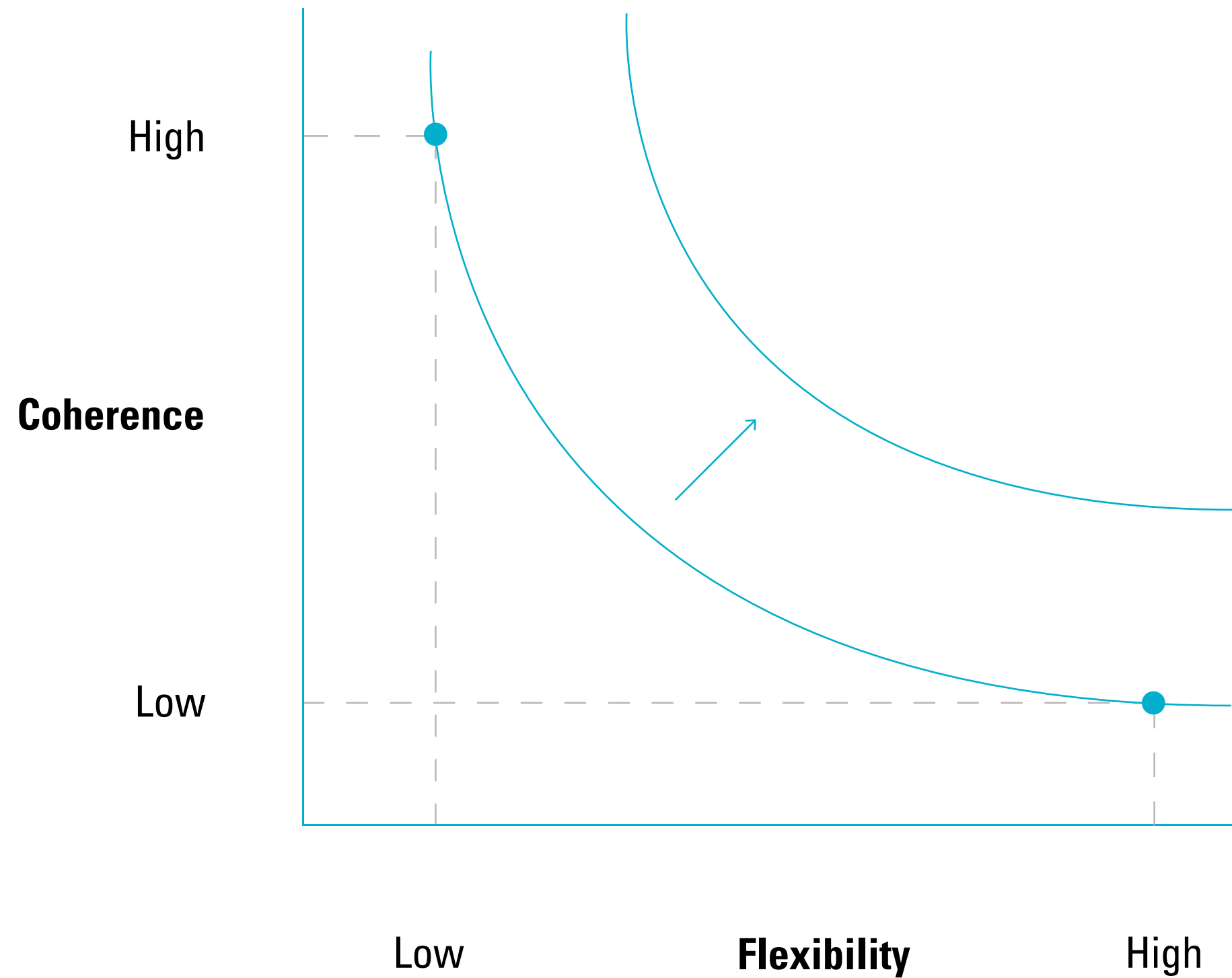
**Undiscussed  
Orthodoxy**

The universe of the undiscovered

# Flow



# Pliant Systems



# Era analysis tables are another type of matrix

# Design practice is moving from a focus on objects to a focus on systems.

1900 - 2000

1995 - now

Values

**Seek simplicity**

**Embrace complexity**

Designer's role

**Expert/Deciding**

**Collaborator/Facilitating**

Construction

**Direct**

**Mediated**

Stopping condition

**Almost perfect**

**Good enough for now**

Result

**More deterministic**

**Less predictable**

End state

**Completed**

**Adapting, growing**

# Product era analysis

Dubberly, Cain, Forlizzi, & Pangaro, 2019

	<b>Hand-crafted Objects</b>	<b>Mass-produced Products</b>	<b>Product-service Ecologies</b>
Scale	Small (one-at-a-time)	Huge (large batches)	Huge (world-wide)
Timeframe	Bounded	Bounded	Ongoing
Complexity	Limited	Greater	Greater still
Outcomes	In the maker's control	Calculated & optimized	Emergent
Objects	Made by hand	Made by machine	Embedded in service systems
Associations	Maker knows user	Anonymous transaction	Surveillance "relationship"
Values	Waste not / want not	Solve / specify	Adapt / test



# Product era analysis (cont.)

Dubberly, Cain, Forlizzi, & Pangaro, 2019

## Handcrafted Objects

Design occurs *during* making, modifications for context.

- Often, made-to-measure (bespoke, personalized)
- Dumb
- Stand-alone
- Knowledge is embedded *in* the artifact and the maker

## Mass-produced Products

Customer input is rare; extremely small samples.

- Mostly, made-in-advance (ready-made to standard sizes)
- Dumb
- Stand-alone
- Knowledge is embedded in artifact *and* production process

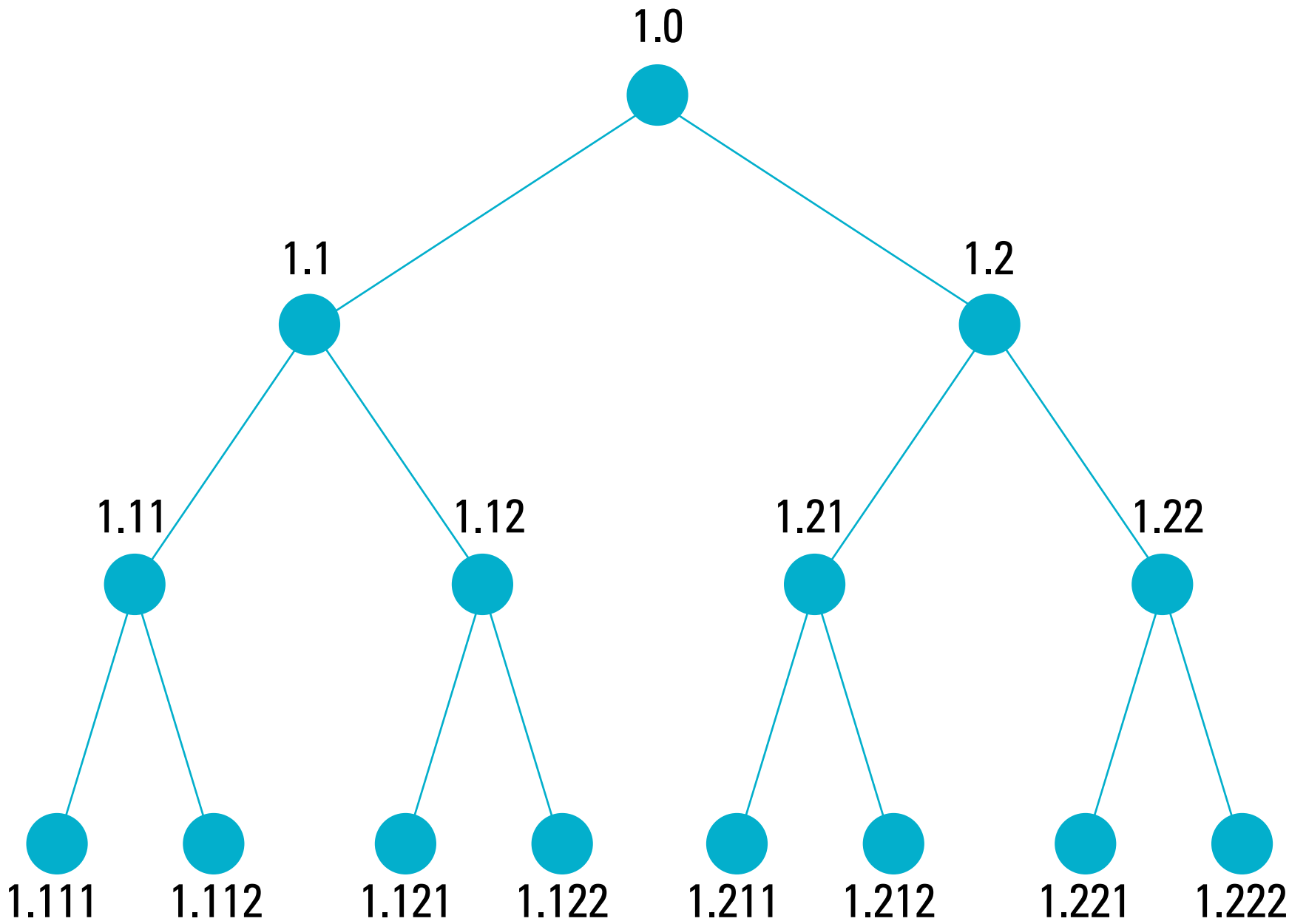
## Product-service Ecologies

A-B testing becomes standard; every action is recorded.

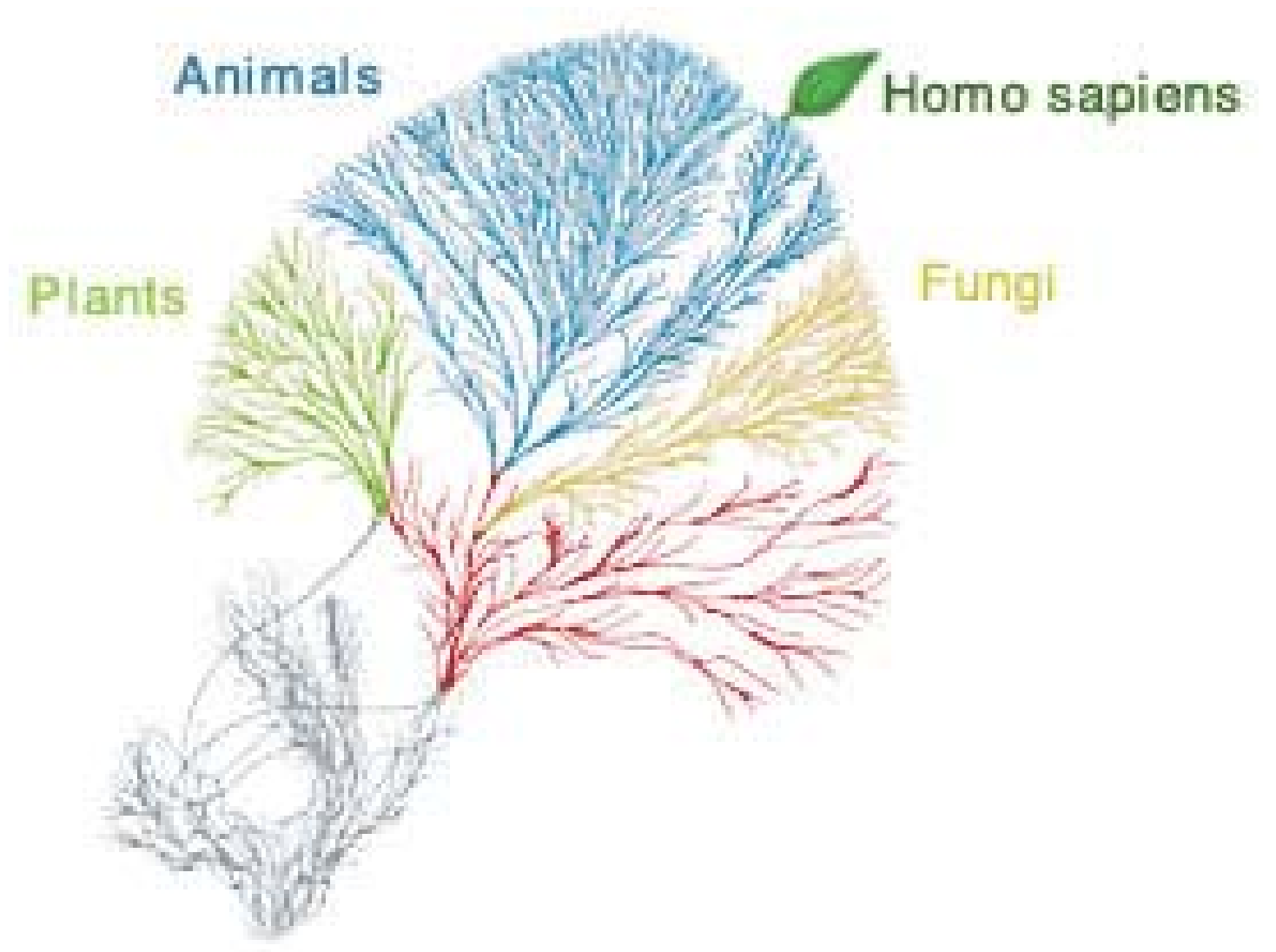
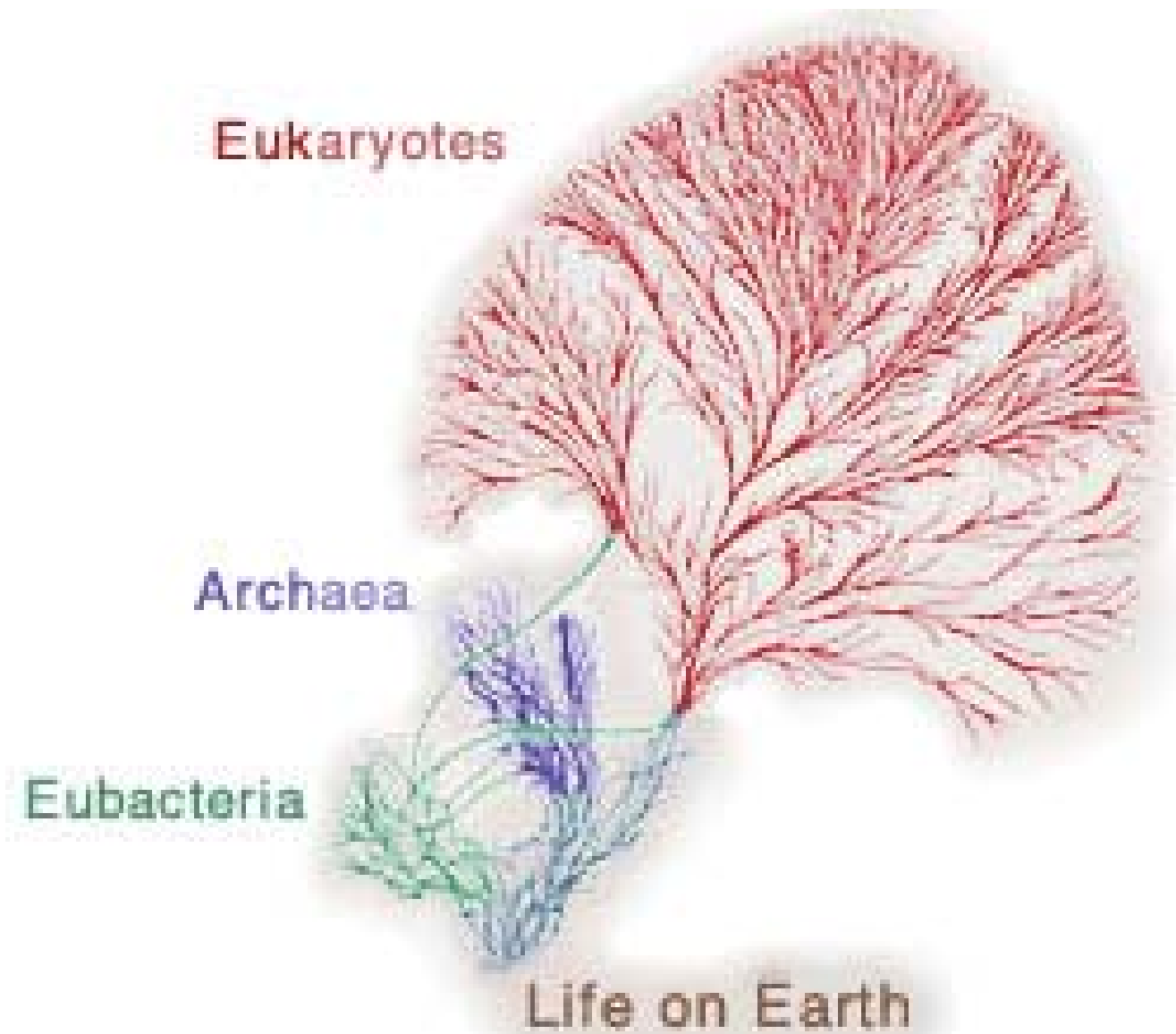
- Mass manufactured *and* mass customized
- Smart & aware
- Connected to cloud storage, compute, and services
- Knowledge flows from users and back-and-forth through the system

# Trees

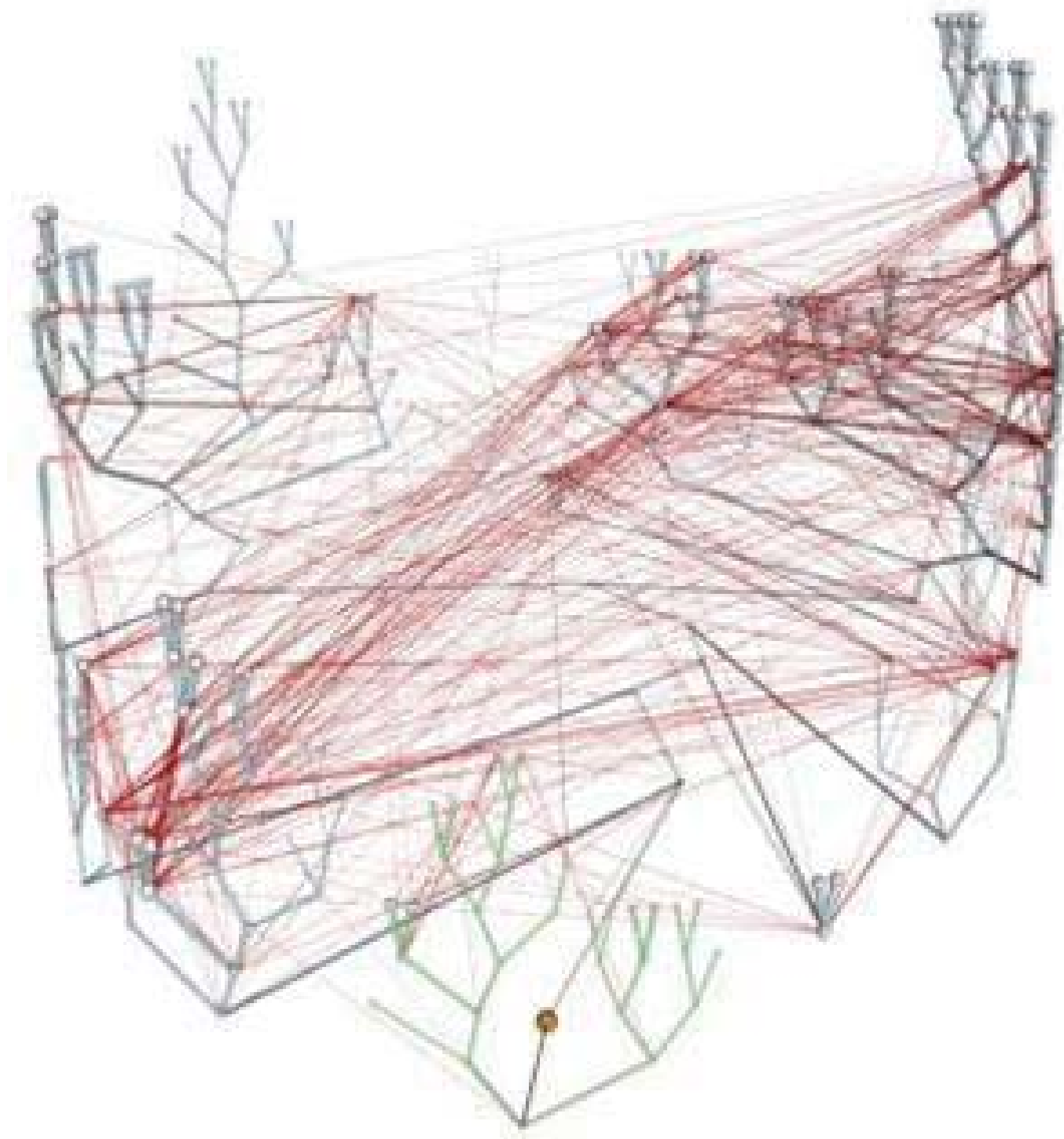
# Tree — also hierarchy, taxonomy



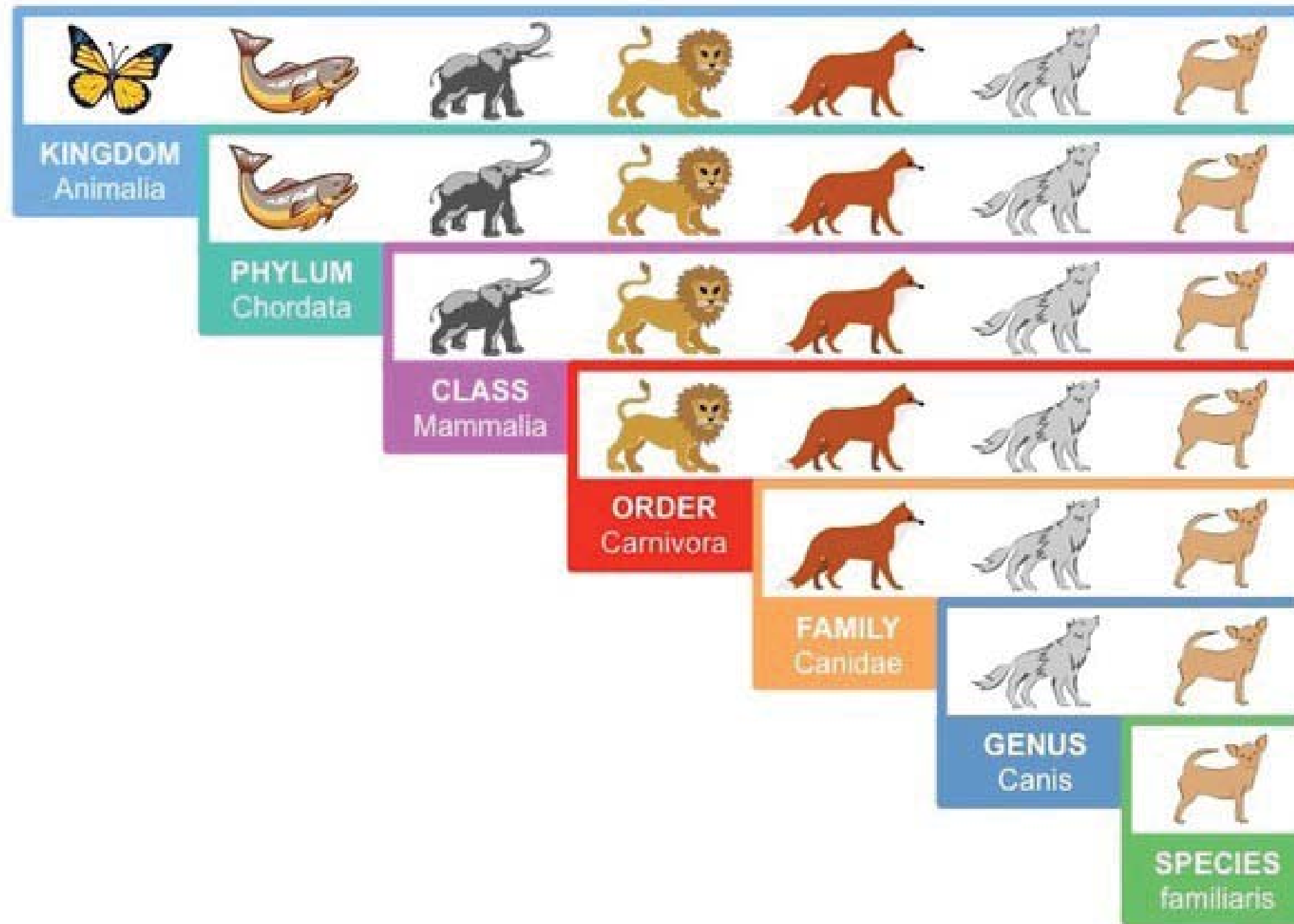
# Tree of life



# Web of life



# Taxonomy





# Binomial naming, Carl Linnaeus, 1735

CAROLI LINNAEI																																																																																																																																																																																																																																		
I. QUADRUPEDIA.			II. AVES.			III. AMPHIBIA.			IV. PISCES.				V. INSECTA.				VI. VERMES.																																																																																																																																																																																																																	
Corpus hirsutum. Pedes quatuor. Femina vivipara. Lactifera.			Corpus plumosum. Ala duo. Pedes duo. Refractus ossium. Femina ovipara.			Corpus nudum, vel squamosum. Dentes molares nulli. Reliqui tempor. Fimra nulla.			Corpus apodum, pinis veris instructum, nudum, vel squamosum.				Corpus crusta ossis cutis loco tectum. Caput antennis instructum.				Corporis Mysterii ab una parte basi cuidam foliis affixi.																																																																																																																																																																																																																	
<b>Homo.</b>	Natus in ipso.	Europaei abstr. Americani rubri. Africani nigri.	<b>Pitracus.</b>	Digiti pedis scilicet 1. pollicis 1. Digiti pedis scilicet 2. pollicis 1. Digiti pedis scilicet 3. pollicis 1.	<b>Piscis.</b>	Subo. Crus. Urolo. Aequia. Vallus. Pado. Cyprip. Latus. Pylagus. Tarsaculus.	<b>Tetudo.</b>	Corpus quadrupedum, nudum, testa munitum.	<b>Rana.</b>	Corpus quadrupedum, crura de fibrato, squamis carens.	<b>Serpentia.</b>	Tetudo testacea. Testa munita. Testa munita. Testa munita. Testa munita.	<b>Thrichechus.</b>	Dentes in utroque maxilla. Dentes impares.	<b>Carodon.</b>	Dentes in inferiore maxilla. Dentes impares.	<b>Monodon.</b>	Dentes in superiore max. Dentes impares.	<b>Balana.</b>	Dentes in sup. max. concol. Dentes in inf. max. impares.	<b>Delphinus.</b>	Dentes in utroque maxilla. Dentes pariter.	<b>Raja.</b>	Femina branch. utriusq. 5. Corpus oblongum.	<b>Squalus.</b>	Femina branch. utriusq. 5. Corpus oblongum.	<b>Acipenser.</b>	Femina branch. utriusq. 5. Corpus oblongum.	<b>Petromyzon.</b>	Femina branch. utriusq. 5. Corpus oblongum.	<b>Lophius.</b>	Corpus magnitudine corporis. Appendices horizontales laterales pinis ambo.	<b>Cyclopterus.</b>	Pinna ventralis in unum circulum concolata.	<b>Halifrax.</b>	Pinna ventralis sola. Cauda duo, saepe aculeata.	<b>Balifrax.</b>	Dentes concolati maxill. Anteriori concolati in medio.	<b>Gasteroleucus.</b>	Membr. branch. officia 3. Pinnae lamina officia infra.	<b>Zeus.</b>	Corpus compressum. Pinnae subaequales.	<b>Cottus.</b>	Membr. branch. offic. 4. Caput scutum, corpore lateri.	<b>Trigla.</b>	Appendix ad pin. vel articulat. a vel j.	<b>Trachinus.</b>	Opercula branch. scutula. Oculi vicini in vertice.	<b>Perca.</b>	Membr. branch. officia 3. Pinnae dorsales. 1 vel 2.	<b>Sparus.</b>	Opercula branch. scutula. Oculi vicini in vertice.	<b>Labrus.</b>	Labiis crudi dentes teg. Color speciosus.	<b>Mugil.</b>	Membr. branch. offic. 6. Caput lateri squamosum.	<b>Scomber.</b>	Membr. branch. offic. 7. Pinnae dorsales. 1 vel 2.	<b>Xiphias.</b>	Opercula branch. scutula. Oculi vicini in vertice.	<b>Gobius.</b>	Pinnae ventralis solae. Pinnae dorsales. 1 vel 2.	<b>Gymnotus.</b>	Membr. branch. officia 3. Pinnae dorsales. 1 vel 2.	<b>Murzena.</b>	Membr. branch. offic. 10. Pinnae dorsales. 1 vel 2.	<b>Blennius.</b>	Pinnae ventralis solae. Pinnae dorsales. 1 vel 2.	<b>Gadus.</b>	Membr. branch. offic. 7. Pinnae dorsales. 1 vel 2.	<b>Pleuronectes.</b>	Membr. branch. offic. 6. Oculi vicini in eodem lateri.	<b>Ammodytes.</b>	Membr. branch. offic. 7. Pinnae ventralis solae.	<b>Coryphina.</b>	Membr. branch. offic. 5. Pinnae dorsales. 1 vel 2.	<b>Echeneis.</b>	Stria transversa, oper. in forma capitis atri.	<b>Elof.</b>	Membr. branch. offic. 14. Pinnae dorsales. 1 vel 2.	<b>Salmo.</b>	Membr. branch. offic. 10-11. Corpus maculatum.	<b>Omerus.</b>	Membr. branch. offic. 7-8. Dentes in max. longi, parvi.	<b>Coregonus.</b>	Membr. branch. offic. 8-10. Appendices pariter.	<b>Clupea.</b>	Membr. branch. offic. 8. Pinnae scutulae laterales.	<b>Cyprinus.</b>	Membr. branch. offic. 3. Dentes ad officium ventralis tantum.	<b>Cubitus.</b>	Corpus compressum. Pinnae corii & ventralis. Oculi a toto siliaculo.	<b>Syngnathus.</b>	Opercula branch. ex lamina 2. Membr. a lateribus caudae.	<b>Blatta.</b>	4. FEMINA BRACHIA NUDA BISTRIATA. Elytra concolata. Antennae tritricatae.	<b>Dytiscus.</b>	Subo. pediculi membrae formae de usu. Ant. fasciae. Elytra apice bifurcata.	<b>Meloe.</b>	Elytra mollia, testacea, corpore breviori. Ant. multiflorae. An articulo oleum fundens.	<b>Forficula.</b>	Elytra brevissima, rigida. Cauda bifurca.	<b>Notopoda.</b>	Pulsus in medio oculi. Ant. capillares. Cauda scutulae rigida simpliciter armata. Ant. fasciae, breves.	<b>Mordella.</b>	Elytra profundius, teres, simpliciter. Ant. clavata in medio Rotii pedum.	<b>Circulio.</b>	Corpus ovale, rugulatum, haum. Ant. capitatae, foliaceae.	<b>Buceros.</b>	Corpus 2. ramis, rigida, mollia. Ant. capitatae, foliaceae.	<b>Lucanus.</b>	4. BRACHIA TRITRICA. Ant. clavata. Cauda bifurca.	<b>Scarabeus.</b>	Corpus ovale. Elytra profundius, teres, simpliciter. Ant. clavata in medio Rotii pedum.	<b>Dermatoc.</b>	Corpus ovale. Elytra profundius, teres, simpliciter. Ant. clavata in medio Rotii pedum.	<b>Caflida.</b>	Corpus ovale. Elytra profundius, teres, simpliciter. Ant. clavata in medio Rotii pedum.	<b>Chrysolina.</b>	Oculi div. sp. Pic. triangul. Ant. capitatae, foliaceae.	<b>Coccionella.</b>	Ant. simpliciter, brevissima. Corpus hemisphaericum.	<b>Gyrinus.</b>	Ant. simpliciter. Corpus breve. Pinnae pedales foliaceae.	<b>Necydalis.</b>	Ant. simpliciter, rotundata. Corpus ovale, rotundatum.	<b>Attalabus.</b>	Ant. simpliciter, concolatae ant. concolatae, praeter ultimam, globosam.	<b>Cantharis.</b>	3. ANTENNAE BRACHIAE. Clypeus planus, marginibus undique prominens. Elytra longiora.	<b>Carabus.</b>	Clypeus fere planus, marg. prominens. Elytra longiora.	<b>Cicindela.</b>	Clypeus cylindricus vel teres. Elytra ovata, prominentia.	<b>Leptura.</b>	Clypeus subrotundus. Pedes longi. Corpus teres acuminatum.	<b>Cerambyx.</b>	Clypeus ad latera mucrone prominens. Ant. capitatae longiorae, saepe bipartitae.	<b>Buprestis.</b>	Clypeus superne punctis elevatis notatus. Elytra ovata.	<b>Papilio.</b>	Elytra ovata. Ant. 4.	<b>Libellula.</b>	Cauda filiformis. Ant. 4. Elytra ovata.	<b>Ephemera.</b>	Cauda filiformis. Ant. 4. Elytra ovata.	<b>Hemipterus.</b>	Cauda filiformis. Ant. 4. Elytra ovata.	<b>Panorpa.</b>	Cauda filiformis. Ant. 4. Elytra ovata.	<b>Raphidia.</b>	Cauda filiformis. Ant. 4. Elytra ovata.	<b>Apis.</b>	Cauda aculeata. Ant. 4.	<b>Ichneumon.</b>	Cauda aculeata. Ant. 4.	<b>Mufa.</b>	Stylus sub alis capitatus. Ant. 4.	<b>Gryllus.</b>	Pedes 6. Ant. 4. Insuperiora callosiora.	<b>Lampyrus.</b>	Pedes 6. Clypeus planus. Ant. 4.	<b>Formica.</b>	Pedes 6. Ant. 4. Cauda scutulae concolata.	<b>Cimex.</b>	Pedes 6. Ant. 4. Cruciferae. Elytra bifurcata, rectum.	<b>Notonecta.</b>	Pedes 6. quorum pedes tertiorum figur. & uti. Ant. 4. Cruciferae.	<b>Nepa.</b>	Pedes 4. Frons chelifera. Ant. 4. Cruciferae.	<b>Scorpio.</b>	Pedes 8. Frons chelifera, scutulae. Ant. 4. Cruciferae.	<b>Pediculus.</b>	Pedes 6. Ant. 4. Cruciferae. Elytra bifurcata, rectum.	<b>Pulex.</b>	Pedes 6. Ant. 4. Cruciferae. Elytra bifurcata, rectum.	<b>Monoculus.</b>	Pedes 6. Ant. 4. Cruciferae. Elytra bifurcata, rectum.	<b>Acarus.</b>	Pedes 8. articuli 4. confusae. Oculi 2. Ant. 4. Cruciferae.	<b>Araneus.</b>	Pedes 8. Oculi communiter 8.	<b>Cancer.</b>	Pedes 12. priores cheliformes.	<b>Oniscus.</b>	Pedes 14.	<b>Scolopendria.</b>	Pedes 30. & ultra.	<b>Gordius.</b>	Corpus filiforme, teres, simpliciter.	<b>Taxia.</b>	Corpus filiforme, planum, articulatam.	<b>Lumbricus.</b>	Corpus teres, annulo prominenti clodum.	<b>Hirudo.</b>	Corpus inflexum planum, fere concolata. Corpi inflexum planum, fere concolata.	<b>Limax.</b>	Corpus ovale, simpliciter.	<b>Cochlea.</b>	Tuba univalvis, spiralis, unilocularis.	<b>Nautilus.</b>	Tuba univalvis, spiralis, multilocularis.	<b>Cyprina.</b>	Tuba univalvis, concolata, rimae longitudinalis.	<b>Halotis.</b>	Tuba univalvis, patula, leviter concolata, perforata, ad angulum spiralem.	<b>Patella.</b>	Tuba univalvis, concolata, simpliciter.	<b>Dentalium.</b>	Tuba univalvis, teres, simpliciter.	<b>Concha.</b>	Tuba bivalvis.	<b>Lepas.</b>	Tuba multivalvis. Valvae duabus plures.	<b>Tethys.</b>	Corpus forma variabile, mole, sedum.	<b>Echinus.</b>	Corpus fibrosum, testa testum, articulatam.	<b>Asterias.</b>	Corpus radiatum, corio testum, fibrosum.	<b>Medusa.</b>	Corpus orbiculatum, gelatinosum, fibrosum filamentosum.	<b>Sopia.</b>	Corpus oblongum, interne ossium, ant. terius ossis artubus duobus.	<b>Microcofimus.</b>	Corpus variis heterogeneis testum.

## PARADOXA

HYDRA corpore anguino, pedibus duobus, collis 6. pennis, & rotundis capitibus, alarum expers, abstraxit Hamburgi, similitudinem refertur Hydre Apocalypiticae a S. JOHANNIS CAP. XII. & XIII. descriptis. Equae tanquam veri animalis speciem plurimum praebet, sed sile. Natura sibi semper per similia plura capia in uno corpore nuncupat produxit naturaliter. Fraudem & artificium, cum ipsi vidimus, denique Perisomulitum, ab Amphibiorum dentibus diveris, sic colline deteguntur.

RANA-PISCIS & RANA IN PISCIBUS METAMORPHOSIS valde paradoxa est, quoniam Natura mutationem Generis unius in aliam diversae Classis non admittit. Rana, ut Amphibia concolata, pulmonibus gaudens & ossibus spinosis. Pices spinoosi, loco pulmonum, branchias instruunt. Ergo legi Naturae contraria foret haec mutatio. Si enim pices hic in strabus essent branchias erant diveris in Rana & Amphibia. Si vero pulmones, erant Lacerta: nam toto casu a Chondropo Trogis & Plagiaris differt.

MOTACILLA PETRARUM, corpore equino, pedibus feminis cornu recto, longoque spirantem innoto, Fideiurum figmentum Simae species est, si unquam aliquis visus fuit. Idemque quoque Casaldi, de quibus recentiora peregrinatorum multa narrant, ejusdem generis sunt.

BOGOMERT & AGNUS SCOTICUS plantis acconferat, & agno assimilatur, cui oculis sterius plantae de terra erumpens umbilicum intrat; idemque sanguine praeditus a feri devovetur temere dicitur. Est autem artificiosus ex radicibus Filicinis Americanis compositus. Naturaliter autem est Erythraeus alioque descriptus, qui concolata habet stri bura.

PARONYX, Avis species, cujus unicum in mundo individuum, & que descripta ex ferri busto, quod fuit ex isto matris fraxine, reperire fibrolo ferat, siliam fibrosum prioris vitae periodum. Est vero PALMA DACTYLIFERA, vid. Remy.

BRUSULA & ANSER SCOTICUS & CONCHA AMANTER, & lignis putridis in mare abjectis nudi a Veneribus creditur Sed fucum impositum Lepas interneis suis penniformibus, & modo adherendi, quasi versus ille enter Bernicia inde orire tur.

DRACO corpore anguino, duobus pedibus, duobus alis Vespertilionis milar, est Lacerta alata, vel Rapsa per artem monstris ficta, & ficta.

ATROMA, Monstrum Horologii minimi fontium odens in perietibus, est Petrus palustris didicus, qui ligna perforat, eoque inhabitat.

# A tree can be represented as an outline.

**1.0** Title

**1.1** Section

**1.11** SubSection

**1.111** Paragraph

**1.112** Paragraph

**1.12** SubSection

**1.121** Paragraph

**1.122** Paragraph

**1.2** Section

**1.21** SubSection

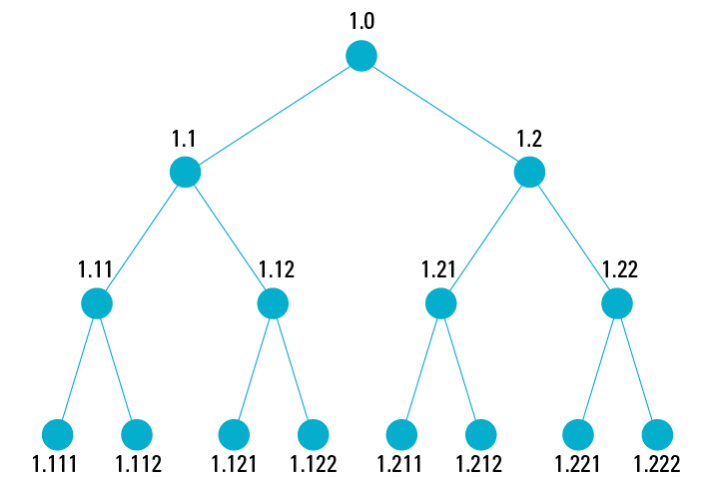
**1.211** Paragraph

**1.212** Paragraph

**1.22** SubSection

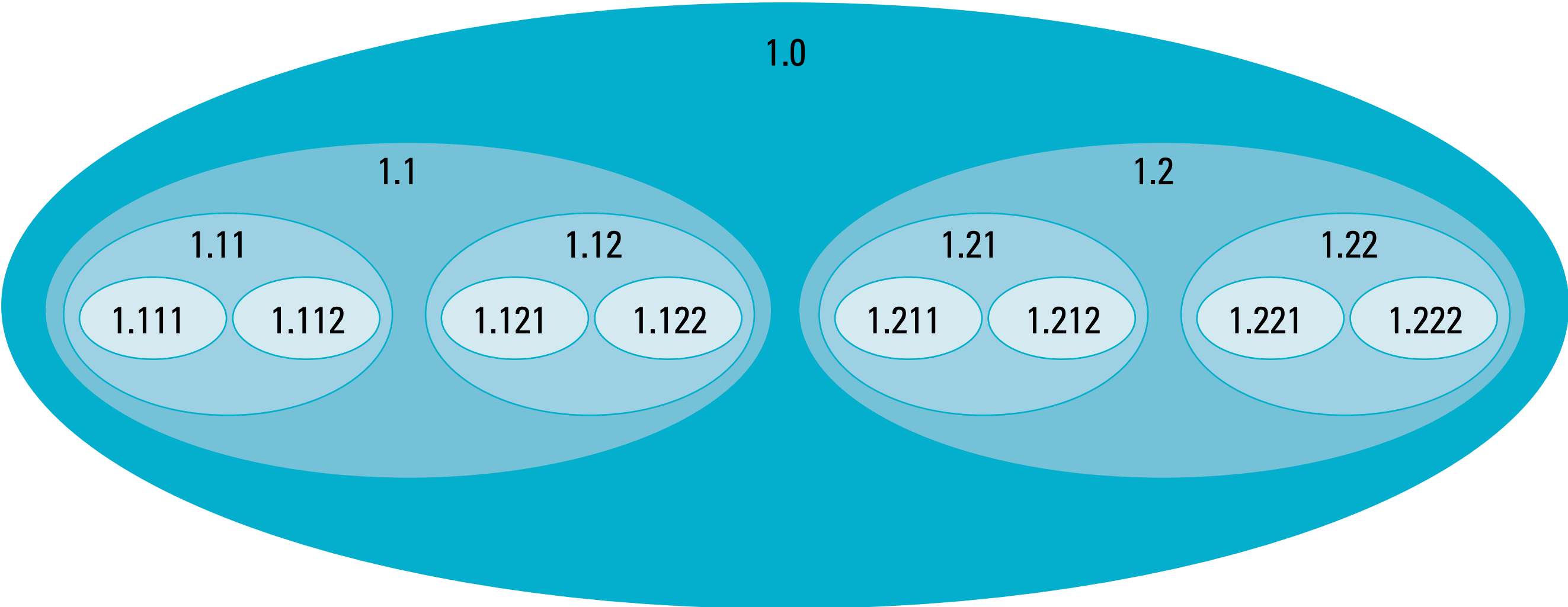
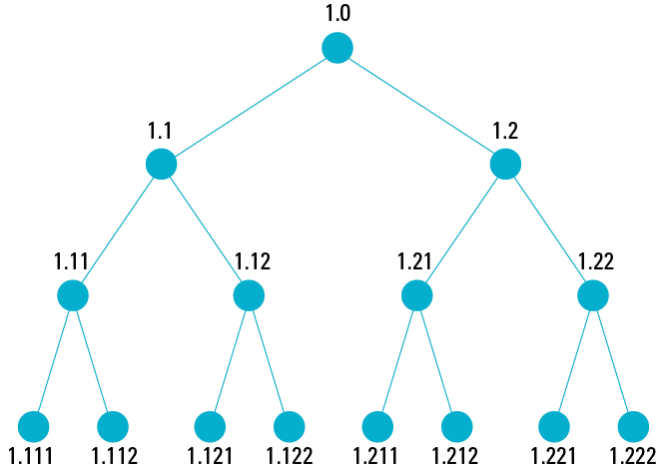
**1.221** Paragraph

**1.222** Paragraph

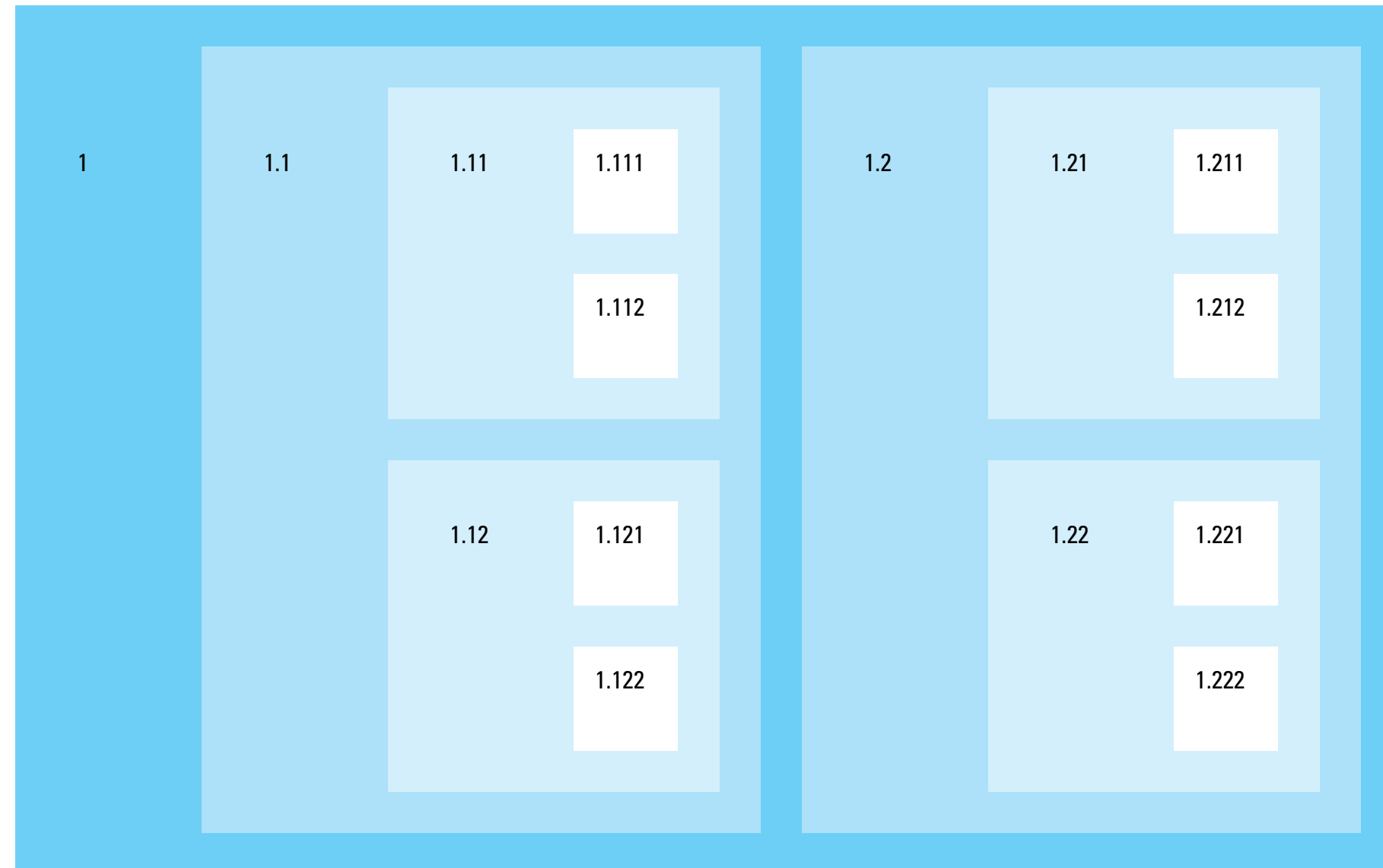




# Trees can also be represented as Venn diagrams.



# Trees represent containers; shape can vary.





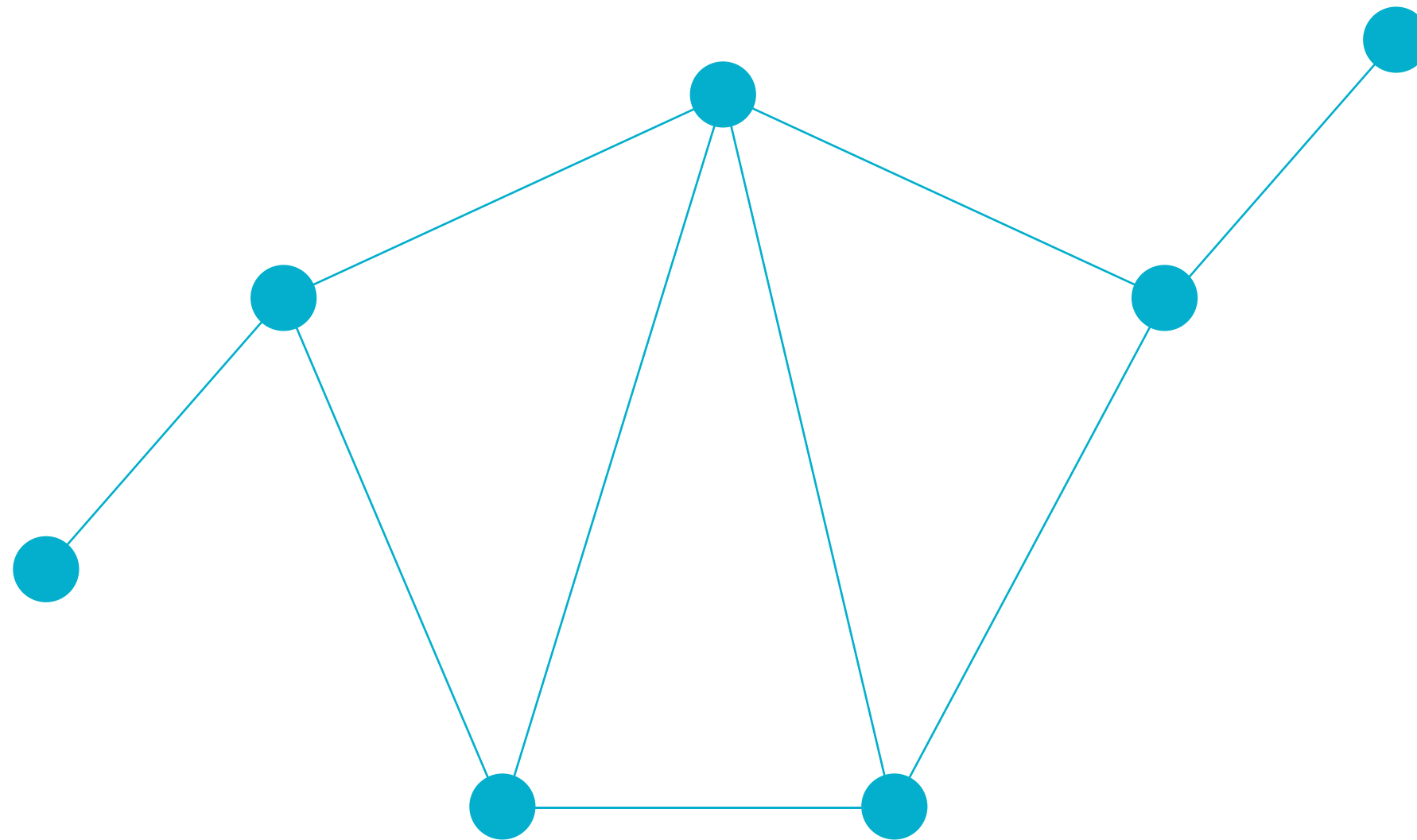
# This market map is also a tree.



# Webs



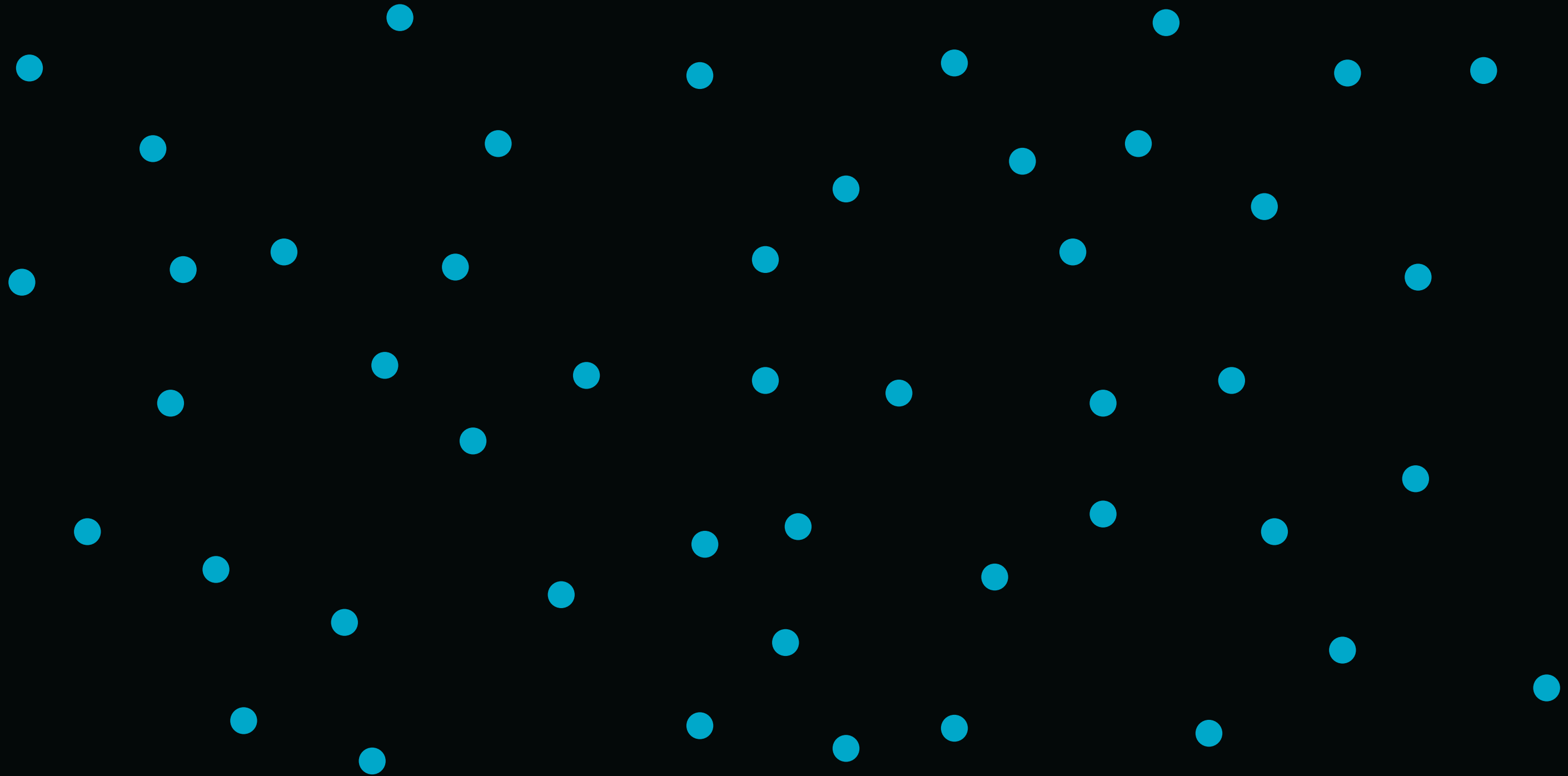
# Web — also graph, network, ontology





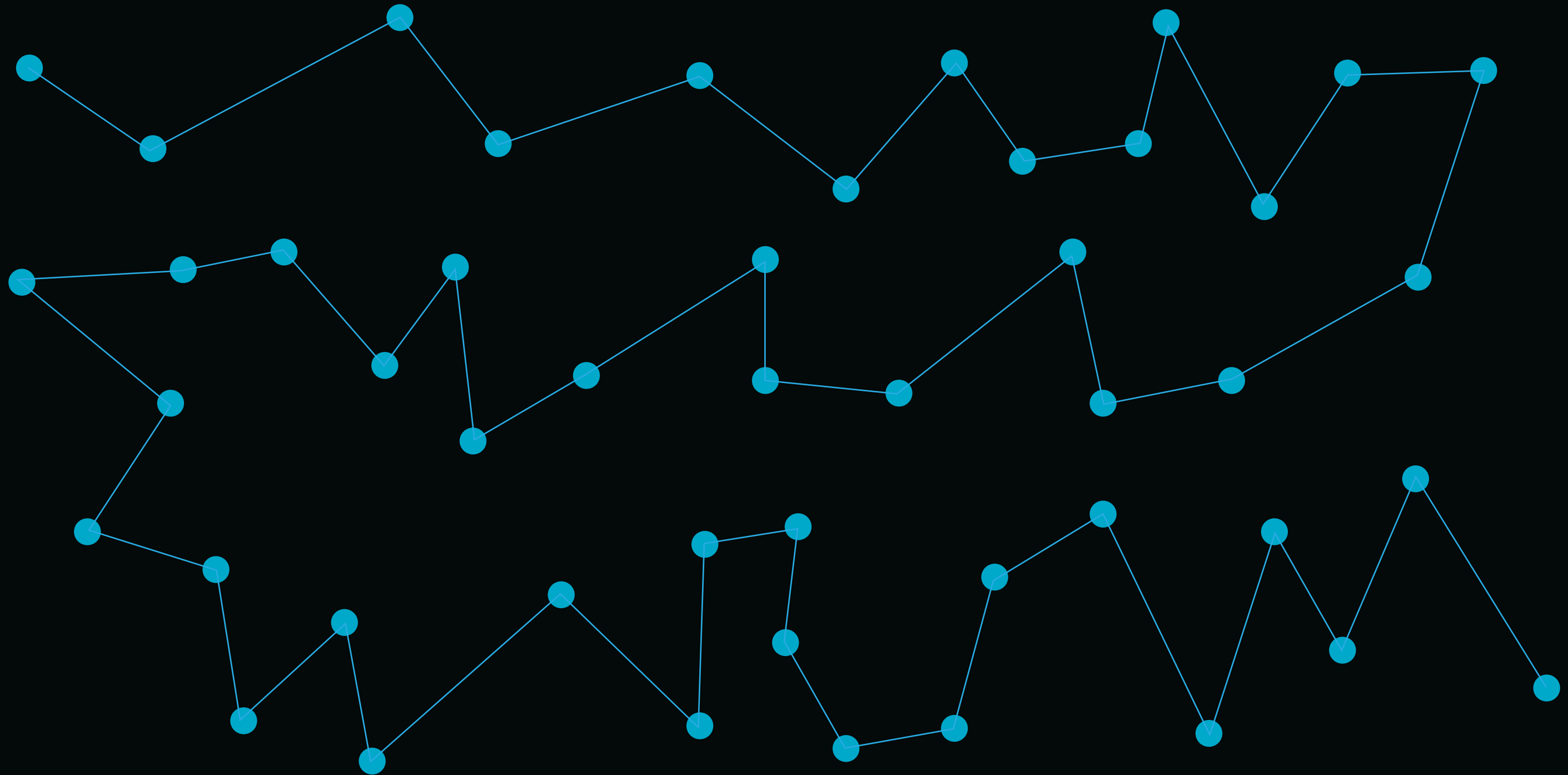
**The same set of nodes may be connected to form many different structures.**

# Nodes

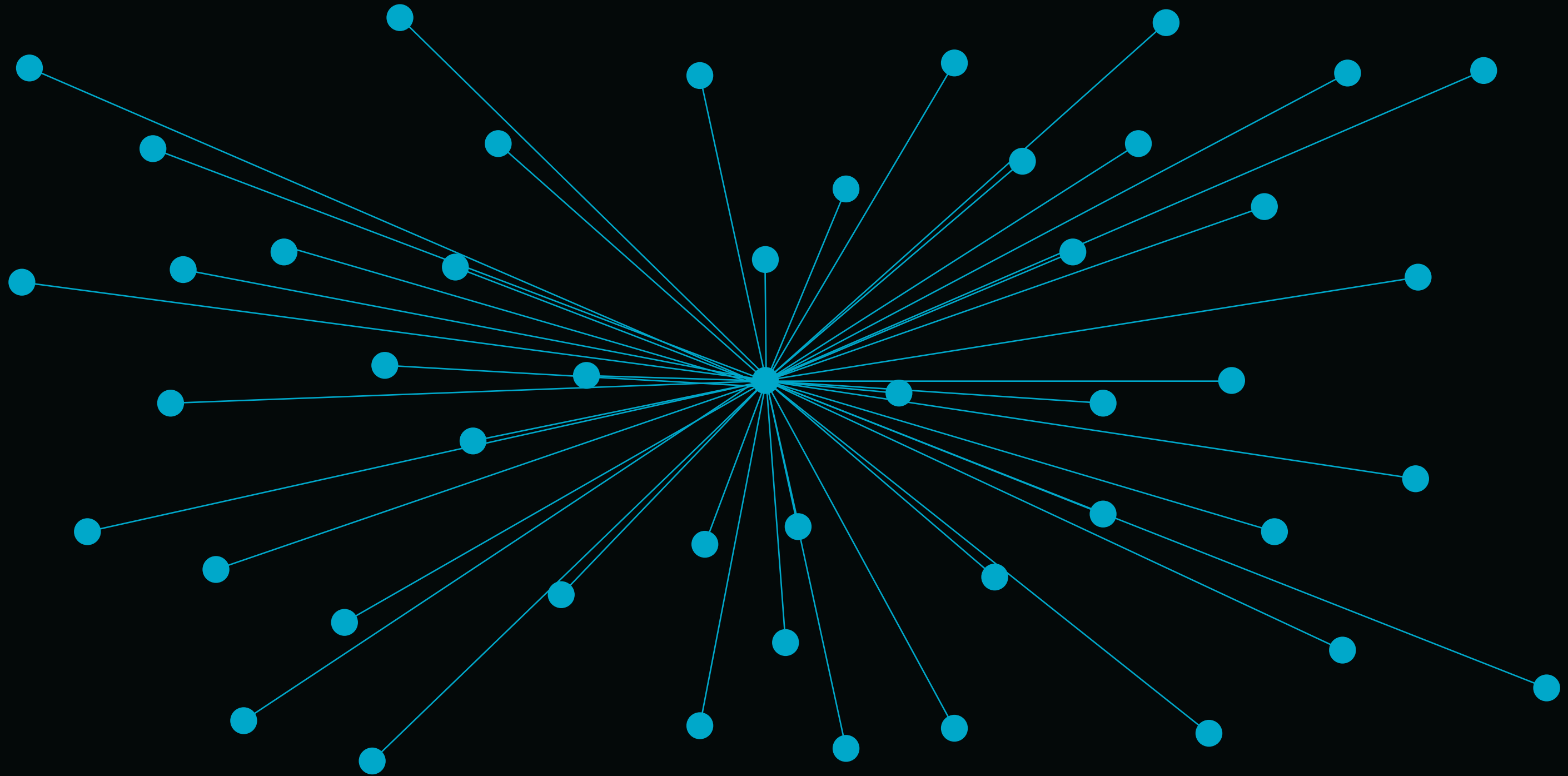




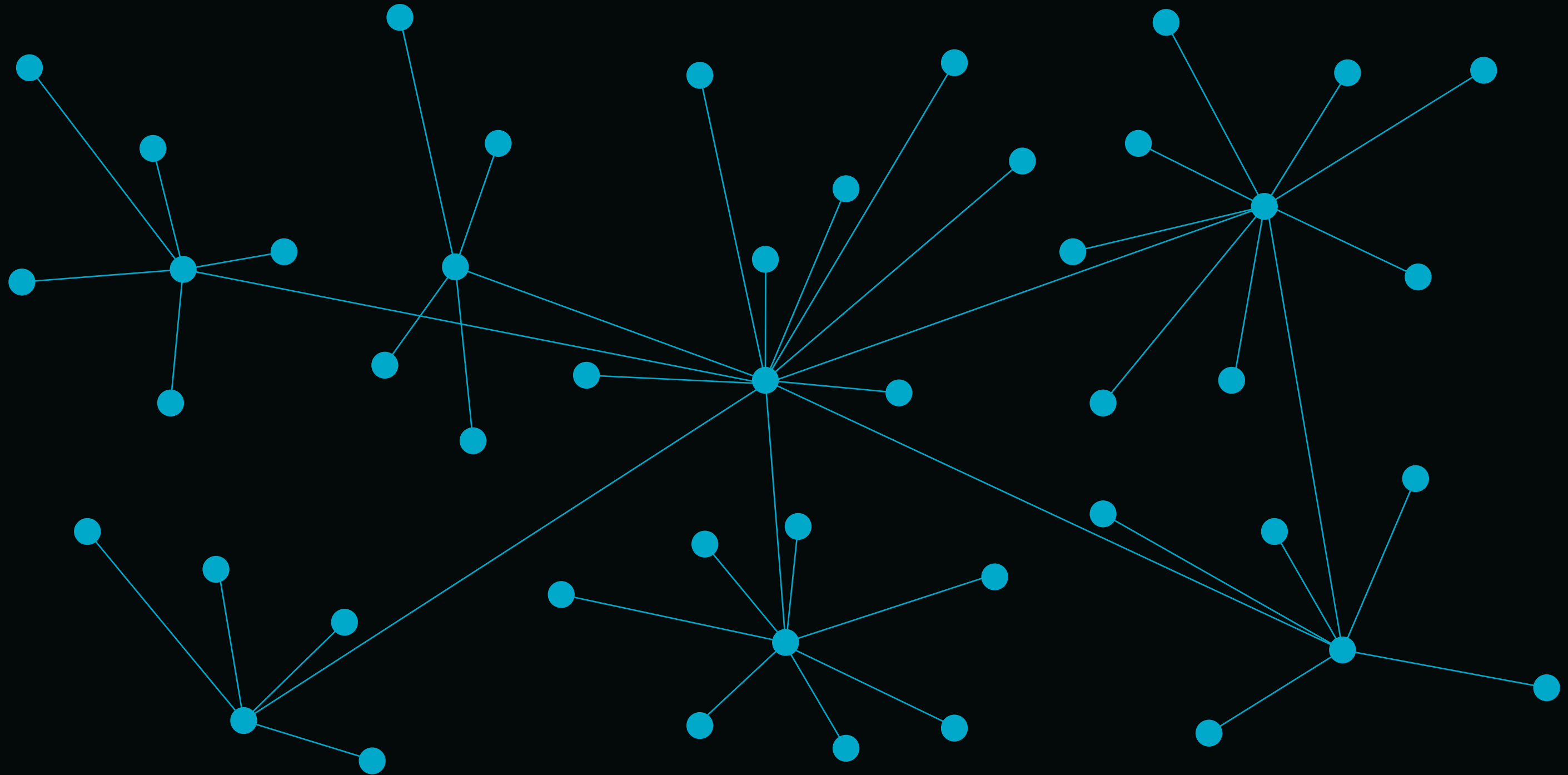
# Sequences — “Daisy Chain”



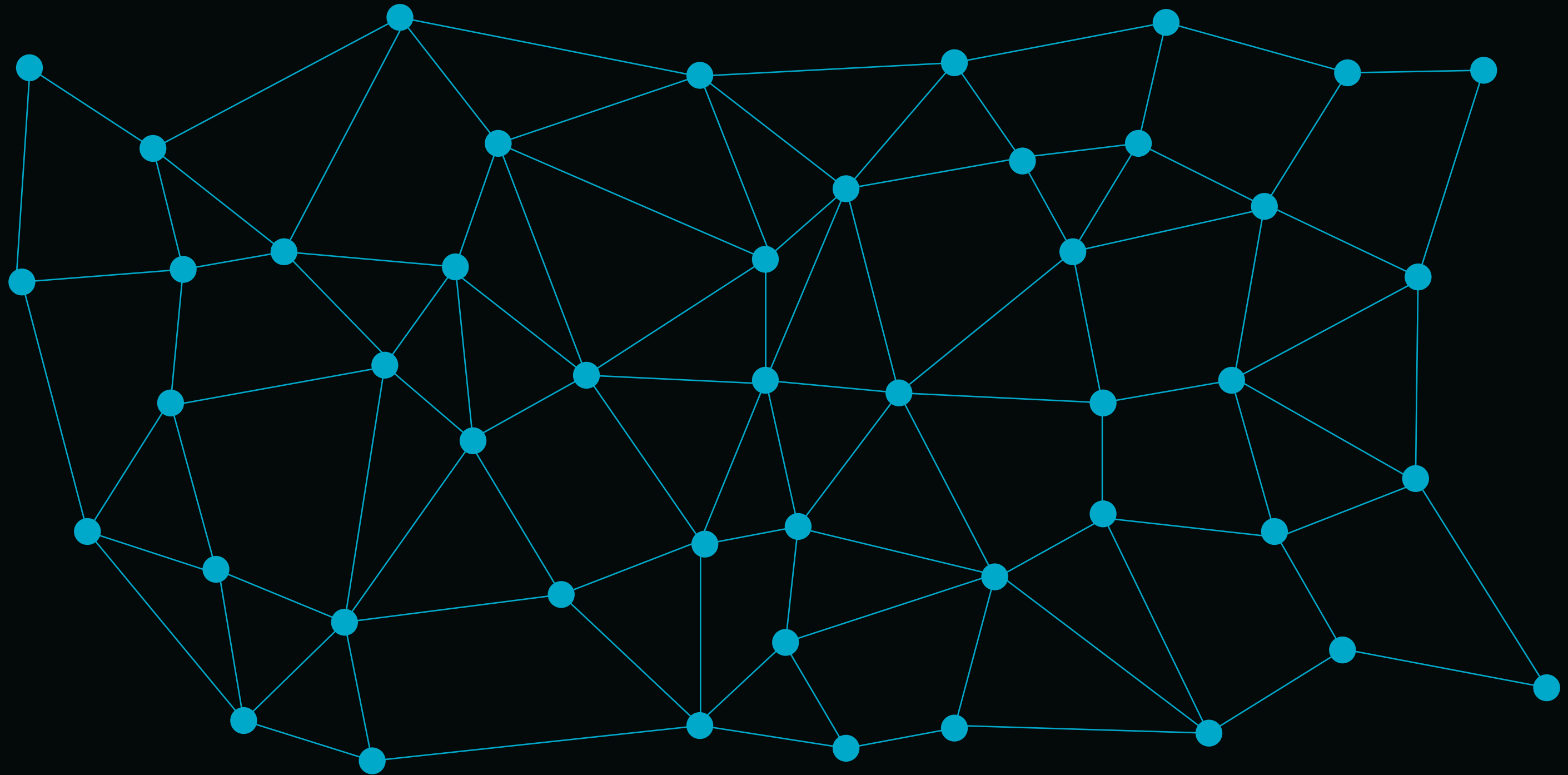
# Centralized System



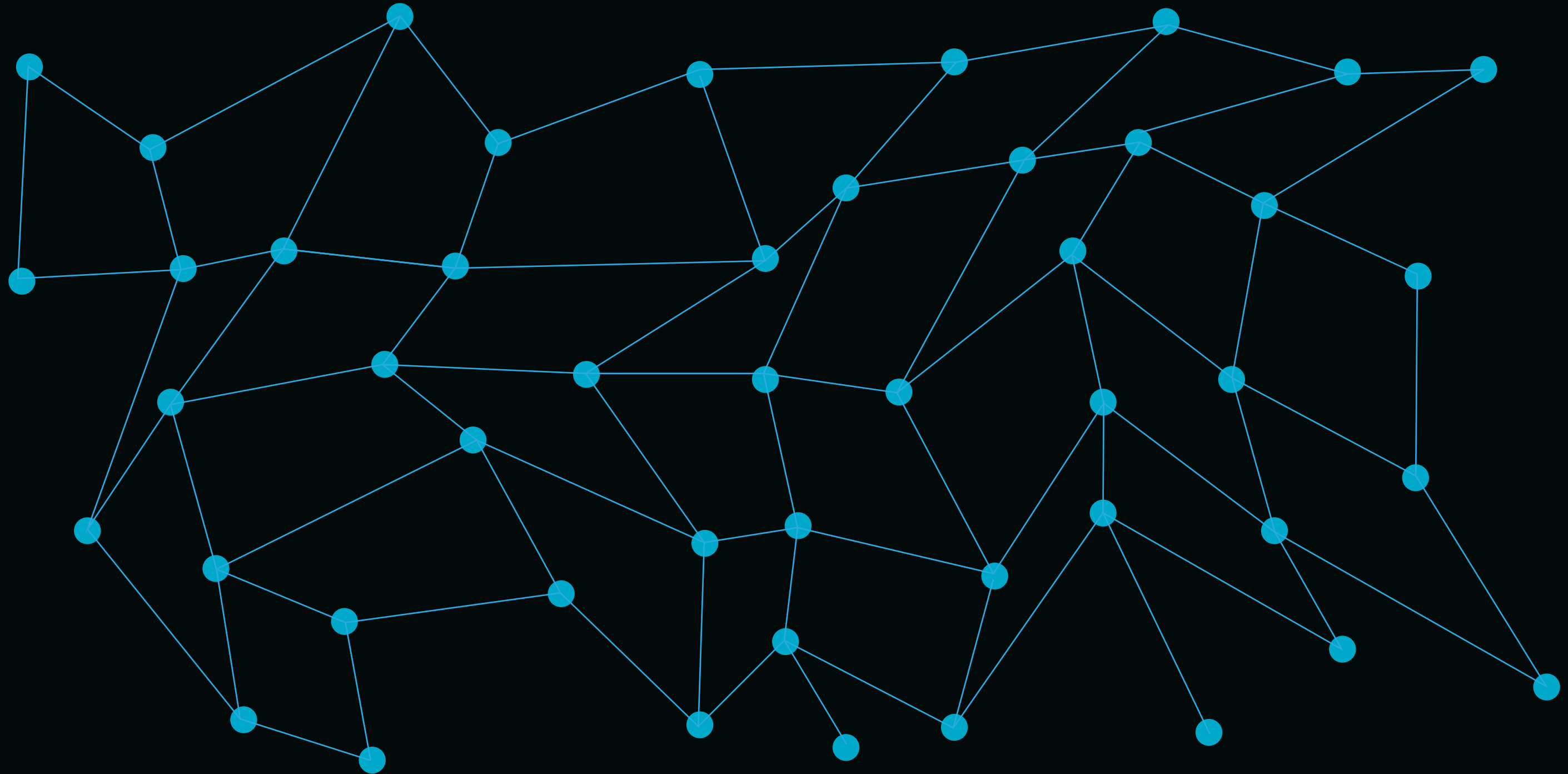
# Decentralized System



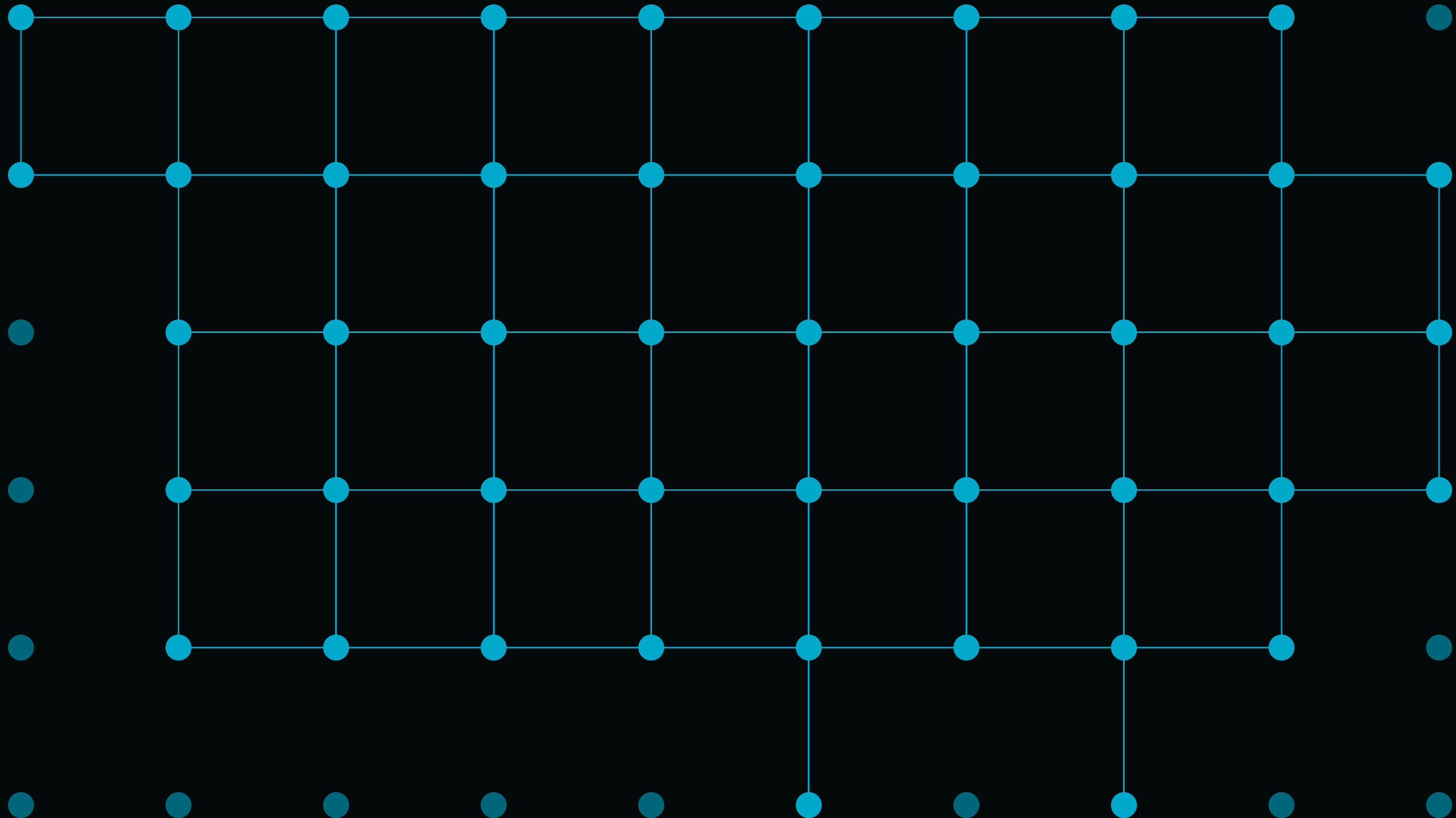
# Distributed System



# Grid (matrix)



# Grid (regularized)



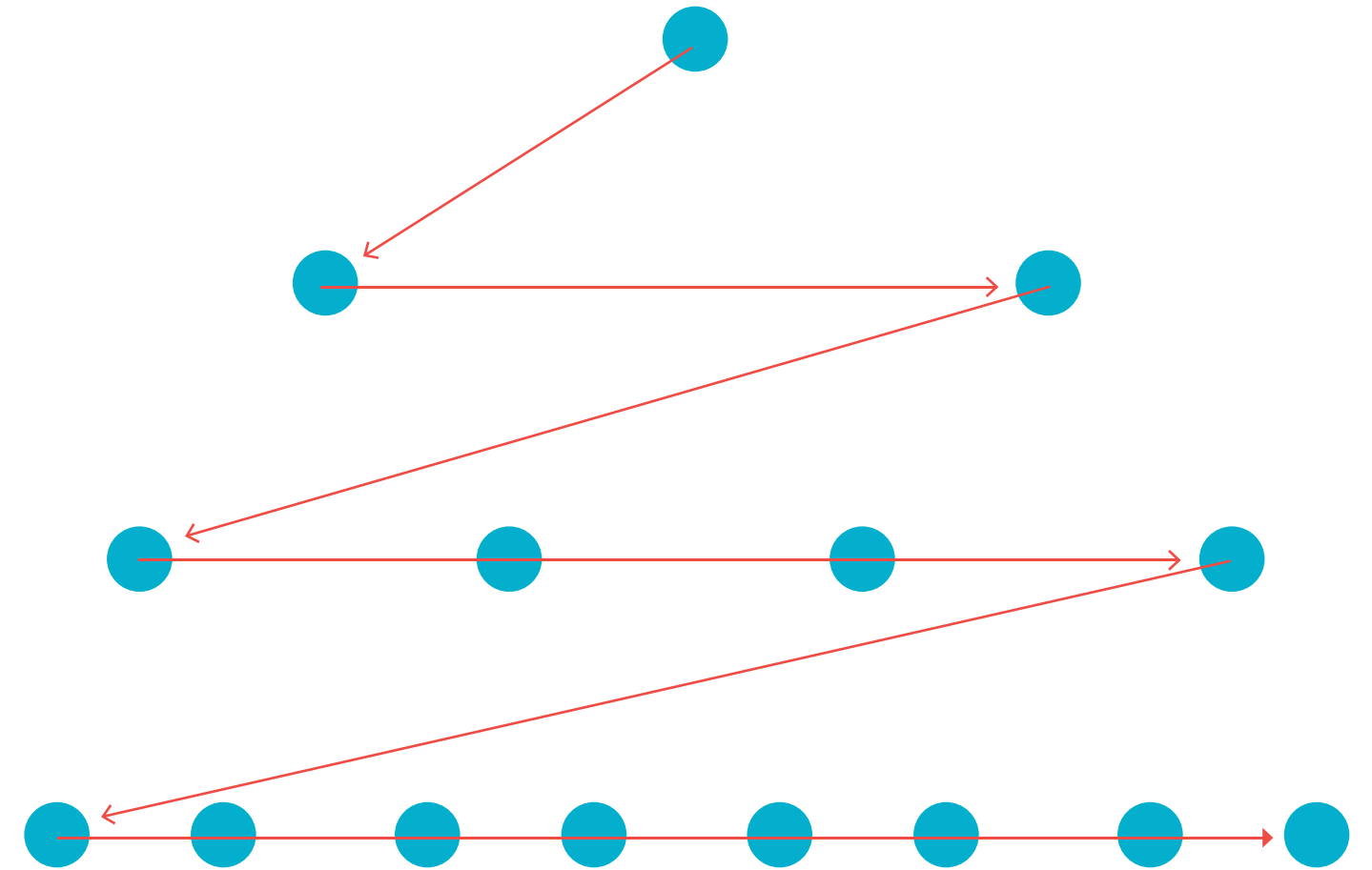
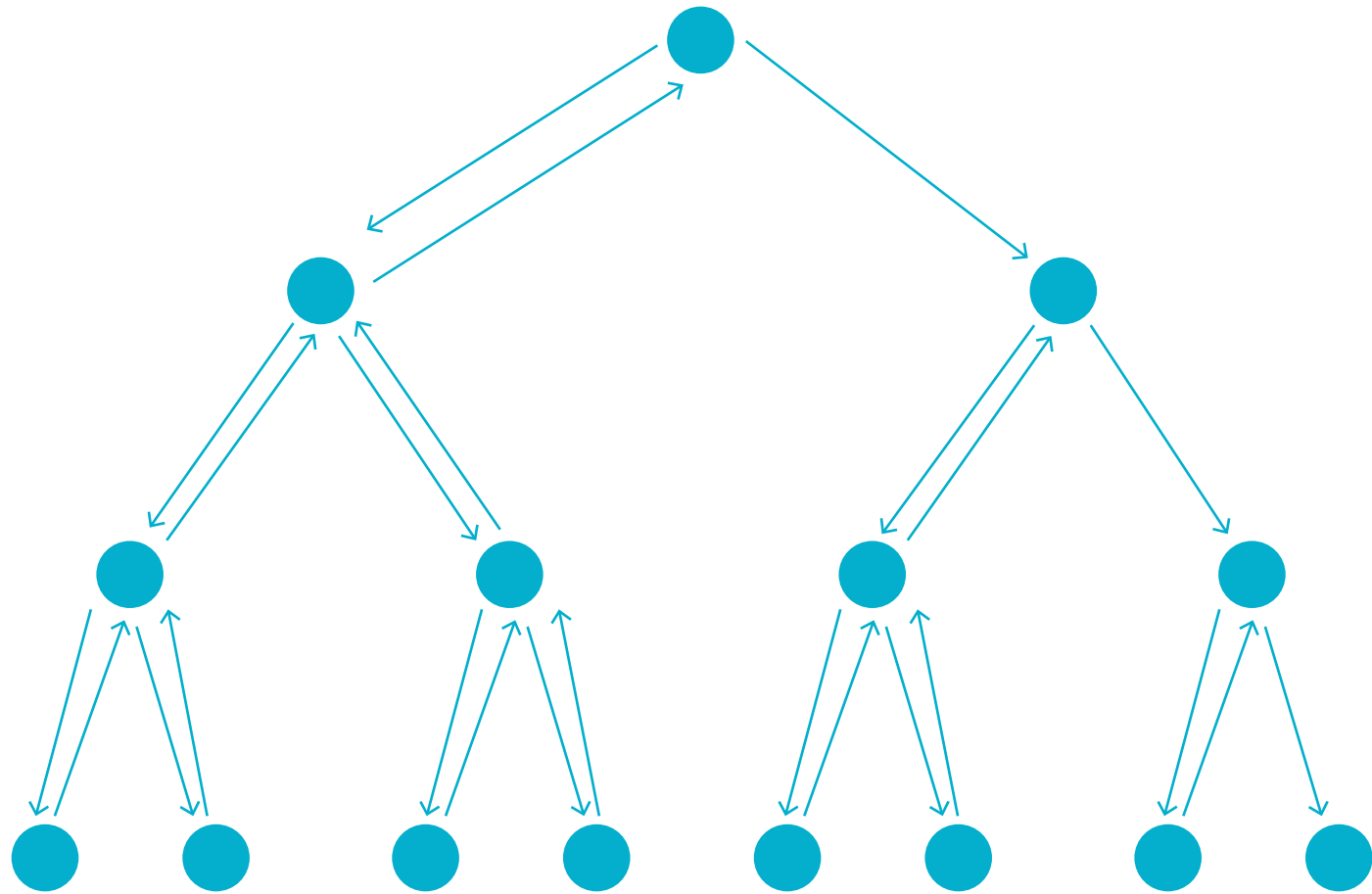
**The basic structures may be mapped onto one another.**

**A tree can be encoded onto an array.**



**A tree can also be encoded onto a matrix.**

# Trees can be traversed **depthwise** or **breadthwise**



**Often, we need to study a particular path through a network.**

**In order to go from one location to another,  
we need a route and an address.**

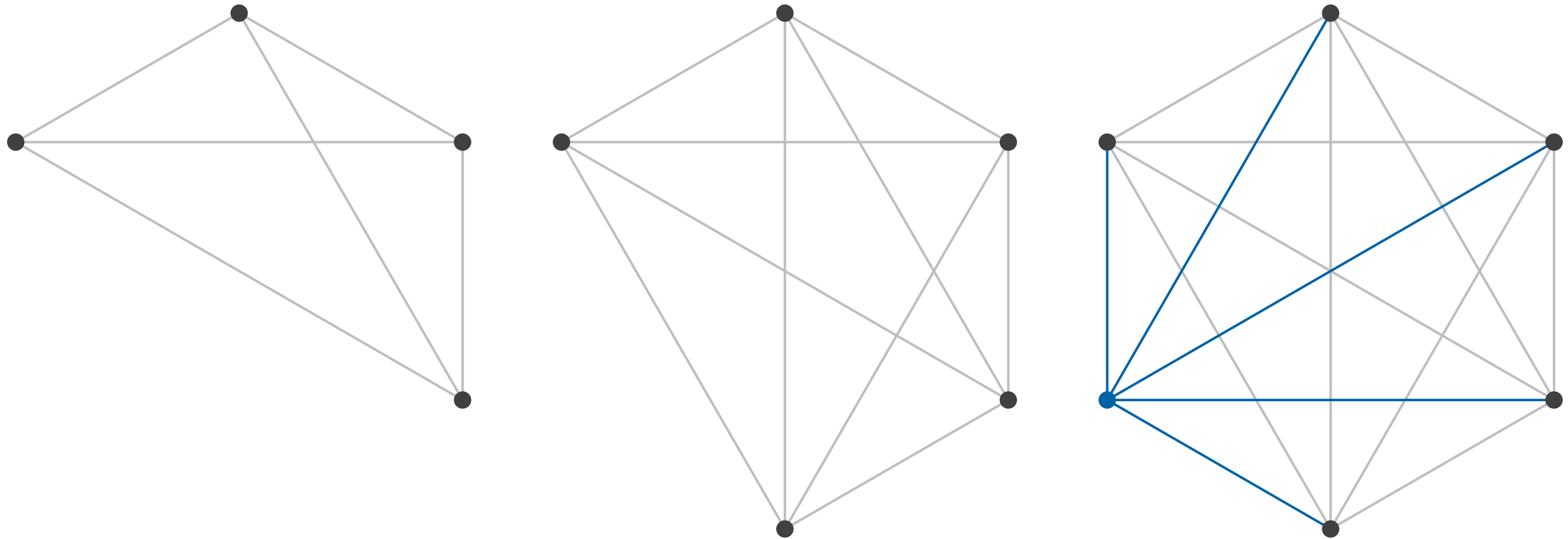
10 Downing Street

123 45 6789

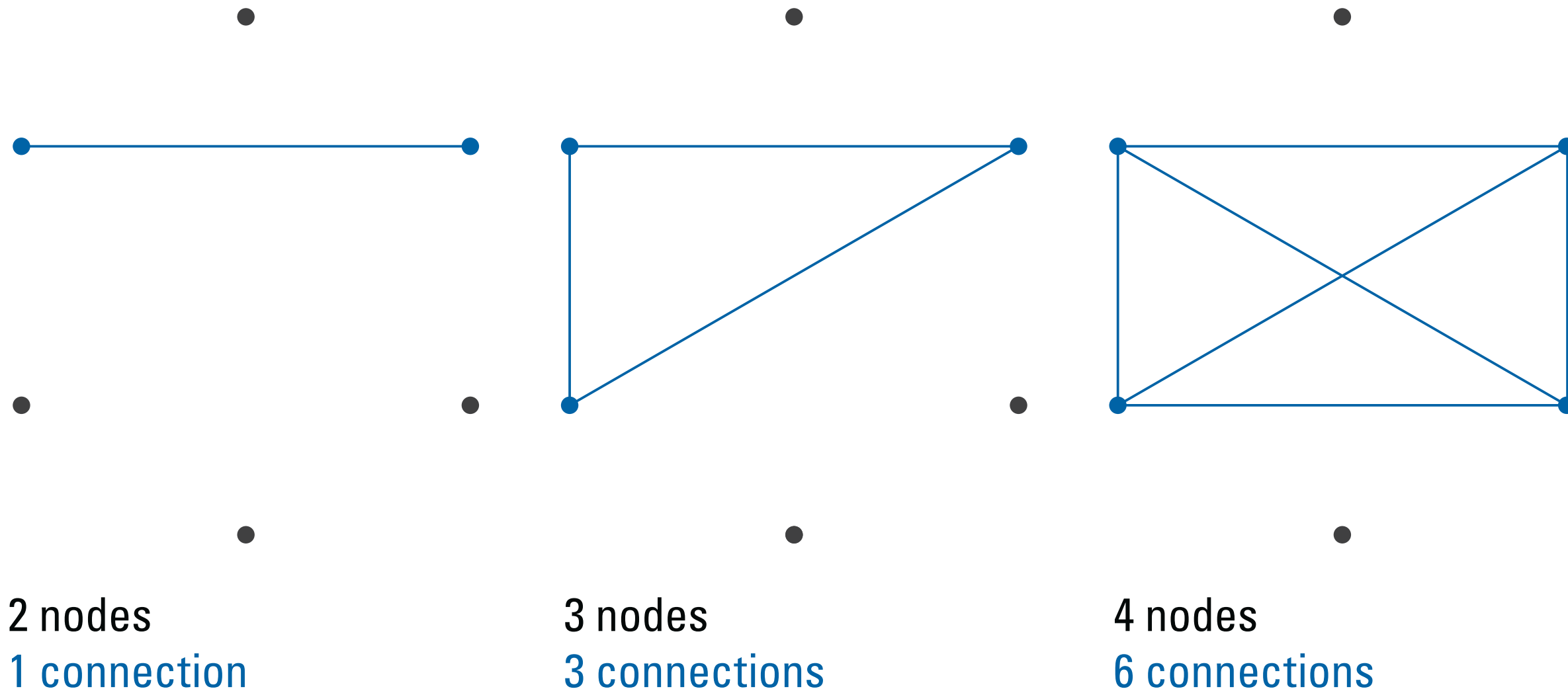
1 415 309 6057

c://university/school/department/faculty\_member/student

**In a network, each node enhances the value of the existing nodes by increasing the number of connections.**



# As the number of nodes grow, each new node brings an increasing number of new connections.

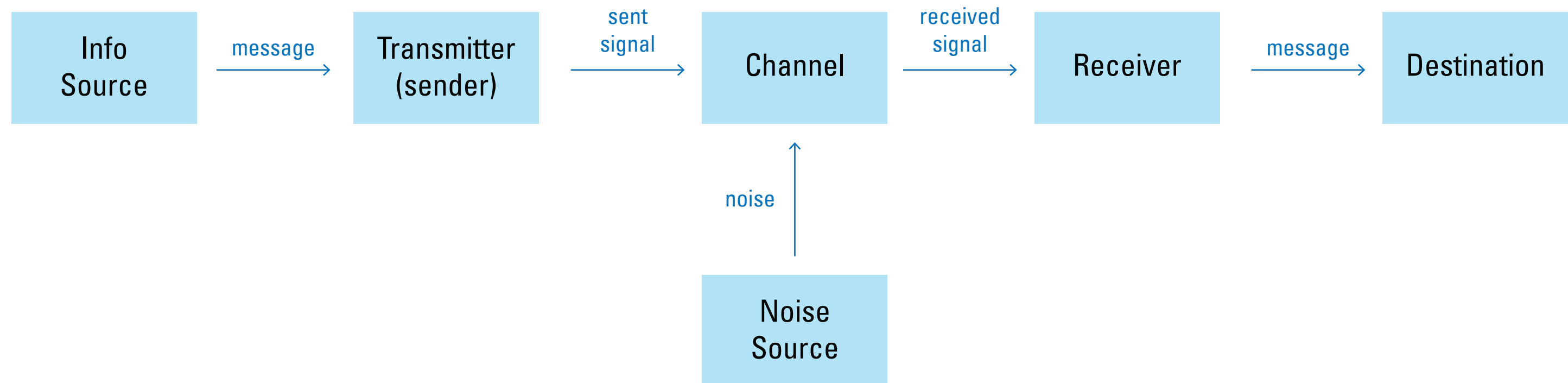


$n$  nodes yield  $\frac{(n^2 - n)}{2}$  connections

1000 nodes yield nearly half a million connections

# Communications within networks

# The Mathematical Model of Communication — Shannon + Weaver



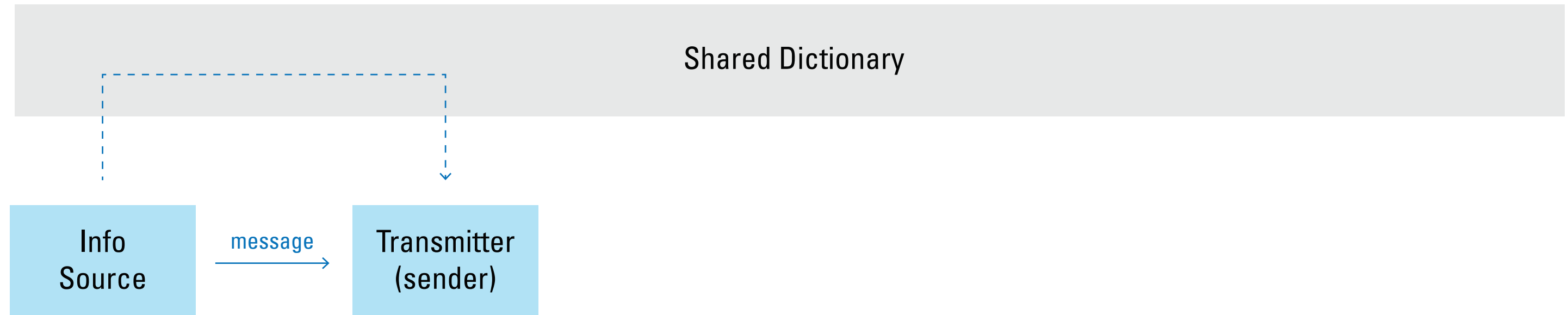


# The model relies on a shared dictionary — a controlled vocabulary.

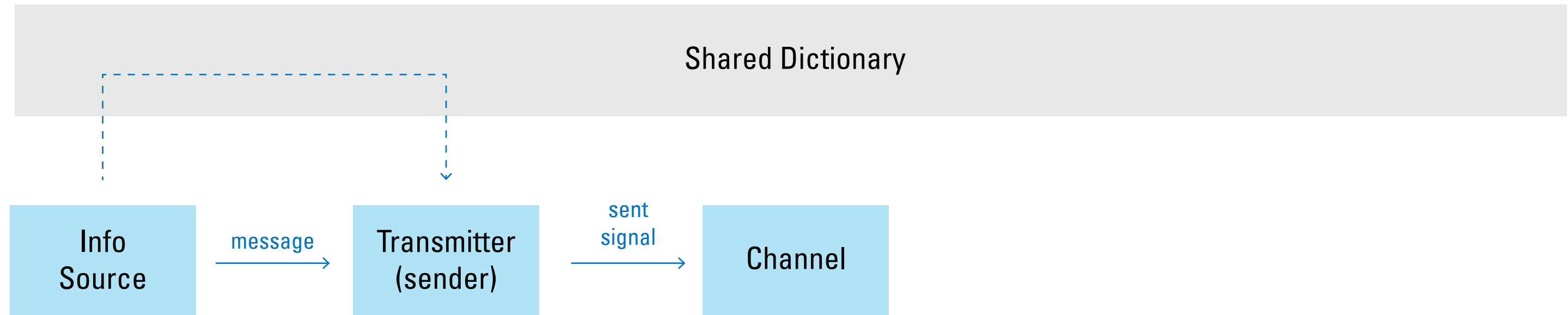
Shared Dictionary

Info  
Source

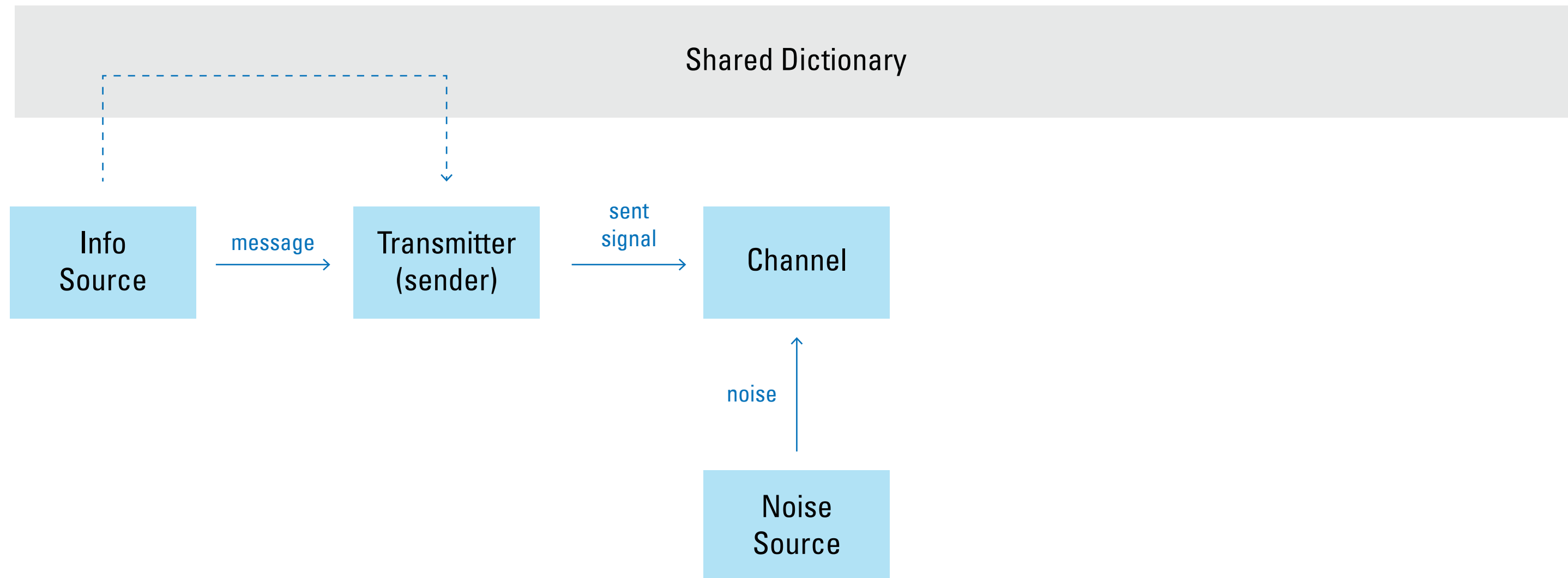
# An information source selects one possible message from the dictionary.



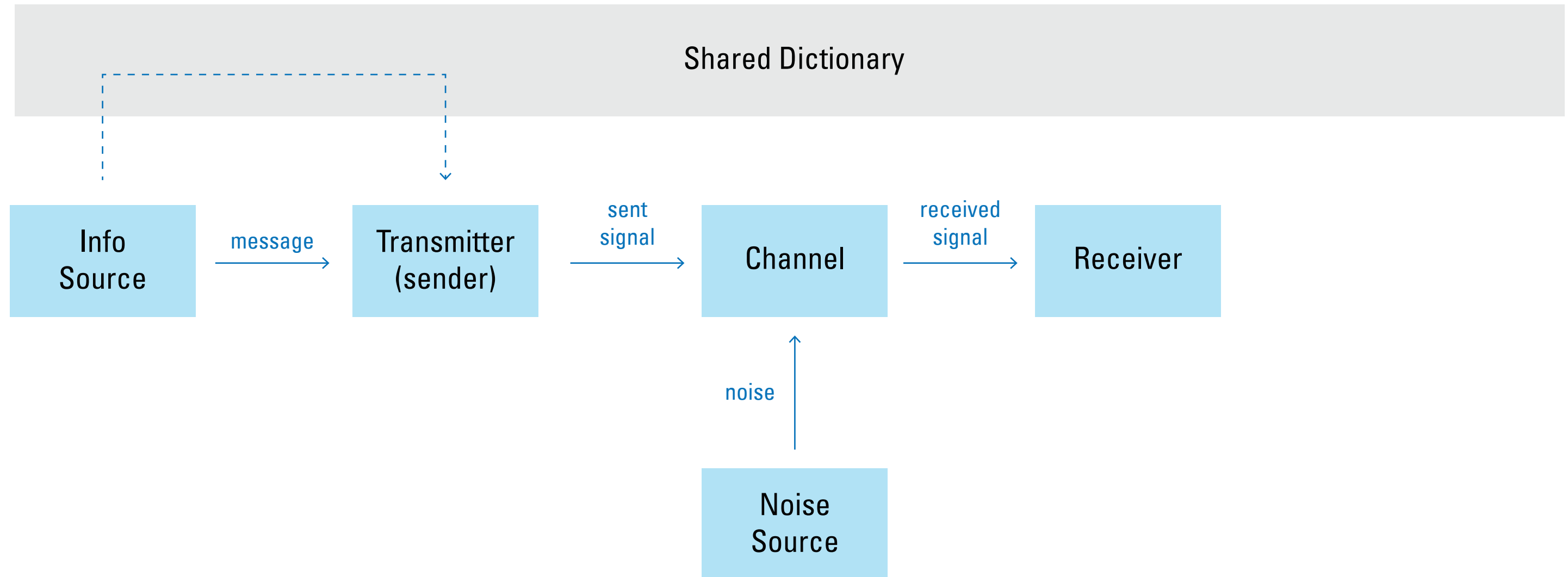
# The transmitter uses a transducer to send signals into the channel.



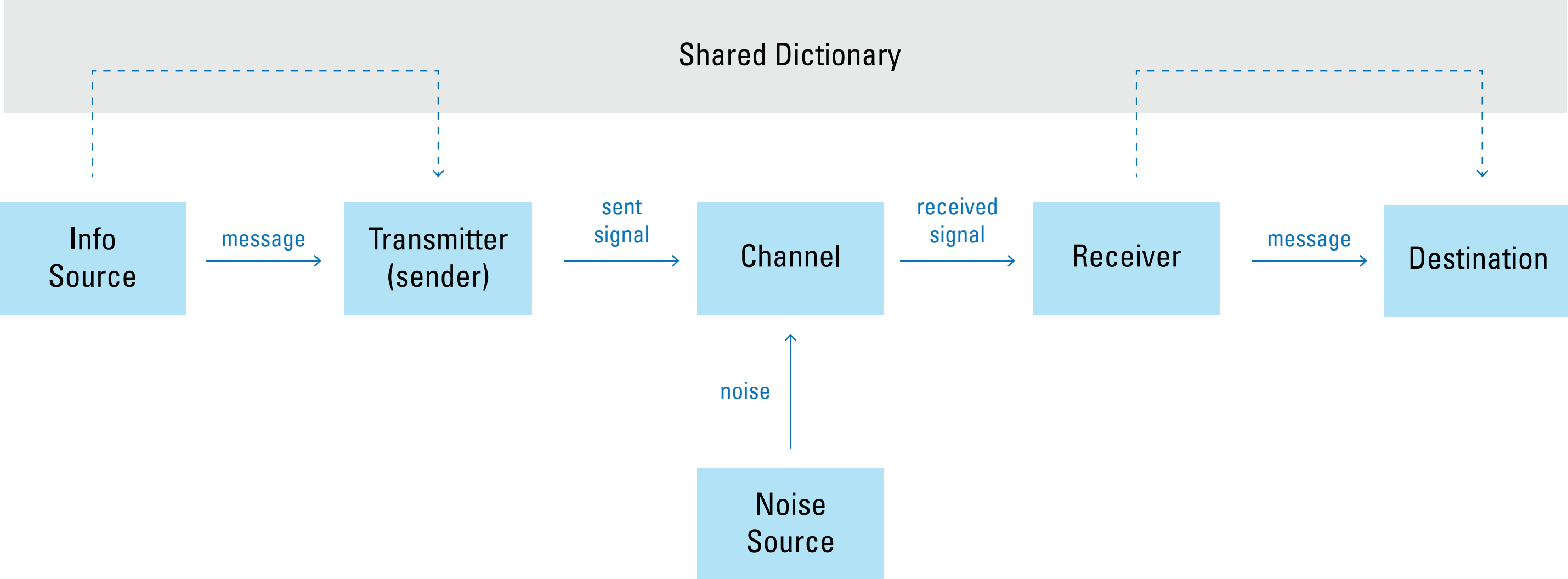
# While passing through the channel, the signal is subject to noise (distortion).



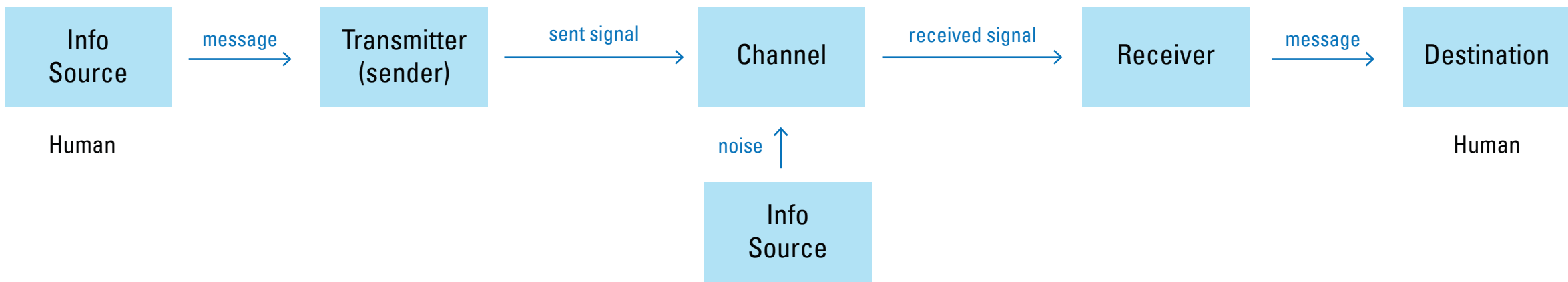
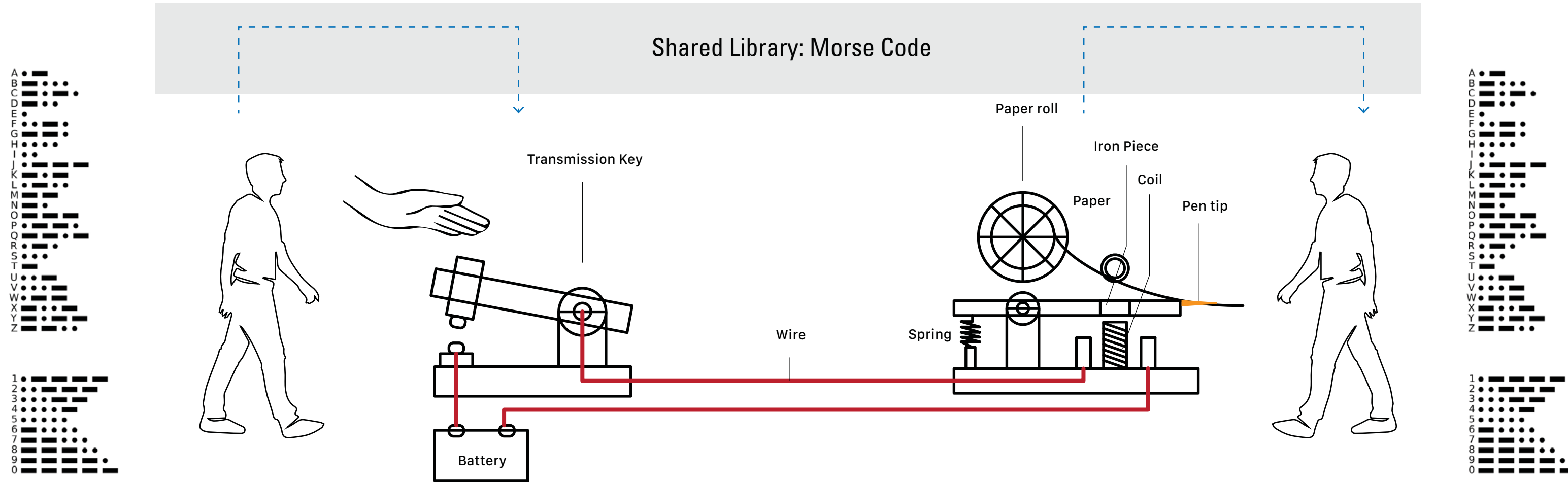
**On the other side, another transducer converts the signal into a "readable" form.**



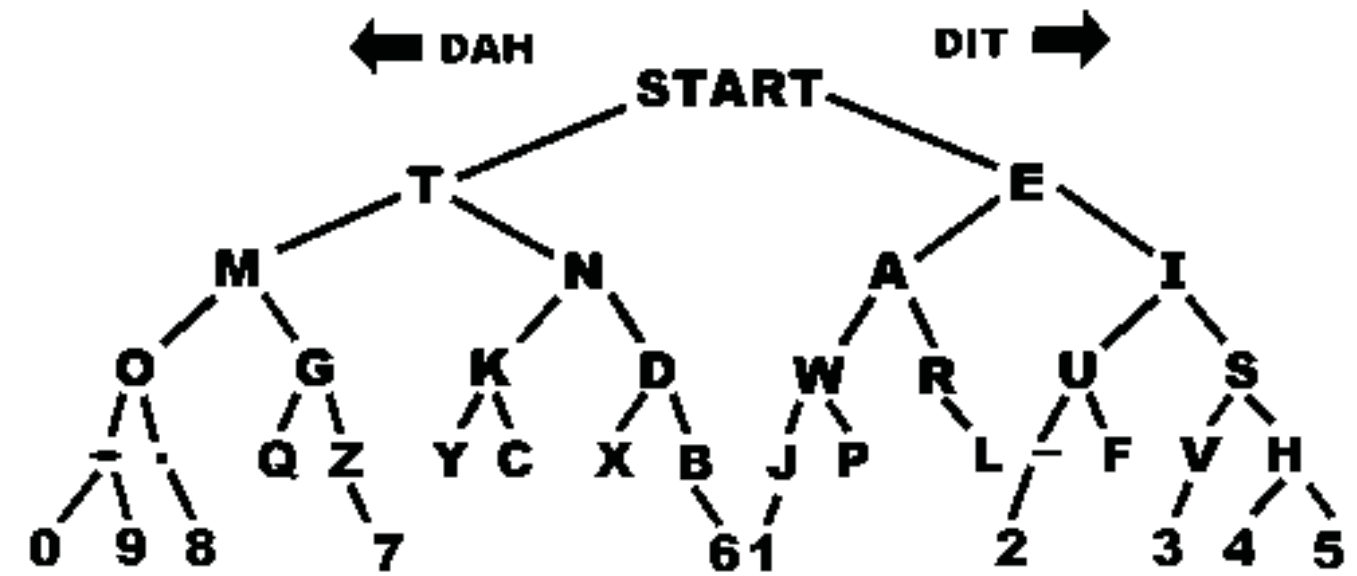
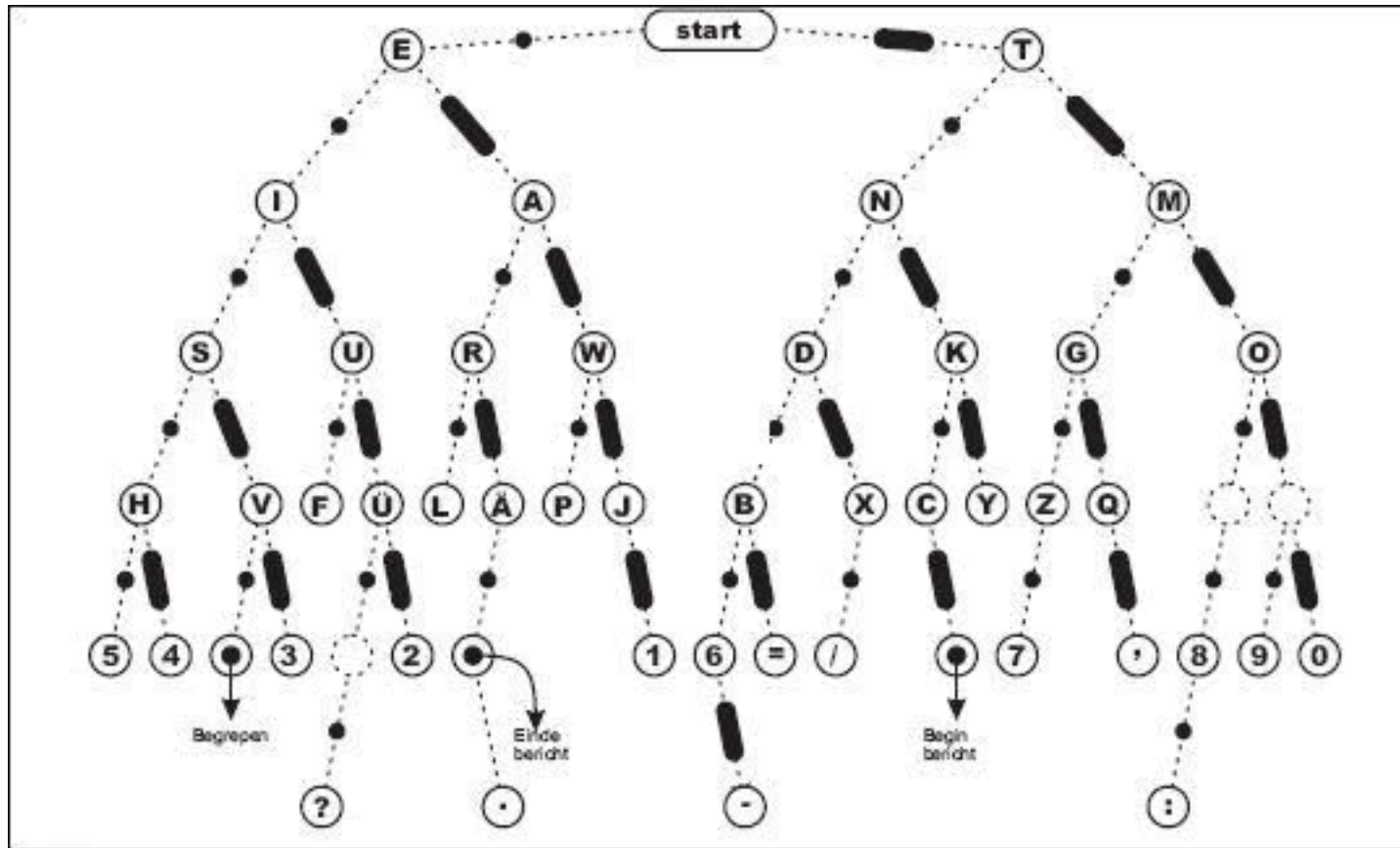
# The receiver then looks up the message in the shared dictionary.



# Telegraph and Morse code

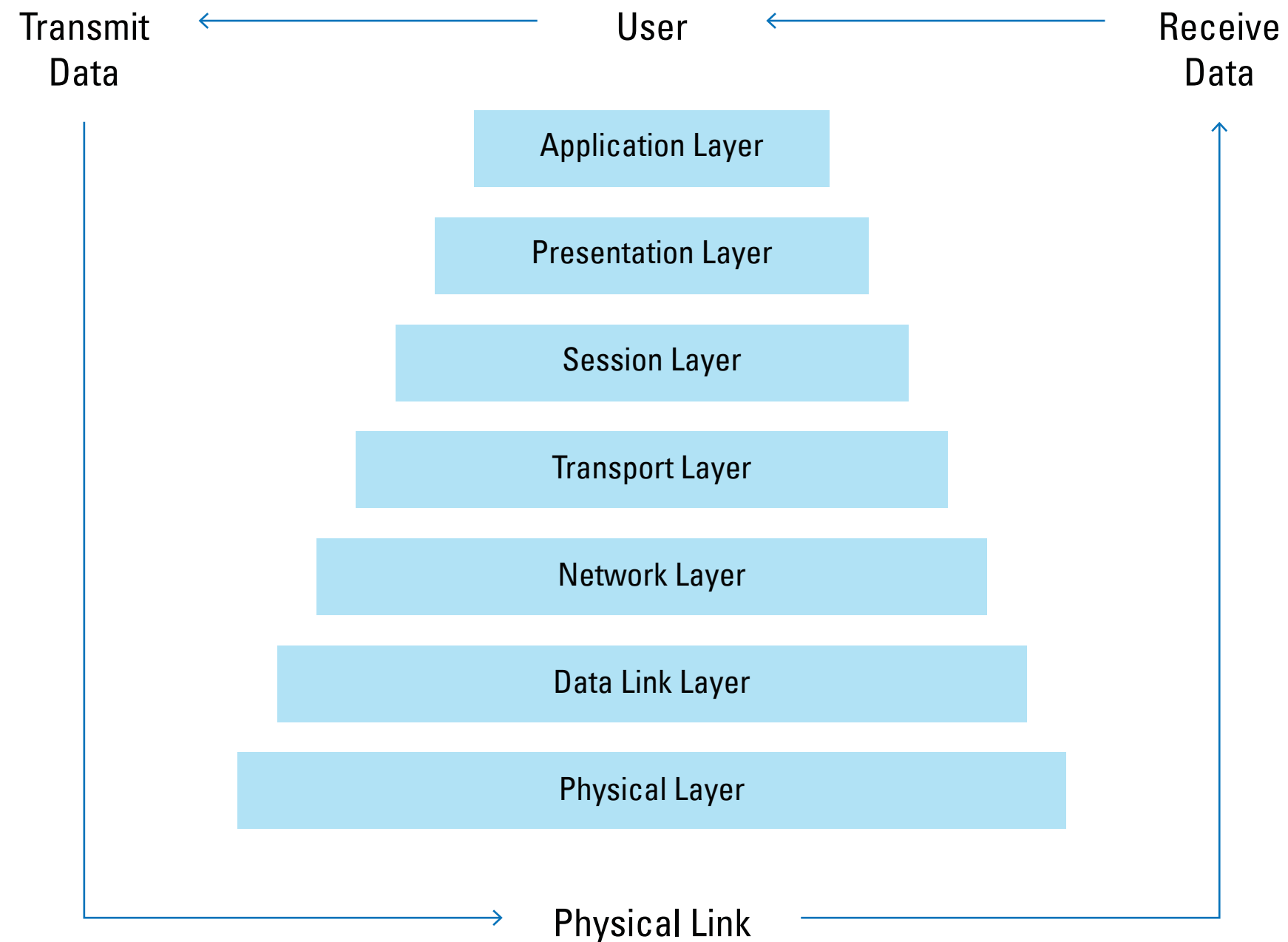


# Morse code itself is organized as a tree





# OSI 7 layer model of networking



**Special thanks to**  
**Jamie Ikeda**  
**Wilson Wu**

[hugh@dubberly.com](mailto:hugh@dubberly.com)

Presentation posted at  
[systems.dubberly.com/nodes\\_links\\_networks.pdf](https://systems.dubberly.com/nodes_links_networks.pdf)