Beautiful Evidence

by **Edward Tufte**

“How observation turns into explanations and evidence.”

“The metaphor for evidence presentations is analytical thinking.”

Mapped picture:
Image as Evidence and Explanation

Data Visualization
2019.11.11

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Image as Evidence and Explanation

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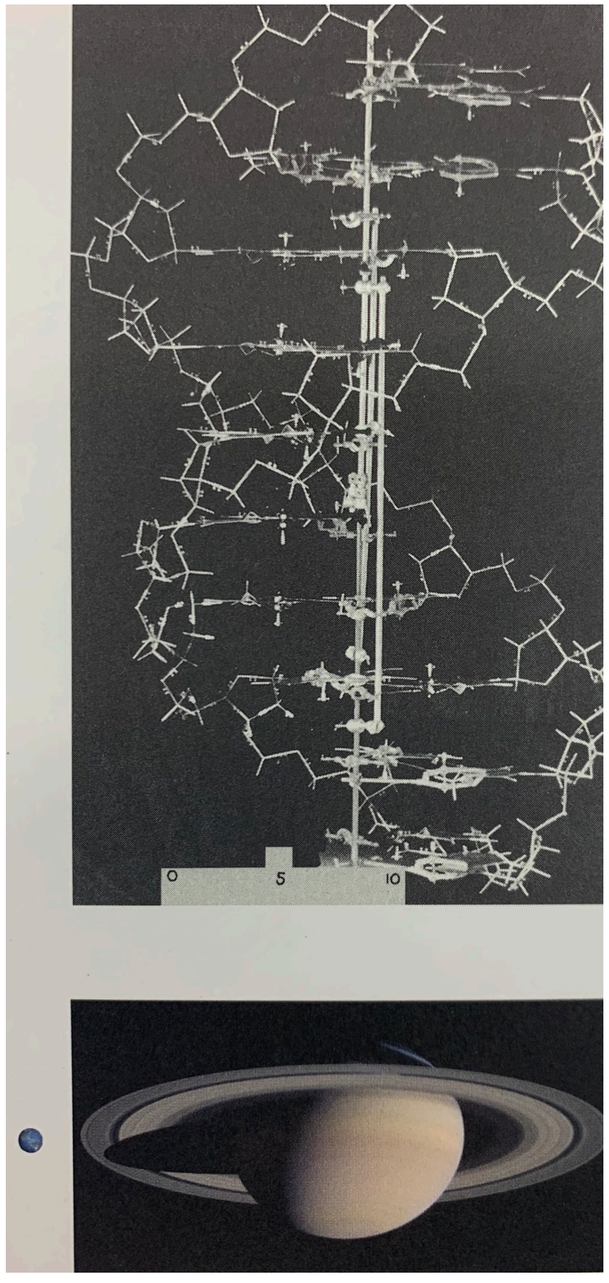
Branden Choi



Explanatory, Journalistic, and Sceintific images should be nearly always mapped, contexturalized, and placed on the universal grid

To contexturalize, provide the image scale, diagram, overlay, numbers, and words to image.

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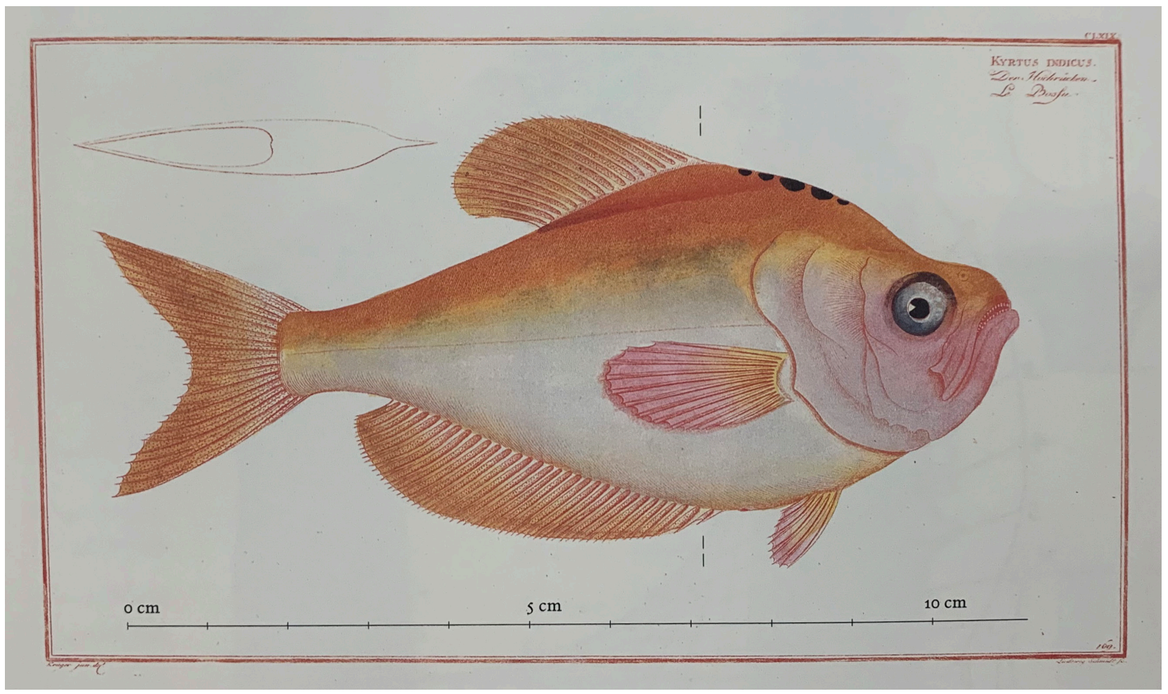
Kakatoes.



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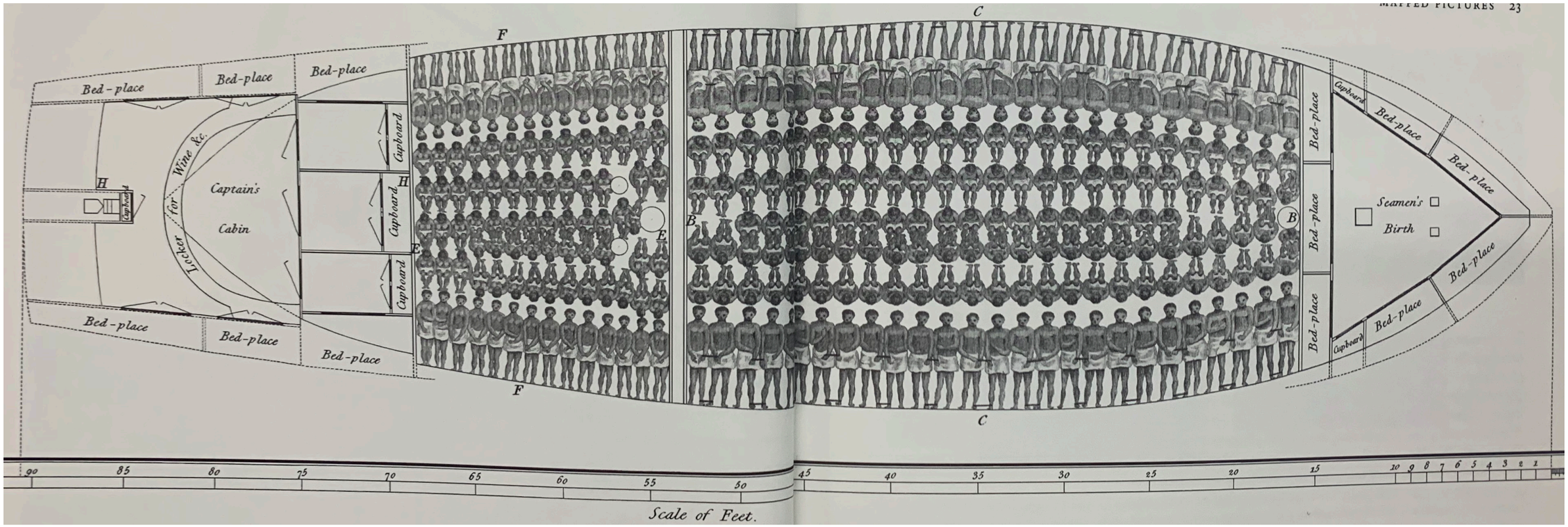

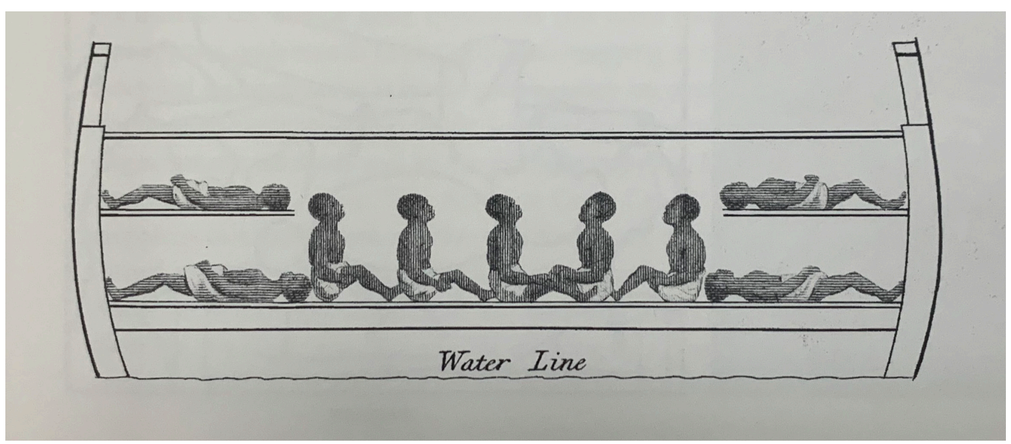

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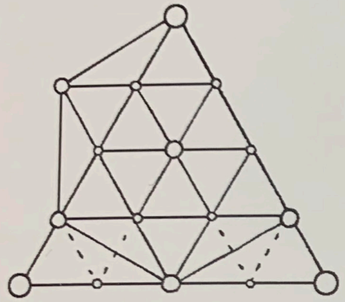
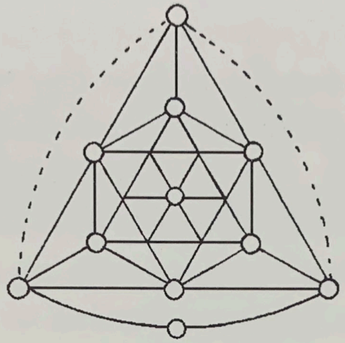
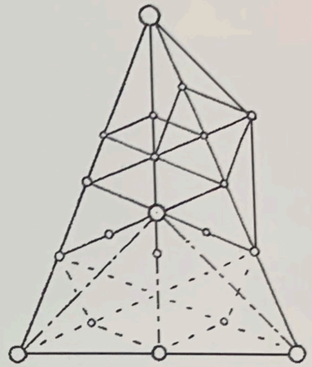
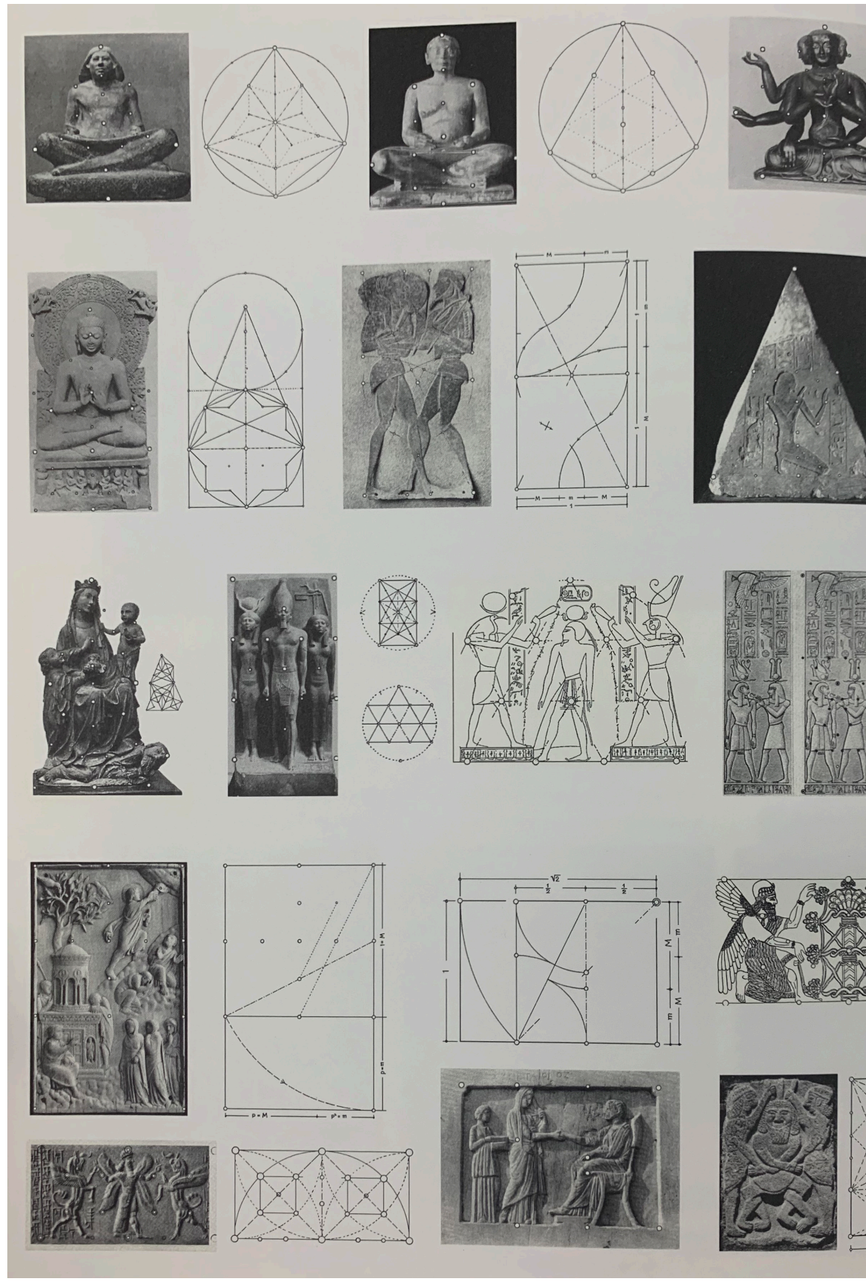
triangles accommodating the infant heads. Links between the images and dots here are as fanciful as the links between star-myth images and actual stars on antique constellation maps.







Tafel 190. Von links nach rechts: Maria mit Kind. Arbeit des 15. Jahrhunderts. Im Deutschen Museum zu Berlin. — Mutter Anna selbdritt. Auf dem Marienaltar im Seitenschiff des Domes zu Bamberg. Vom Anfang des 16.Jahrhunderts. — Muttergottes. Vom Anfang des 16.Jahrhunderts. Im Museum der Stadt Ulm



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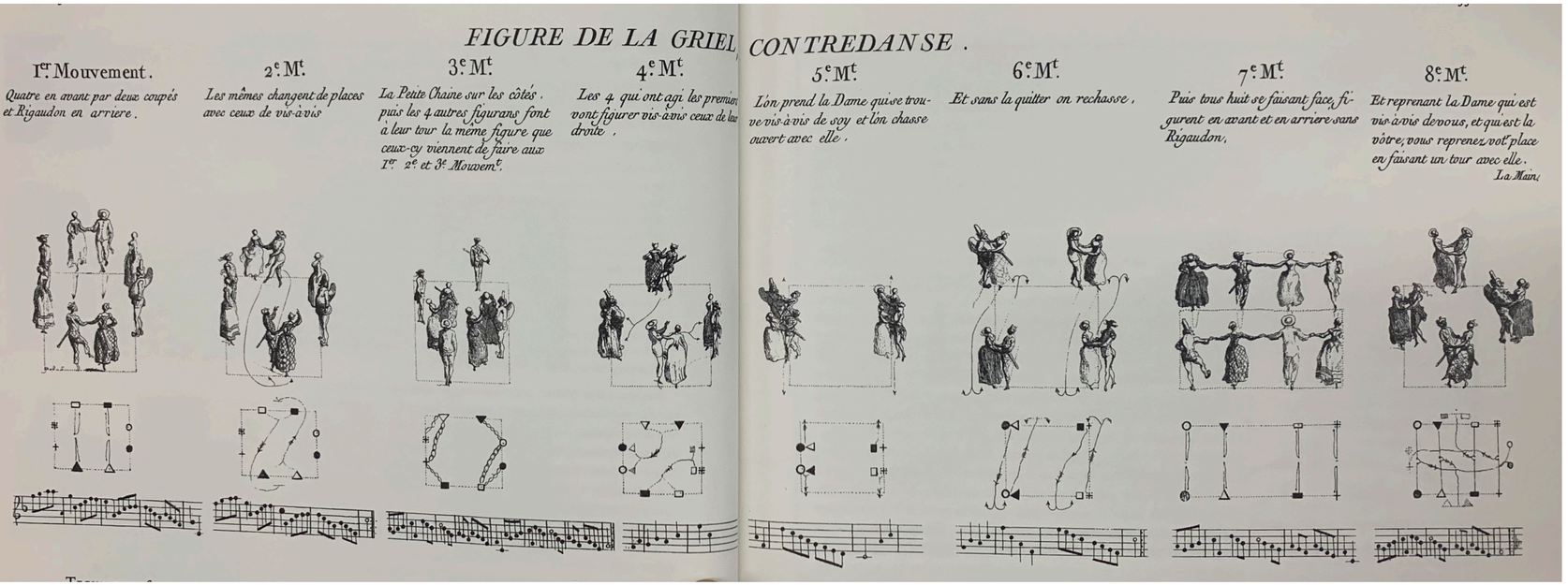
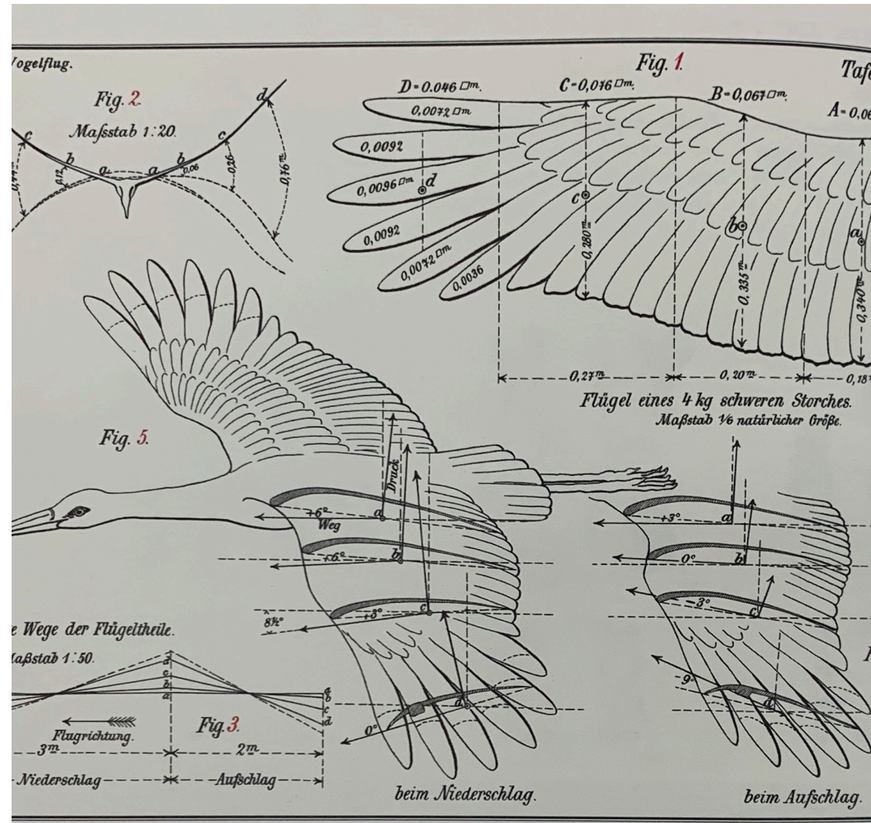
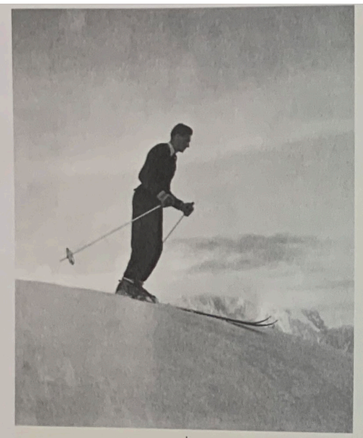
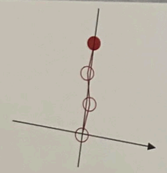
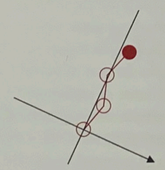




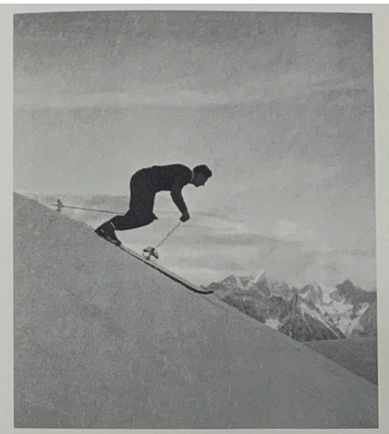


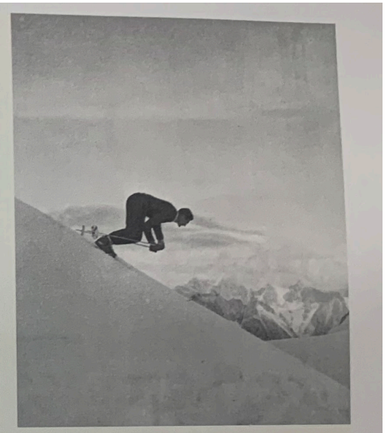


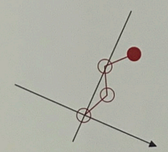


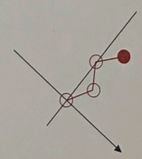
NORMAL POSITION ON GENTLE SLOPE. The body is slightly ahead of an imaginary line which being perpendicular to the slope, passes through the ankles of the skier.

POSITION ON MEDIUM SLOPE. The body is more bent and the hands are further forward.









The weight of the body rests on the ball of each foot.

POSITION ON STEEP SLOPE. Greatest possible forward bend of the ankles and upper body.

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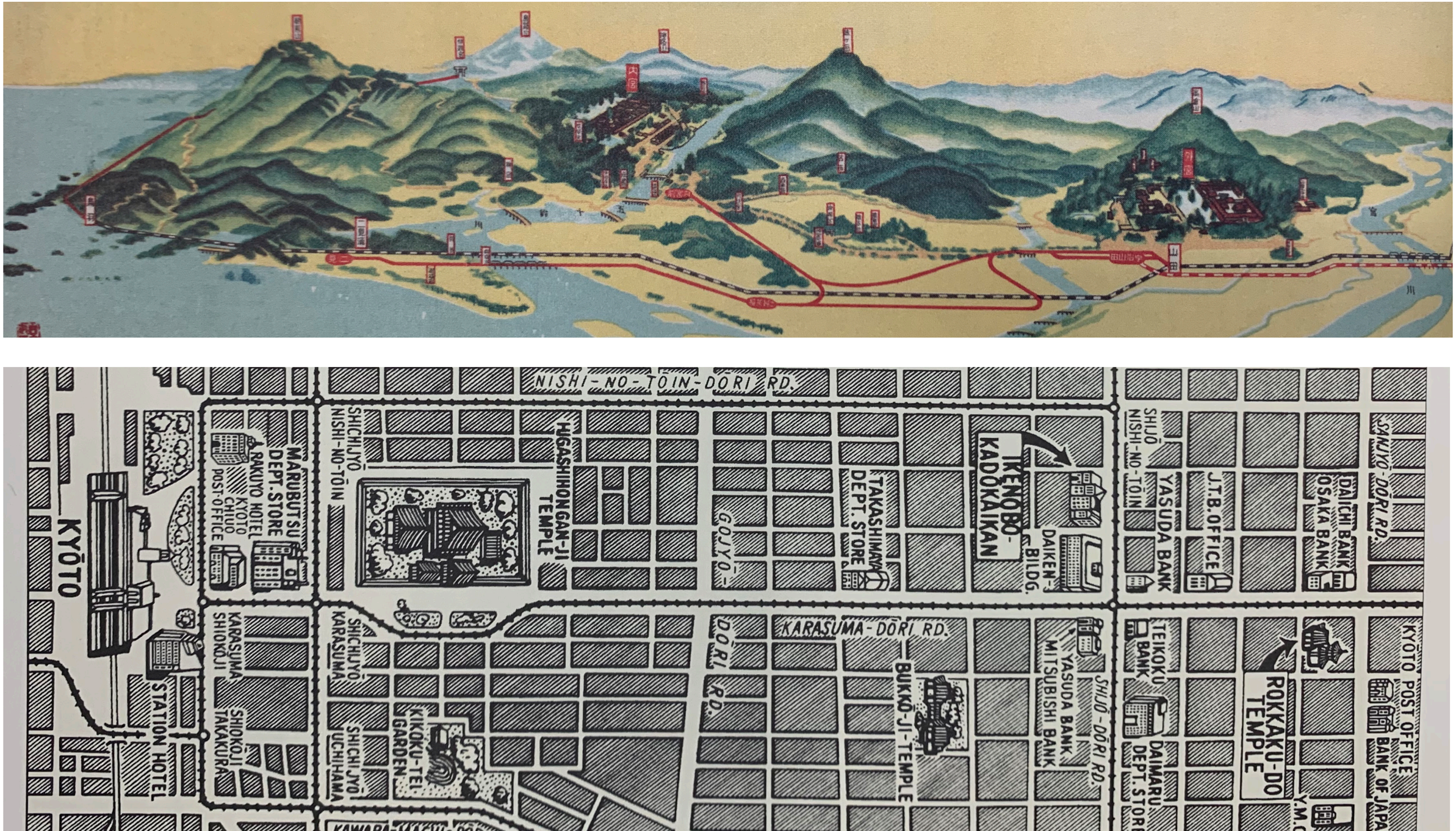

Links and Casual Arrows: Ambiguity in Action

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Links and Causal Arrows:
Ambiguity in Action

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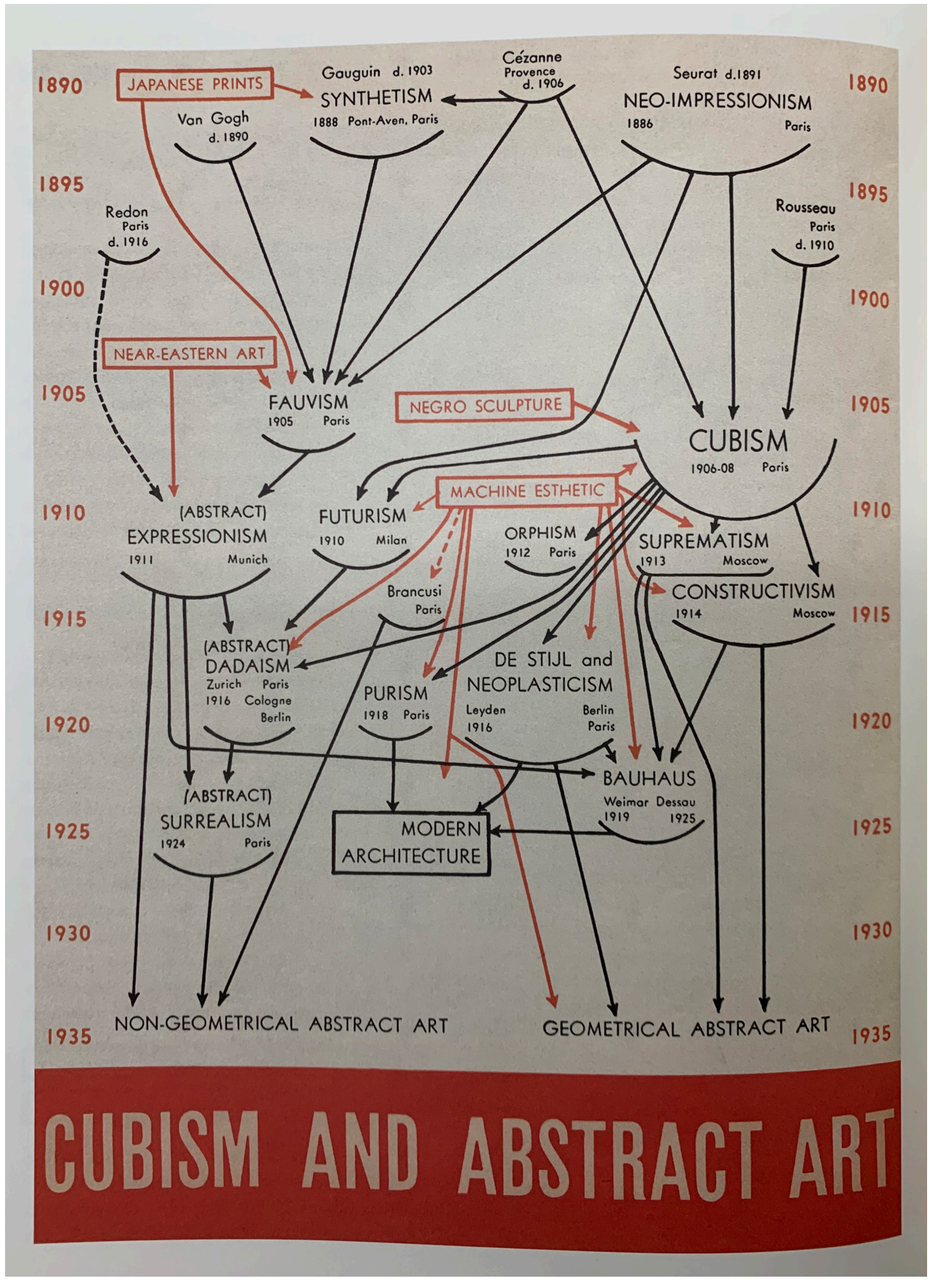
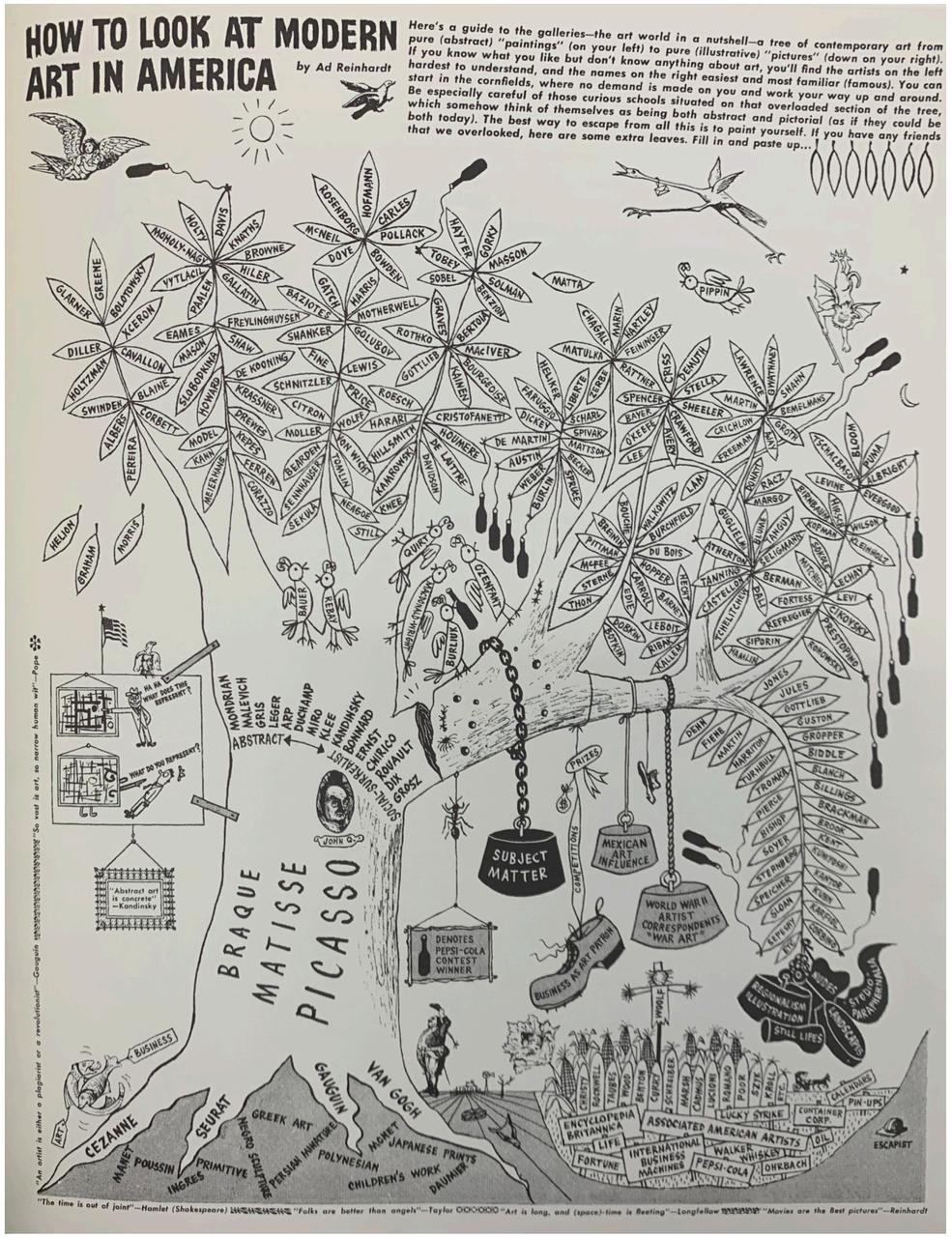
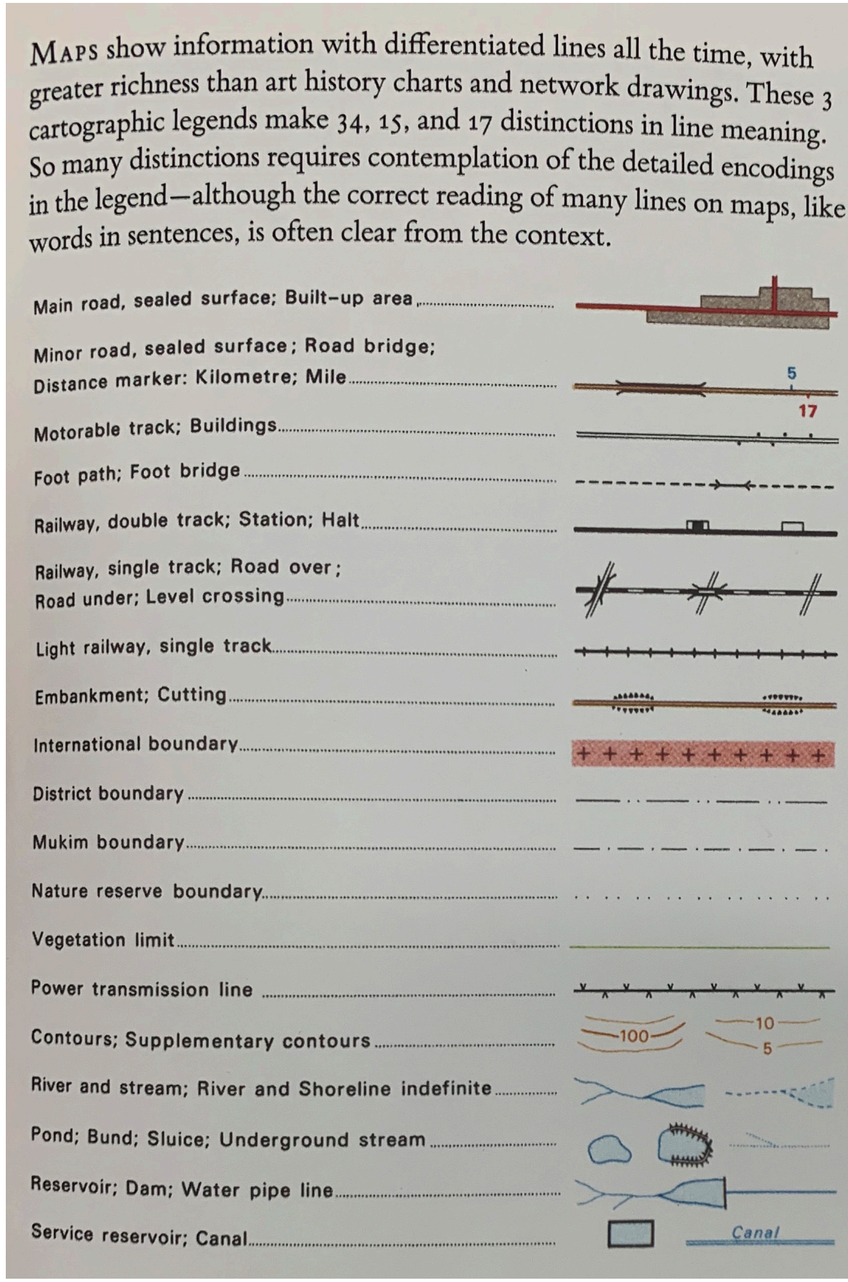
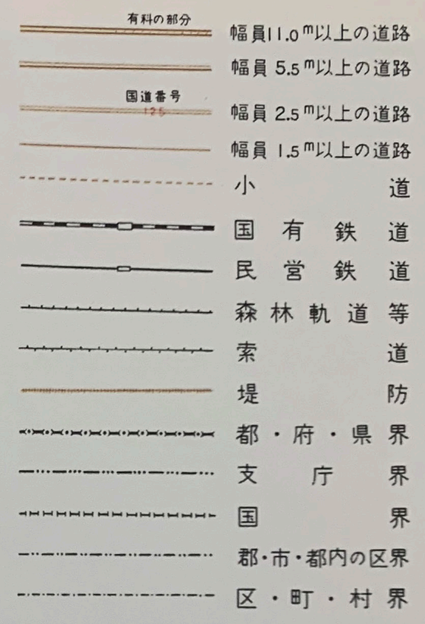
Branden Choi

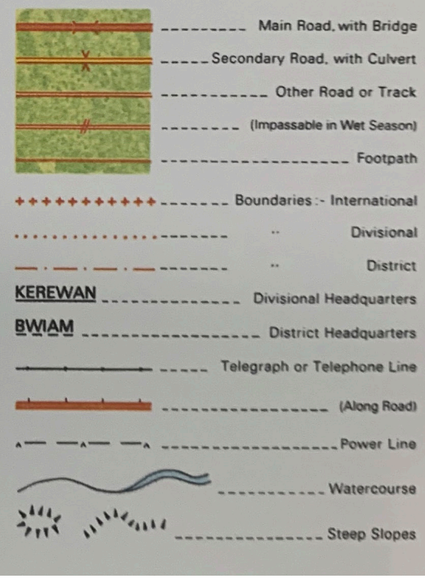




MAPS show information with differentiated lines all the time, with greater richness than art history charts and network drawings. These 3 cartographic legends make 34, 15, and 17 distinctions in line meaning. So many distinctions requires contemplation of the detailed encodings in the legend—although the correct reading of many lines on maps, like words in sentences, is often clear from the context.







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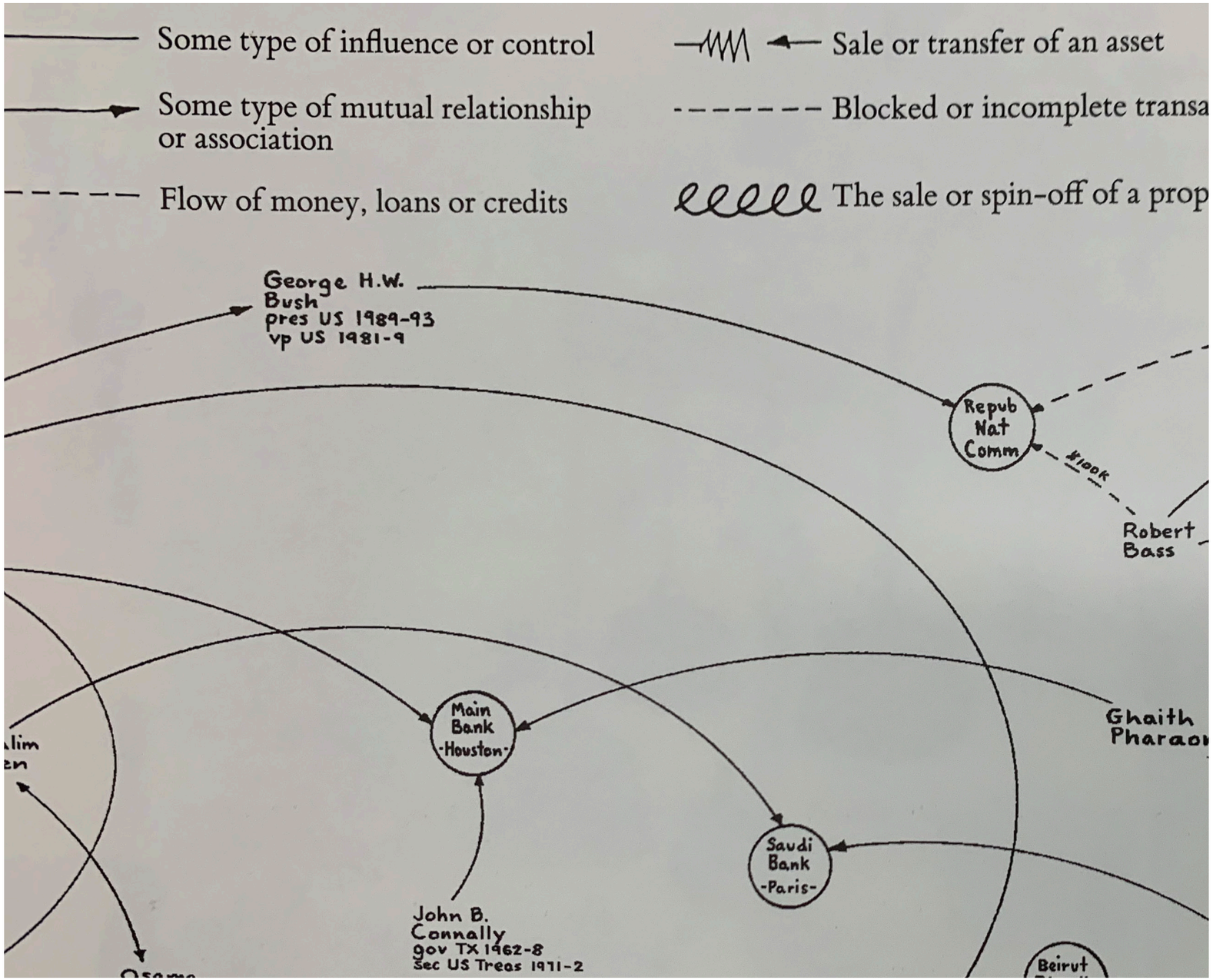
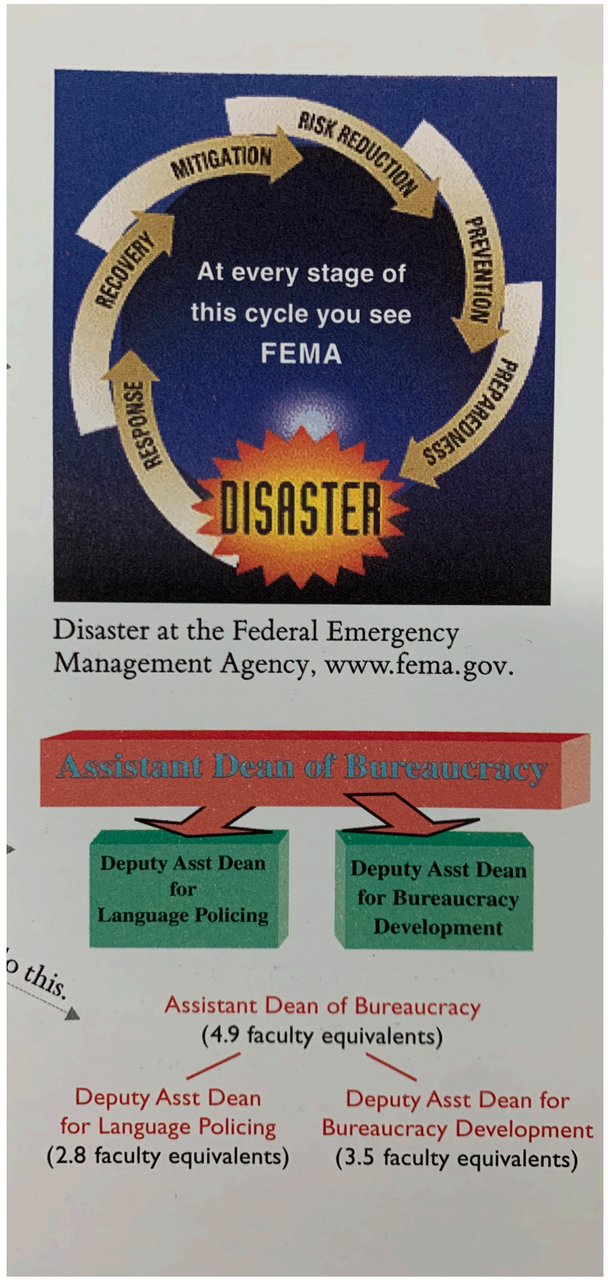




Disaster at the Federal Emergency Management Agency, www.fema.gov.

Analytical Design:
The Fundamental Principles

Data Visualization
2019.11.11

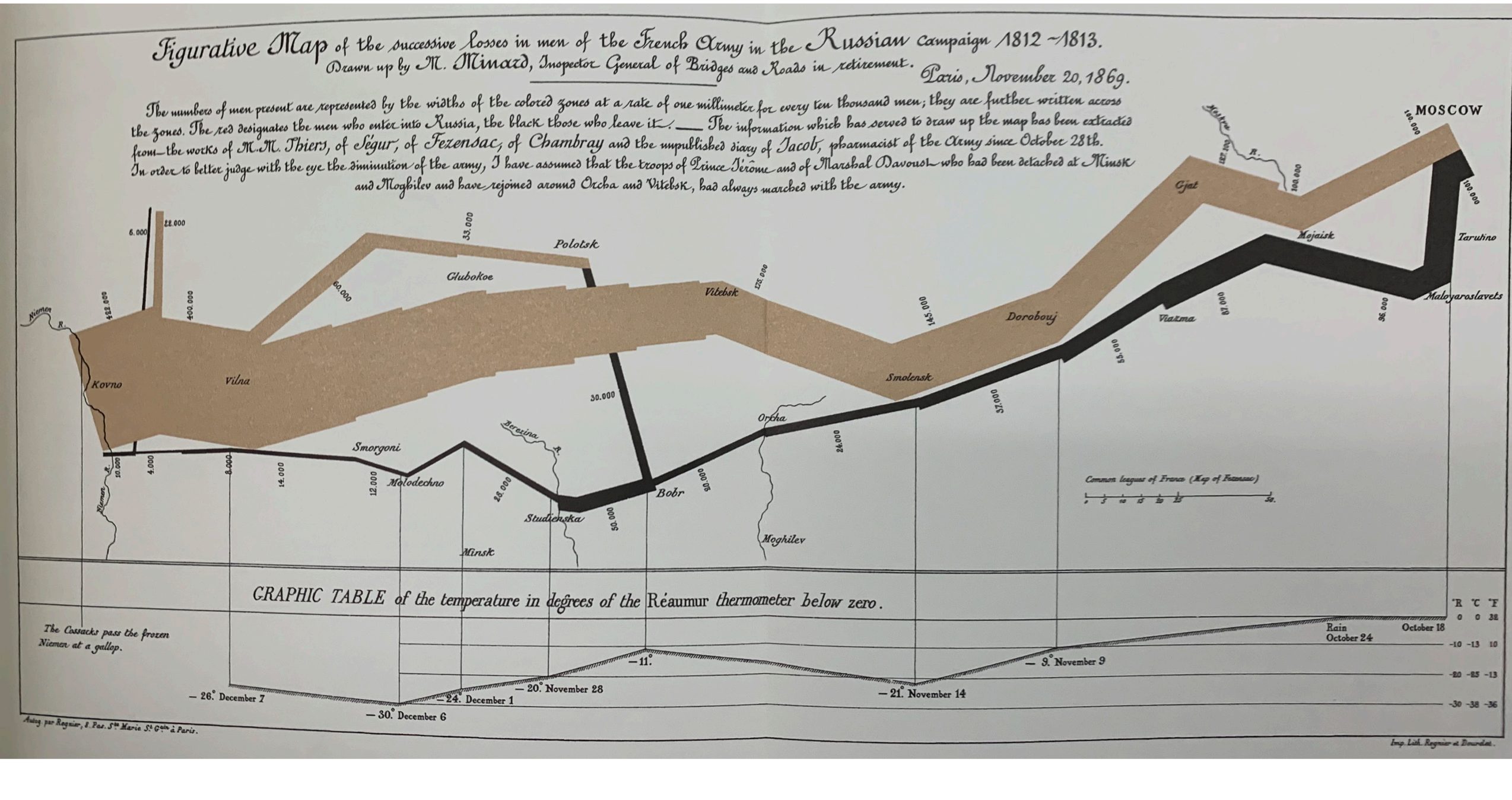
Analytical Design:
The Fundimental Principles

Sage Park &
Branden Choi

Figurative Map of the successive losses in men of the French Army in the Russian campaign 1812 ~1813.

Drawn up by M. Minard, Inspector General of Bridges and Roads in retirement. Paris, November 20, 1869.

The numbers of men present are represented by the widths of the colored zones at a rate of one millimeter for every ten thousand men; they are further written across the zones. The red designates the men who enter into Russia, the black those who leave it. — The information which has served to draw up the map has been extracted from the works of M.M. Thiers, of Ségur, of Fezensac, of Chambray and the unpublished diary of Jacob, pharmacist of the Army since October 28th. In order to better judge with the eye the diminution of the army, I have assumed that the troops of Prince Jérôme and of Marshal Davoust who had been detached at Minsk and Mogbilev and have rejoined around Orcha and Vitebsk, had always marched with the army.



Imp. Lith. Regnier et Dourdet.

Autog par Regnier, 8 Pas. Ste Marie St Cain à Paris.

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Analytical Design:
The Fundimental Principles

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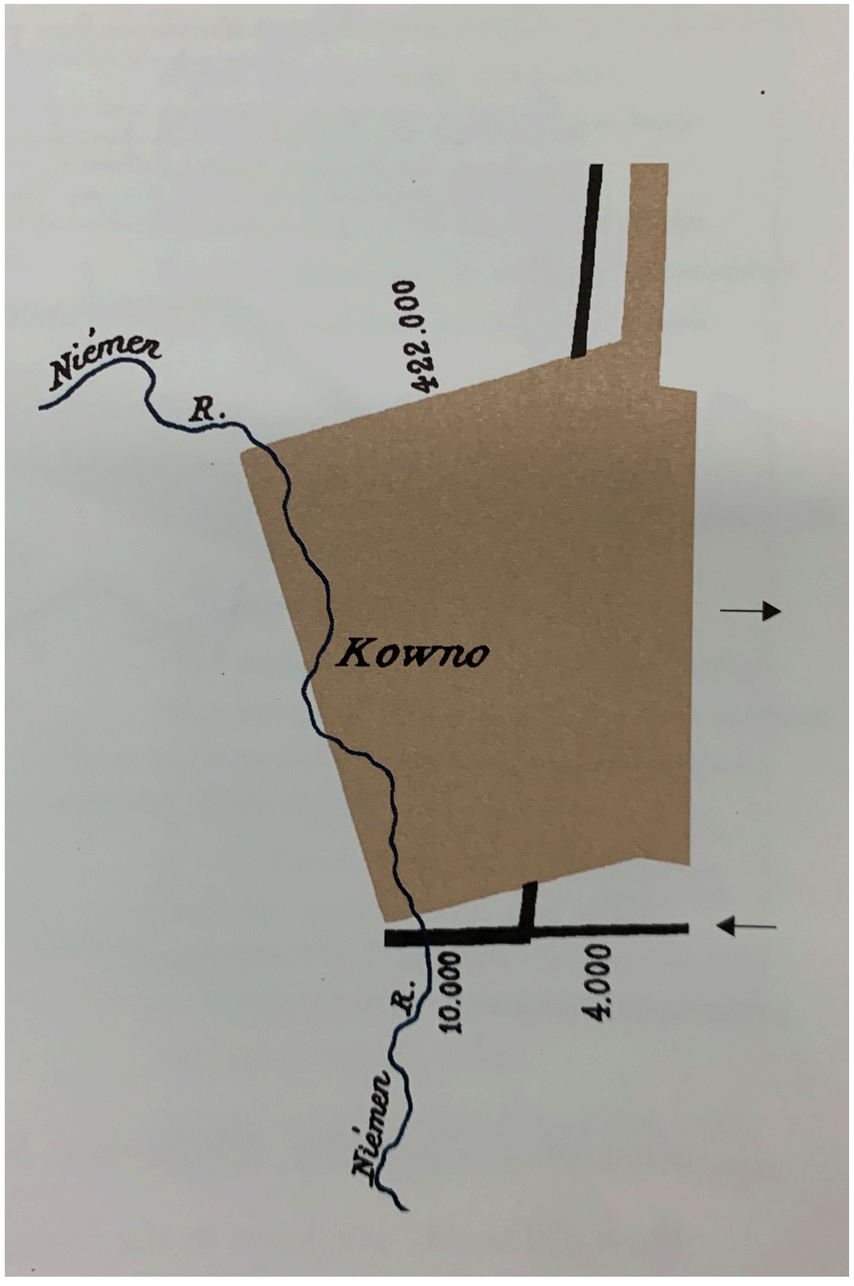
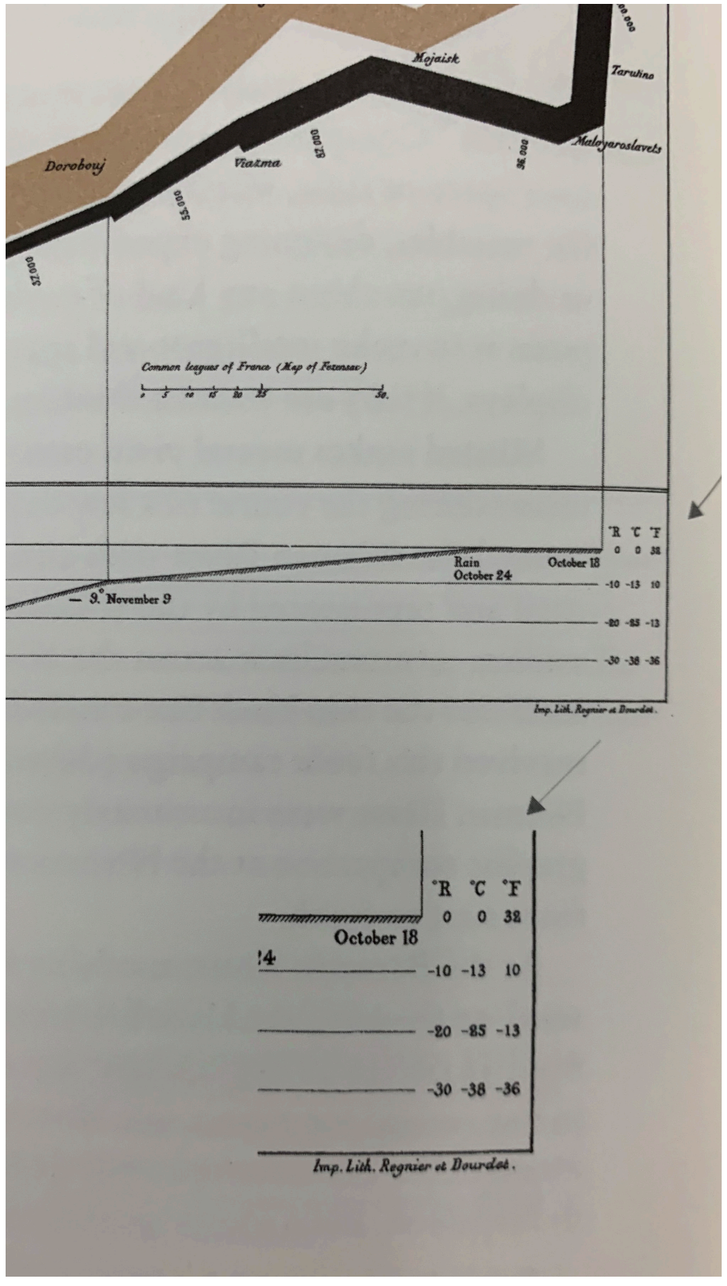
Branden Choi





Data Visualization
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Analytical Design:
The Fundimental Principles

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What is the display about? Losses in men of the French Army in the Russian Campaign 1812~1813.

Who did the work? Drawn up by M. Minard

Who's that? Inspector General of Bridges and Roads in retirement.

Where and when was the work done? Paris, November 20, 1869.

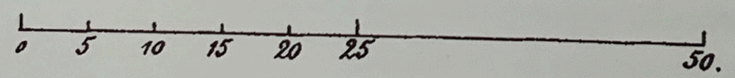
What are the data sources? The information which has served to draw up the map has been extracted from the works of M.M. Thiers, of Ségur, of Fezensac, of Chambray and the unpublished diary of Jacob, the pharmacist of the Army since October 28th.

Any assumptions? In order to better judge with the eye the diminution of the army, I have assumed that the troops of Prince Jérôme and of Marshal Davoust who had been detached at Minsk and Mogbilev and have rejoined around Orcha and Vitebsk, had always marched with the army.

What are the scales of measurement?

for invasion and retreat flow-lines: one millimeter for every ten thousand men

for the underlying map: Common leagues of France (Map of Fezensac)



The French "lieue" is of variable length, approximately 2.5 miles or 4 kilometers (historically varying by up to 10%).

for the temperature: degrees of the Réaumur thermometer below zero

Who published and printed the work? Autog. par Regnier, 8. Pas. Ste Marie St Gain à Paris. Imp. Lith. Regnier et Dourdet.

Power Point:
Cognitive Style

Data Visualization
2019.11.11

Power Point:
Cognitive Style

Sage Park &
Branden Choi

On this one Columbia slide, a PowerPoint festival of bureaucratic hyper-rationalism, 6 different levels of hierarchy are used to display, classify, and arrange 11 phrases:

Level 1	Title of Slide
Level 2	● Very Big Bullet
Level 3	– big dash
Level 4	◆ medium-small diamond
Level 5	• tiny bullet
Level 6	( ) parentheses ending level 5

The analysis begins with the dreaded Executive Summary, with a conclusion presented as a headline: "Test Data Indicates Conservatism for Tile Penetration." This turns out to be unmerited reassurance. Executives, at least those who don't want to get fooled, had better read far beyond the title.

The "conservatism" concerns the *choice of models* used to predict damage. But why, after 112 flights, are foam-debris models being calibrated during a crisis? How can "conservatism" be inferred from a loose comparison of a spreadsheet model and some thin data? Divergent evidence means divergent evidence, not inferential security. Claims of analytic "conservatism" should be viewed with skepticism by presentation consumers. Such claims are often a rhetorical tactic that substitutes verbal fudge factors for quantitative assessments.

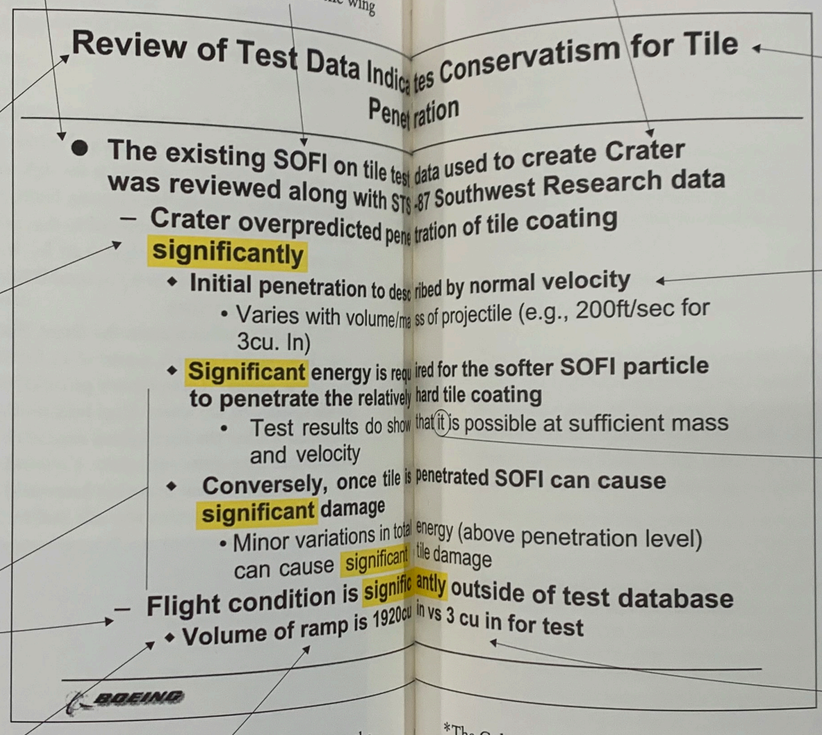
As the bullet points march on, the seemingly reassuring headline fades away. Lower-level bullets at the end of the slide undermine the executive summary. This third-level point notes that "Flight condition [that is, the debris hit on the Columbia] is significantly outside of test database." How far outside? The final bullet will tell us.

This fourth-level bullet concluding the slide reports that the debris hitting the Columbia is estimated to be $1920/3 = 640$ times larger than data used in the tests of the model! The correct headline should be "Review of Test Data Indicates Irrelevance of Two Models." This is a powerful conclusion, indicating that pre-launch safety standards no longer hold. The original optimistic headline has been eviscerated by the lower-level bullets. Note how close attentive readings can help consumers of presentations evaluate the presenter's reasoning and credibility.

The Very-Big-Bullet phrase fragment does not seem to make sense. No other VBBs appear in the rest of the slide, so this VBB is not necessary.

Spray On Foam Insulation, a fragment of which caused the hole in the wing

A model to estimate damage to the tiles protecting flat surfaces of the wing



Here "ramp" refers to foam debris (from the bipod ramp) that hit Columbia. Instead of the cryptic "Volume of ramp," say "estimated volume of foam debris that hit the wing." Such clarifying phrases, which may help upper level executives understand what is going on, are too long to fit on low-resolution bullet outline formats. PP demands a shorthand of acronyms, phrase fragments, clipped jargon, and vague pronoun references in order to get at least some information into the tight format.

*The Columbia Accident Investigation Board (final report, p. 191) referred to this point about units of measurement: "While such inconsistencies might seem minor, in highly technical fields like aerospace engineering a misplaced decimal point or mistaken unit of measurement can easily engender inconsistencies and inaccuracies." The phrase "mistaken unit of measurement" is an unkind veiled reference to a government agency that had crashed $250 million of spacecraft into Mars because of a mix-up between metric and non-metric units of measurement.

The vigorous but vaguely quantitative words "significant" and "significantly" are used five times on this slide, with meanings ranging from "detectable in a perhaps irrelevant calibration case study" to "an amount of damage so that everyone dies" to "a difference of 640-fold." The five "significants" cannot refer to statistical significance, for no formal statistical analysis has been done.

Note the analysis is about *tile* penetration. But what about RCC penetration? As investigators later demonstrated, the foam did not hit the tiles on the wing surface, but instead the delicate reinforced-carbon-carbon (RCC) protecting the wing leading edge. Alert consumers should carefully watch how presenters delineate *the scope of their analysis*, a profound and sometimes decisive matter.

?

Slideville's low resolution and large type generate space-wasting typographic orphans, lonely words dangling on 4 separate lines:

Penetration **significantly** 3cu. In and velocity

The really vague pronoun reference "it" refers to *damage to the left wing*, which ultimately destroyed Columbia (although the slide here deals with tile, not RCC damage). Low-resolution presentation formats encourage vague references because there isn't enough space for specific and precise phrases.

The same unit of measurement for volume (cubic inches) is shown in a slightly different way every time

3cu. In **1920cu in** **3 cu in**

rather than in clear and tidy exponential form 1920 in^3. Shakiness in conventions for units of measurement should always provoke concern, as it does in grading the problem sets of sophomore engineering students.* PowerPoint is not good at math and science; here at NASA, engineers are using a presentation tool that apparently makes it difficult to write scientific notation. The pitch-style typography of PP is hopeless for science and engineering, yet this important analysis relied on PP. Technical articles are not published in PP; why then should PP be used for serious technical analysis, such as diagnosing the threat to Columbia?

Data Visualization
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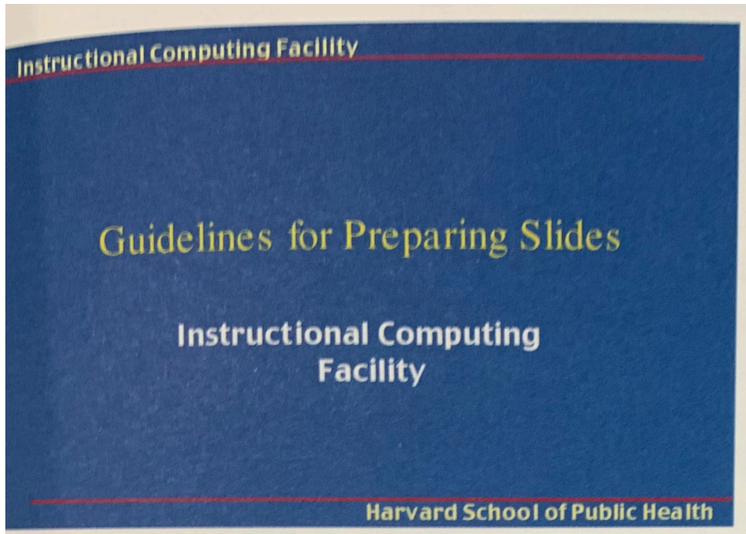
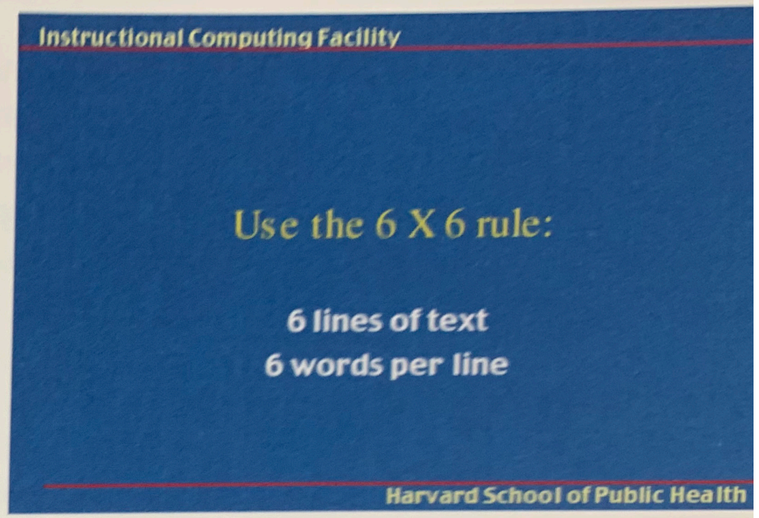
Power Point:
Cognitive Style

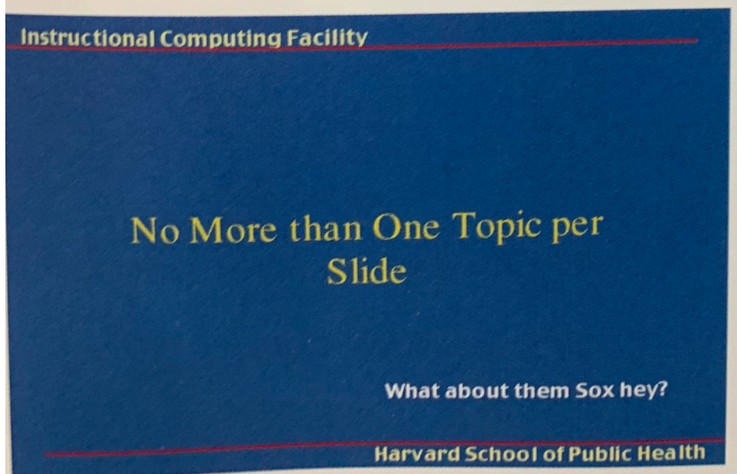
Sage Park &
Branden Choi



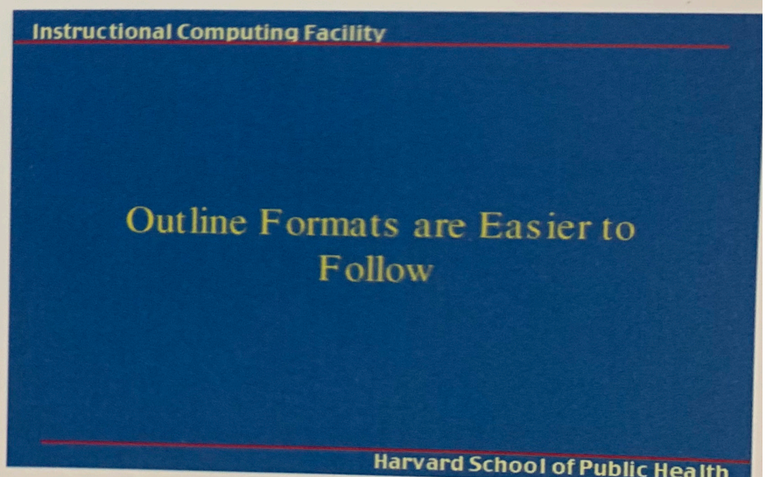
Stylesheet-makers often seek to leave *their* name on *your* show; "branding," as they say in the Marketing Department. In case you didn't notice, this presentation is from the "Instructional Computing Facility." But where are the names of the people responsible for this? No names appear on any of the 21 slides.



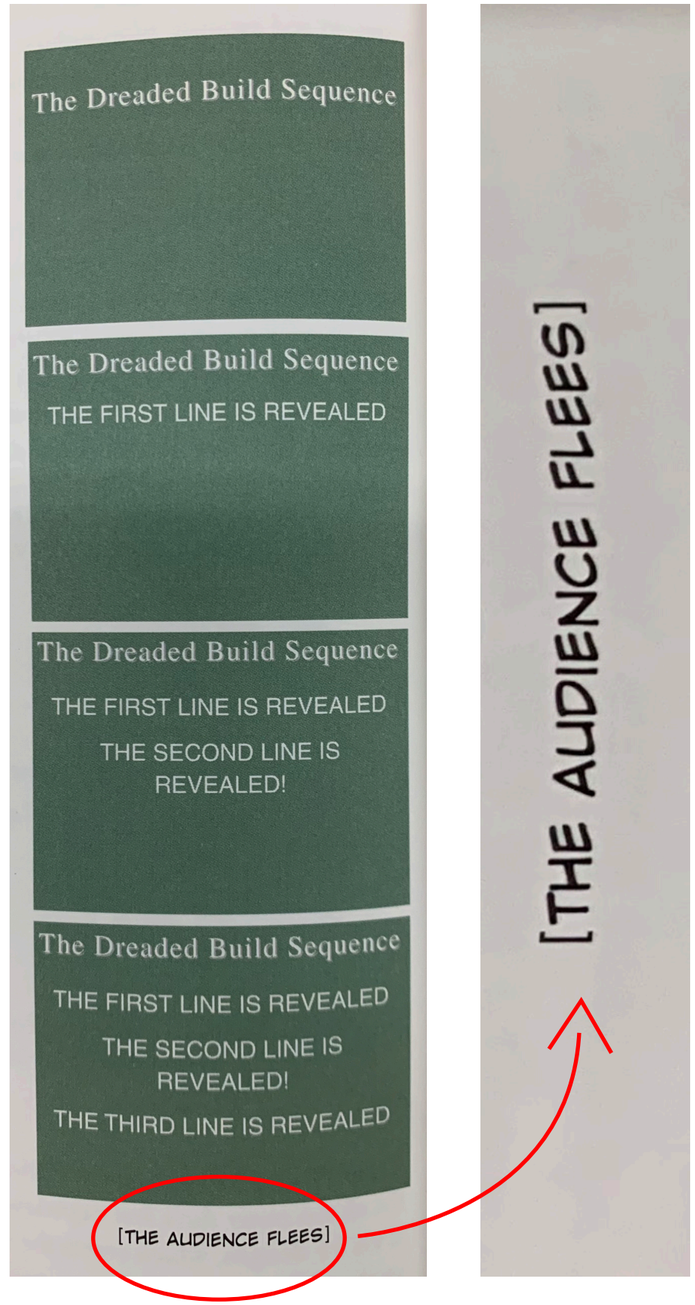
This must be the Haiku Rule for formatting scientific lectures. At least we're not limited to 17 syllables per slide. Above this slide, the rule can be seen in action—in a first-grade reading primer. The stylesheet typography, distinctly unscientific, uses a capital X instead of a multiplication sign.



But this breaks up the evidence into arbitrary fragments. Why



Why is this relevant to scientific presentations? Are there other



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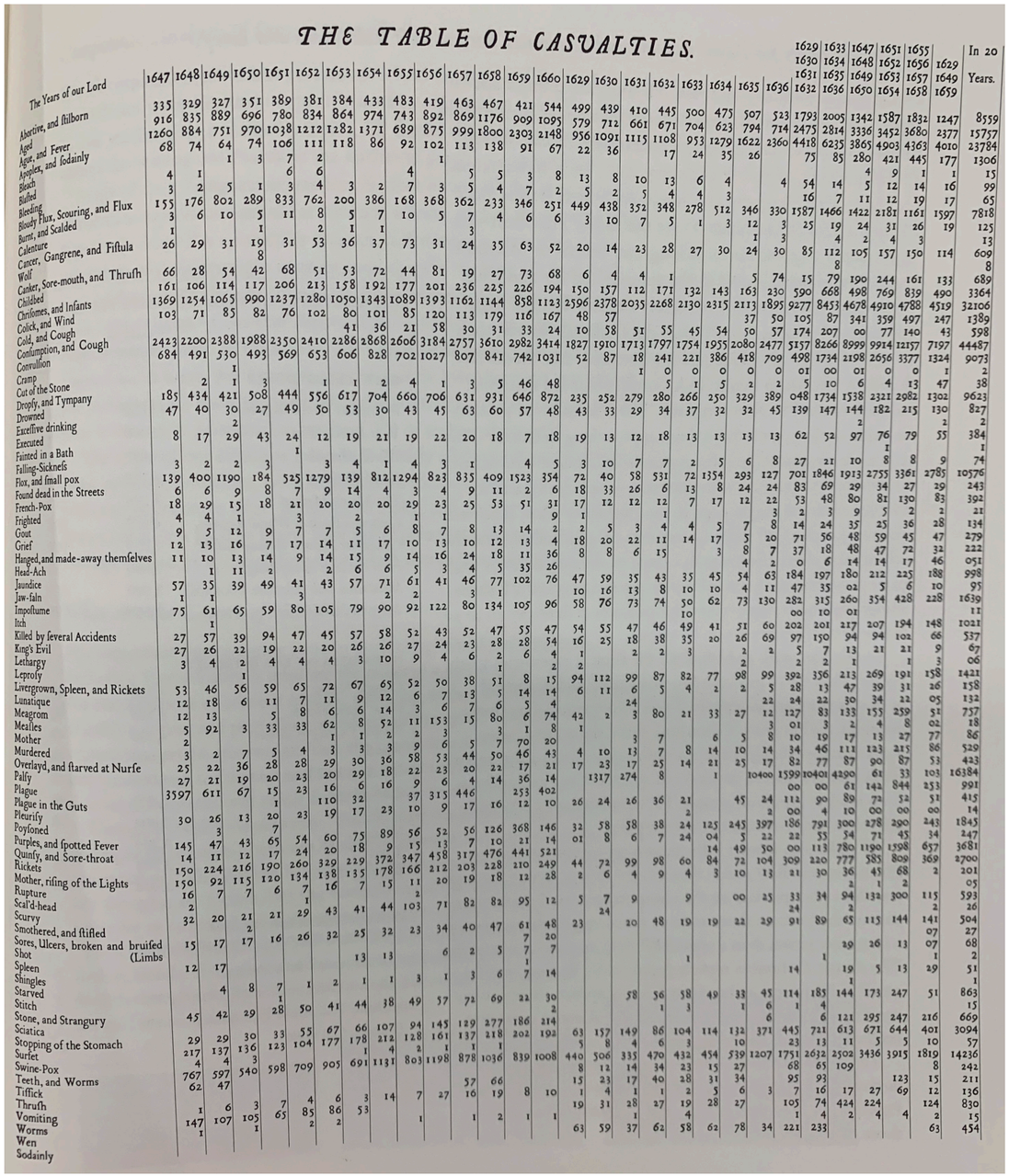

THE TABLE OF CASUALTIES.

The Years of our Lord	1647	1648	1649	1650	1651	1652	1653	1654	1655	1656	1657	1658	1659	1660	1629	1630	1631	1632	1633	1634	1635	1636	1629 1630 1631 1632	1633 1634 1635 1636	1647 1648 1649 1650	1651 1652 1653 1654	1655 1656 1657 1658	1629 1649 1659	In 20 Years.
Abortive, and ftilborn	335	329	327	351	389	381	384	433	483	419	463	467	421	544	499	439	410	445	500	475	507	523	1793	2005	1342	1587	1832	1247	8559
Aged	916	835	889	696	780	834	864	974	743	892	869	1176	909	1095	579	712	661	671	704	623	794	714	2475	2814	3336	3452	3680	2377	15757
Ague, and Fever	1260	884	751	970	1038	1212	1282	1371	689	875	999	1800	2303	2148	956	1091	1115	1108	953	1279	1622	2360	4418	6235	3865	4903	4363	4010	23784
Apoplex, and fodainly	68	74	64	74	106	111	118	86	92	102	113	138	91	67	22	36		17	24	35	26		75	85	280	421	445	177	1306
Bleach			1	3	7	2				1												4	54	14	4	9	1	1	15
Blafted	4	1			6	6			4		5	5	3	8	13	8	10	13	6	4			16	7	11	12	19	17	65
Bleeding	3	2	5	1	3	4	3	2	7	3	5	4	7	2	5	2	5	4	4	3			1587	1466	1422	2181	1161	1597	7818
Bloudy Flux, Scouring, and Flux	155	176	802	289	833	762	200	386	168	368	362	233	346	251	449	438	352	348	278	512	346	330							
Burnt, and Scalded	3	6	10	5	11	8	5	7	10	5	7	4	6	6	3	10	7	5	1	3	12	3	25	19	24	31	26	19	125
Calenture	1			1		2	1	1			3										1	3		4	2	4	3		13
Cancer, Gangrene, and Fiftula	26	29	31	19	31	53	36	37	73	31	24	35	63	52	20	14	23	28	27	30	24	30	85	112	105	157	150	114	609
Wolf				8																				8					8
Canker, Sore-mouth, and Thrufh	66	28	54	42	68	51	53	72	44	81	19	27	73	68	6	4	4	1			5	74	15	79	190	244	161	133	689
Childbed	161	106	114	117	206	213	158	192	177	201	236	225	226	194	150	157	112	171	132	143	163	230	590	668	498	769	839	490	3364
Chriſomes, and Infants	1369	1254	1065	990	1237	1280	1050	1343	1089	1393	1162	1144	858	1123	2596	2378	2035	2268	2130	2315	2113	1895	9277	8453	4678	4910	4788	4519	32106
Colick, and Wind	103	71	85	82	76	102	80	101	85	120	113	179	116	167	48	57					37	50	105	87	341	359	497	247	1389
Cold, and Cough							41	36	21	58	30	31	33	24	10	58	51	55	45	54	50	57	174	207	00	77	140	43	598
Conſumption, and Cough	2423	2200	2388	1988	2350	2410	2286	2868	2606	3184	2757	3610	2982	3414	1827	1910	1713	1797	1754	1955	2080	2477	5157	8266	8999	9914	12157	7197	44487
Convulſion	684	491	530	493	569	653	606	828	702	1027	807	841	742	1031	52	87	18	241	221	386	418	709	498	1734	2198	2656	3377	1324	9073
Cramp			1														1	0	0	0	0	0	01	00	01	0	0	1	2
Cut of the Stone		2	1	3		1	1	2	4	1	3	5	46	48				5	1	5	2	2	5	10	6	4	13	47	38
Dropſy, and Tympany	185	434	421	508	444	556	617	704	660	706	631	931	646	872	235	252	279	280	266	250	329	389	048	1734	1538	2321	2982	1302	9623
Drowned	47	40	30	27	49	50	53	30	43	45	63	60	57	48	43	33	29	34	37	32	32	45	139	147	144	182	215	130	827
Exceſſive drinking			2																						2			2	2
Executed	8	17	29	43	24	12	19	21	19	22	20	18	7	18	19	13	12	18	13	13	13	13	62	52	97	76	79	55	384
Fainted in a Bath					1																					1			1
Falling-Sickneſs	3	2	2	3		3	4	1	4	3	1		4	5	3	10	7	7	2	5	6	8	27	21	10	8	8	9	74
Flox, and ſmall pox	139	400	1190	184	525	1279	139	812	1294	823	835	409	1523	354	72	40	58	531	72	1354	293	127	701	1846	1913	2755	3361	2785	10576
Found dead in the Streets	6	6	9	8	7	9	14	4	3	4	9	11	2	6	18	33	26	6	13	8	24	24	83	69	29	34	27	29	243
French-Pox	18	29	15	18	21	20	20	20	29	23	25	53	51	31	17	12	12	12	7	17	12	22	53	48	80	81	130	83	392
Frighted	4	4	1		3		2		1	1				9	1			1				3	2	3	9	5	2	1	21
Gout	9	5	12	9	7	7	5	6	8	7	8	13	14	2	2	5	3	4	4	5	7	8	14	24	35	25	36	28	134
Grief	12	13	16	7	17	14	11	17	10	13	10	12	13	4	18	20	22	11	14	17	5	20	71	56	48	59	45	47	279
Hanged, and made-away themſelves	11	10	13	14	9	14	15	9	14	16	24	18	11	36	8	8	6	15		3	8	7	37	18	48	47	72	32	222
Head-Ach		1	11	2		2	6	6	5	3	4	5	35	26							4	2	0	6	14	14	17	46	051
Jaundice	57	35	39	49	41	43	57	71	61	41	46	77	102	76	47	59	35	43	35	45	54	63	184	197	180	212	225	188	998
Jaw-faln	1	1			3			2	2		3	1			10	16	13	8	10	10	4	11	47	35	02	5	6	10	95
Impoſtume	75	61	65	59	80	105	79	90	92	122	80	134	105	96	58	76	73	74	50	62	73	130	282	315	260	354	428	228	1639
Itch		1																	10				00	10	01				11
Killed by ſeveral Accidents	27	57	39	94	47	45	57	58	52	43	52	47	55	47	54	55	47	46	49	41	51	60	202	201	217	207	194	148	1021
King's Evil	27	26	22	19	22	20	26	26	27	24	23	28	28	54	16	25	18	38	35	20	26	69	97	150	94	94	102	66	537
Lethargy	3	4	2	4	4	4	3	10	9	4	6	2	6	4	1			2	2	3		2	5	7	13	21	21	9	67
Leproſy			1									1		2	2						2	2	2	2	1		1	3	06
Livergrown, Spleen, and Rickets	53	46	56	59	65	72	67	65	52	50	38	51	8	15	94	112	99	87	82	77	98	99	392	356	213	269	191	158	1421
Lunatique	12	18	6	11	7	11	9	12	6	7	13	5	14	14	6	11	6	5	4	2	2	5	28	13	47	39	31	26	158
Meagrom	12	13		5	8	6	6	14	3	6	7	6	5	4			24					22	24	22	30	34	22	05	132
Meaſles	5	92	3	33	33	62	8	52	11	153	15	80	6	74	42	2	3	80	21	33	27	12	127	83	133	155	259	51	757
Mother	2					1	1	2	2	3		3	1	8	1							3	01	3	2	4	8	02	18
Murdered	3	2	7	5	4	3	3	3	9	6	5	7	70	20			3	7		6	5	8	10	19	17	13	27	77	86
Overlayd, and ſtarved at Nurſe	25	22	36	28	28	29	30	36	58	53	44	50	46	43	4	10	13	7	8	14	10	14	34	46	111	123	215	86	529
Palſy	27	21	19	20	23	20	29	18	22	23	20	22	17	21	17	23	17	25	14	21	25	17	82	77	87	90	87	53	423
Plague	3597	611	67	15	23	16	6	16	9	6	4	14	36	14		1317	274	8		1		10400	1599	10401	4290	61	33	103	16384
Plague in the Guts				1		110	32		37	315	446		253	402									00	00	61	142	844	253	991
Pleuriſy	30	26	13	20	23	19	17	23	10	9	17	16	12	10	26	24	26	36	21		45	24	112	90	89	72	52	51	415
Poyſoned		3		7															2			2	00	4	10	00	00	00	14
Purples, and ſpotted Fever	145	47	43	65	54	60	75	89	56	52	56	126	368	146	32	58	58	38	24	125	245	397	186	791	300	278	290	243	1845
Quinſy, and Sore-throat	14	11	12	17	24	20	18	9	15	13	7	10	21	14	01	8	6	7	24	04	5	22	22	55	54	71	45	34	247
Rickets	150	224	216	190	260	329	229	372	347	458	317	476	441	521						14	49	50	00	113	780	1190	1598	657	3681
Mother, riſing of the Lights	150	92	115	120	134	138	135	178	166	212	203	228	210	249	44	72	99	98	60	84	72	104	309	220	777	585	809	369	2700
Rupture	16	7	7	6	7	16	7	15	11	20	19	18	12	28	2	6	4	9	4	3	10	13	21	30	36	45	68	2	201
Scal'd-head	2				1				2																2	1	2		05
Scurvy	32	20	21	21	29	43	41	44	103	71	82	82	95	12	5	7	9		9		00	25	33	34	94	132	300	115	593
Smothered, and ſtifled			2												24								24		2			2	26
Sores, Ulcers, broken and bruiſed	15	17	17	16	26	32	25	32	23	34	40	47	61	48	23		20	48	19	19	22	29	91	89	65	115	144	141	504
Shot (Limbs													7	20														07	27
Spleen	12	17					13	13		6	2	5	7	7					1						29	26	13	07	68
Shingles													1											1				1	2
Starved		4	8	7	1	2	1	1	3	1	3	6	7	14								14			19	5	13	29	51
Stitch				1																				1					1
Stone, and Strangury	45	42	29	28	50	41	44	38	49	57	72	69	22	30			58	56	58	49	33	45	114	185	144	173	247	51	863
Sciatica														2				1	3		1	6	1	4					15
Stopping of the Stomach	29	29	30	33	55	67	66	107	94	145	129	277	186	214								6		6	121	295	247	216	669
Surfet	217	137	136	123	104	177	178	212	128	161	137	218	202	192	63	157	149	86	104	114	132	371	445	721	613	671	644	401	3094
Swine-Pox	4	4	3				1	4	2	1	1	1			5	8	4	6	3		10		23	13	11	5	5	10	57
Teeth, and Worms	767	597	540	598	709	905	691	1131	803	1198	878	1036	839	1008	440	506	335	470	432	454	539	1207	1751	2632	2502	3436	3915	1819	14236
Tiffick	62	47									57	66			8	12	14	34	23	15	27		68	65	109			8	242
Thruſh															15	23	17	40	28	31	34		95	93			123	15	211
Vomiting	1	6	3	7	4	6	3	14	7	27	16	19	8	10	1	4	1	1	2	5	6	3	7	16	17	27	69	12	136
Worms	147	107	105	65	85	86	53				1				19	31	28	27	19	28	27		103	74	424	224		124	830
Wen	1		1		2	2			1			2	1	1			1		4				1	4	2	4	4	2	15
Sodainly															63	59	37	62	58	62	78	34	221	233				63	454

Data Visualization
2019.11.11

Power Point:
Cognitive Style

Sage Park &
Branden Choi

Instructional Computing Facility

Use Simple Tables to Present Numbers

	Use Tables	For Your Numbers	But Not too Many
This row	10	90	100
This row	0.6	0.4	1
This row	1	2	3
That row	1	2	3

Try not to make footnotes too small

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