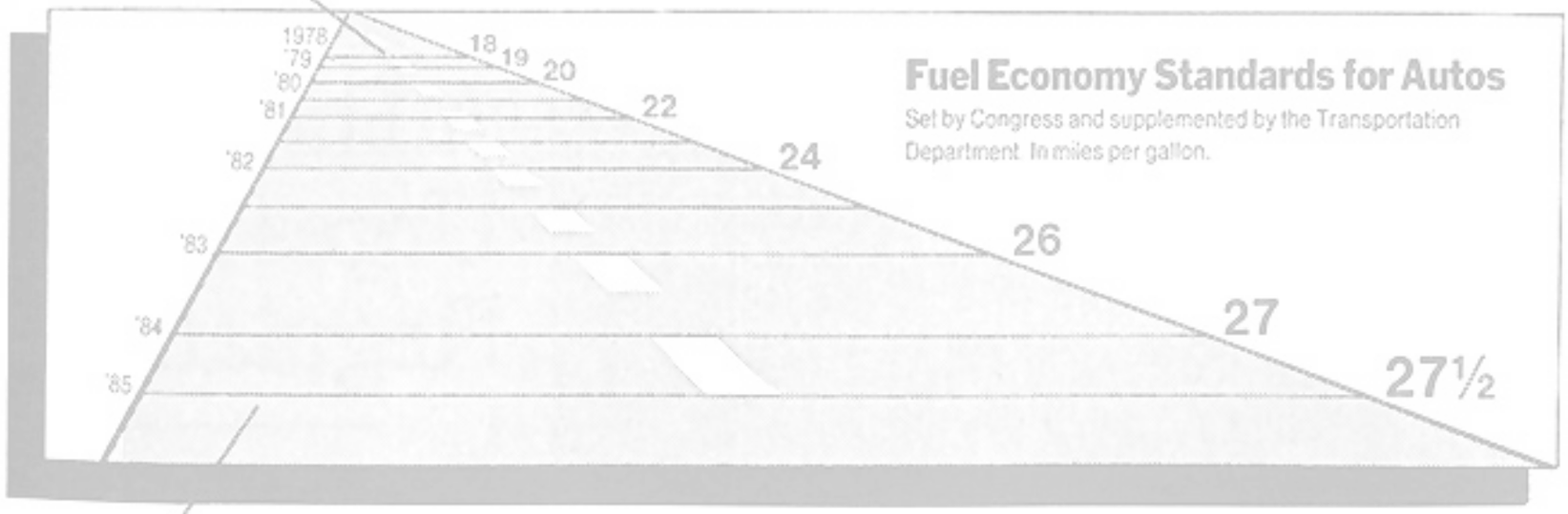
Tufte's Principles

from *Envisioning Information* and *The Visual Display of Quantitative Information*

This line, representing 18 miles per gallon in 1978, is 0.6 inches long.



This line, representing 27.5 miles per gallon in 1985, is 5.3 inches long.

New York Times, August 9, 1978, p. D-2.

Graphical Integrity

Avoid distortion of numbers by graphic devices, whether accidental or intentional. Show data variation in context, and label them.

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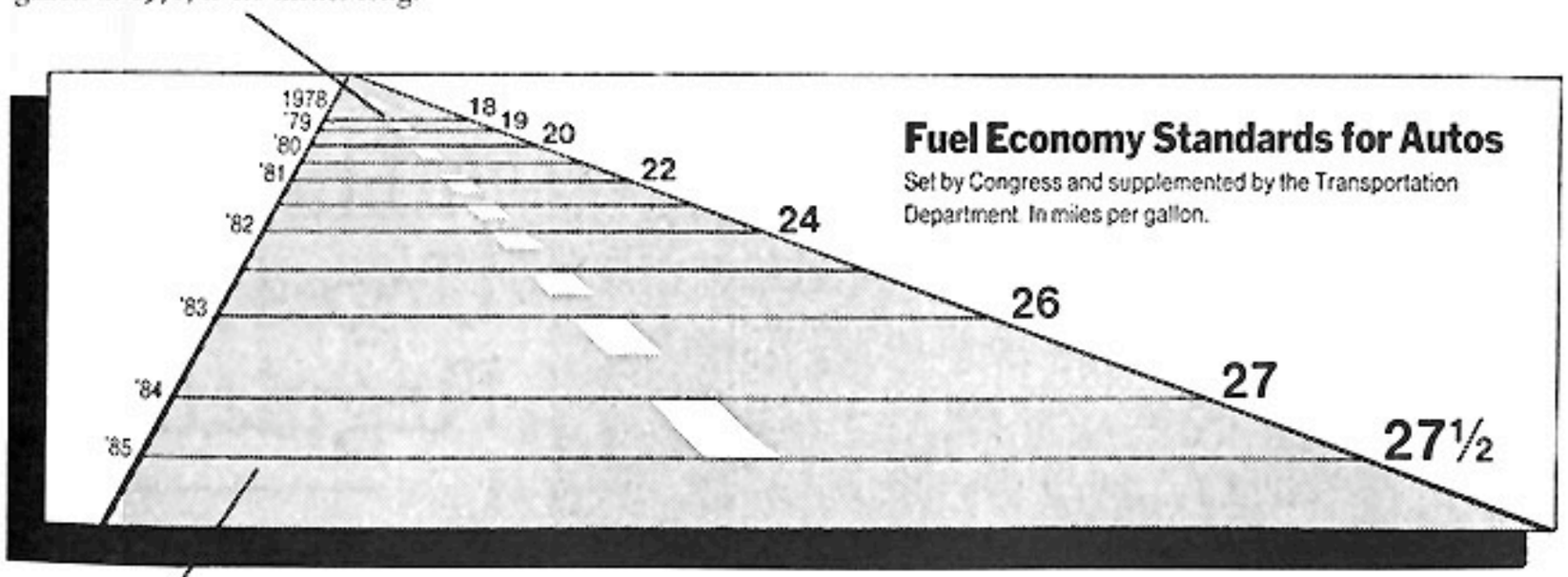

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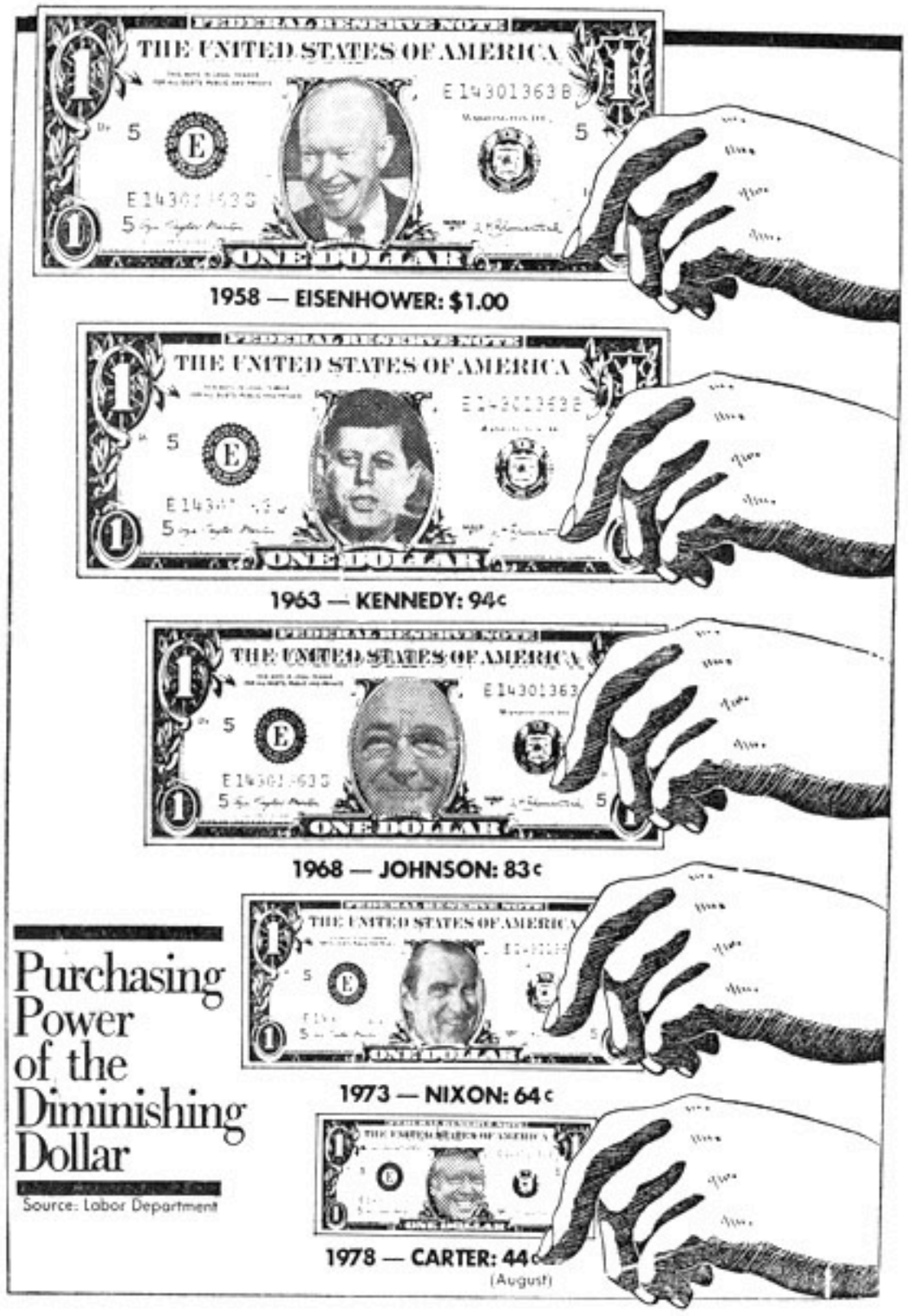
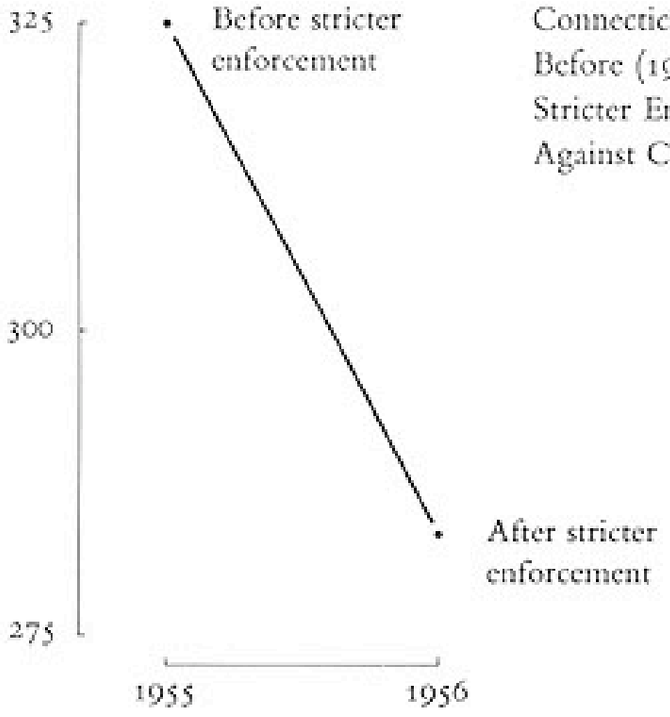
New York Times, August 9, 1978, p. D-2.

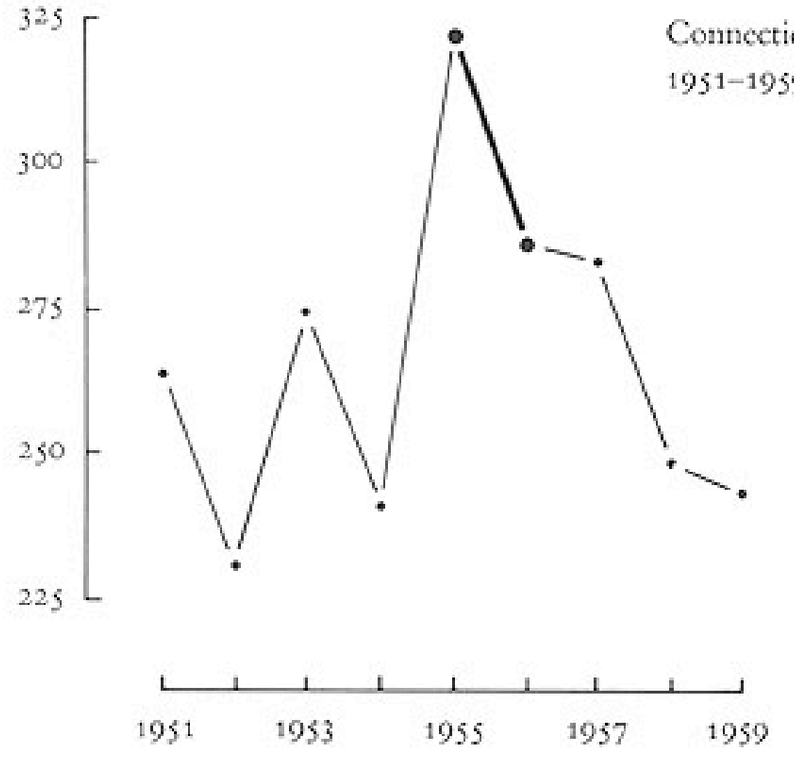


Washington Post, October 25, 1978, p. 1.

If the area of the dollar is accurately to reflect its purchasing power, then the 1978 dollar should be about twice as big as that shown



Connecticut Traffic Deaths, Before (1955) and After (1956) Stricter Enforcement by the Police Against Cars Exceeding Speed limit



Connecticut Traffic Deaths, 1951–1959

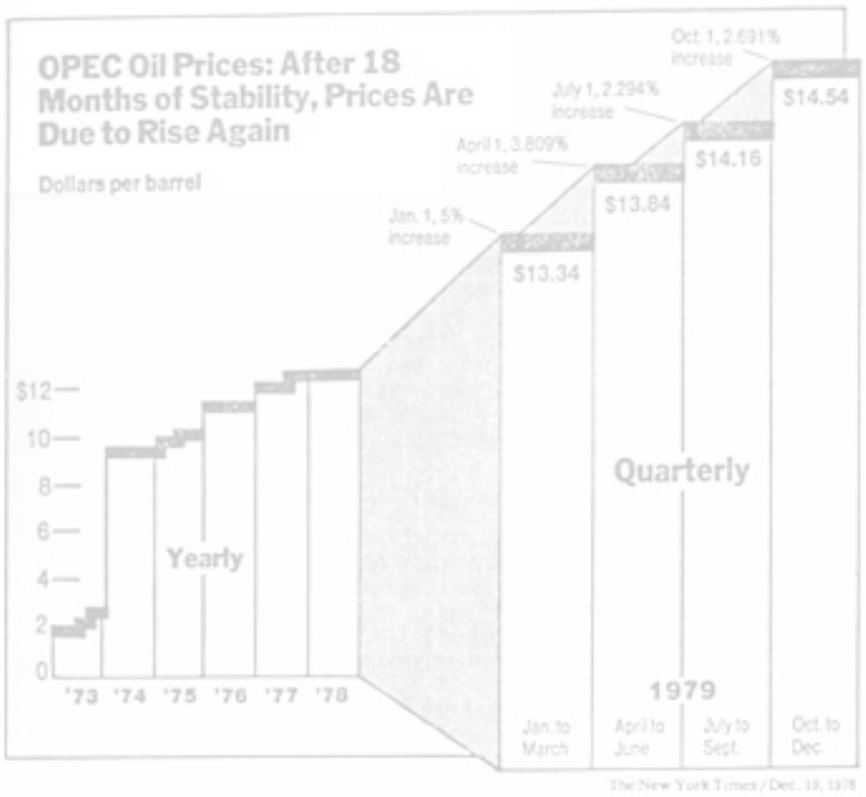
New York Times, December 19, 1978, p. D-7.

Five different vertical scales show the price:

During this time	one vertical inch equals
1973–1978	$8.00
January–March 1979	$4.73
April–June 1979	$4.37
July–September 1979	$4.16
October–December 1979	$3.92

And two different horizontal scales show the passage of time:

During this time	one horizontal inch equals
1973–1978	3.8 years
1979	0.57 years



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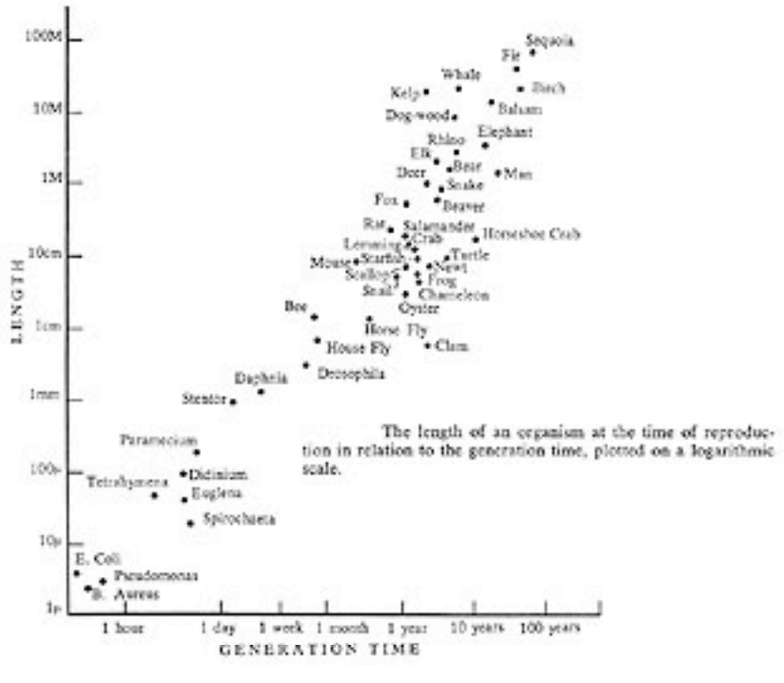
Five different vertical scales show the price:

During this time	one vertical inch equals
1973–1978	$8.00
January–March 1979	$4.73
April–June 1979	$4.37

Graphical Integrity

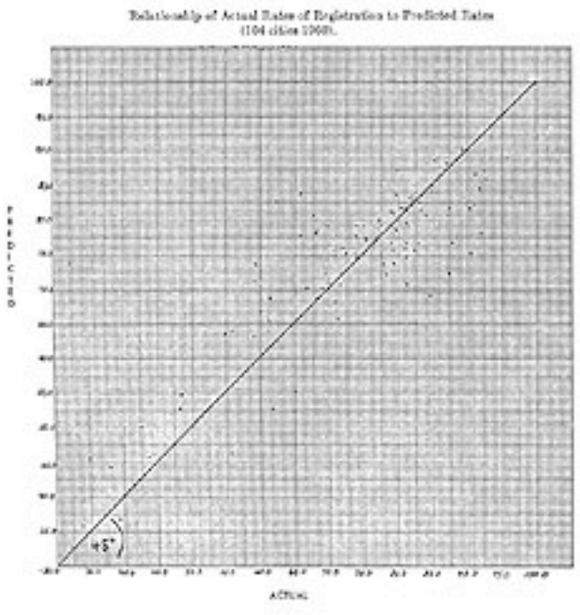
Avoid distortion of numbers by graphic devices, whether accidental or intentional. Show data variation in context, and label them.

Most of the ink in this graphic is data-ink (the dots and labels on the diagonal), with perhaps 10–20 percent non-data-ink (the grid ticks and the frame):

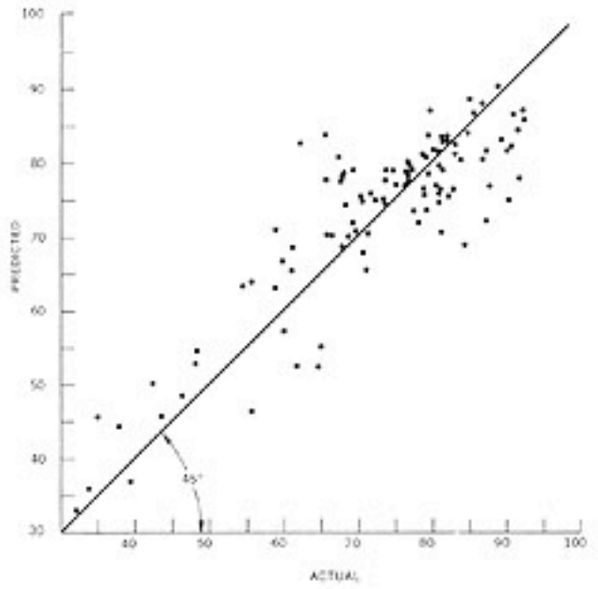


The length of an organism at the time of reproduction in relation to the generation time, plotted on a logarithmic scale.

In this display with nearly all its ink devoted to matters other than data, the grid sea overwhelms the numbers (the faint points scattered about the diagonal):

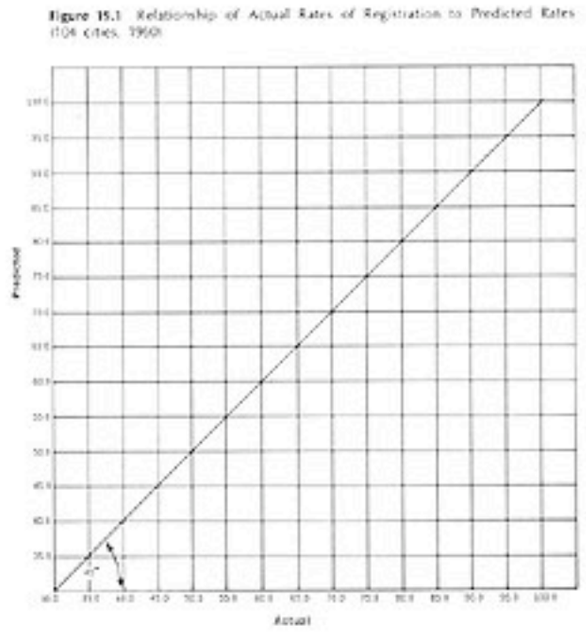


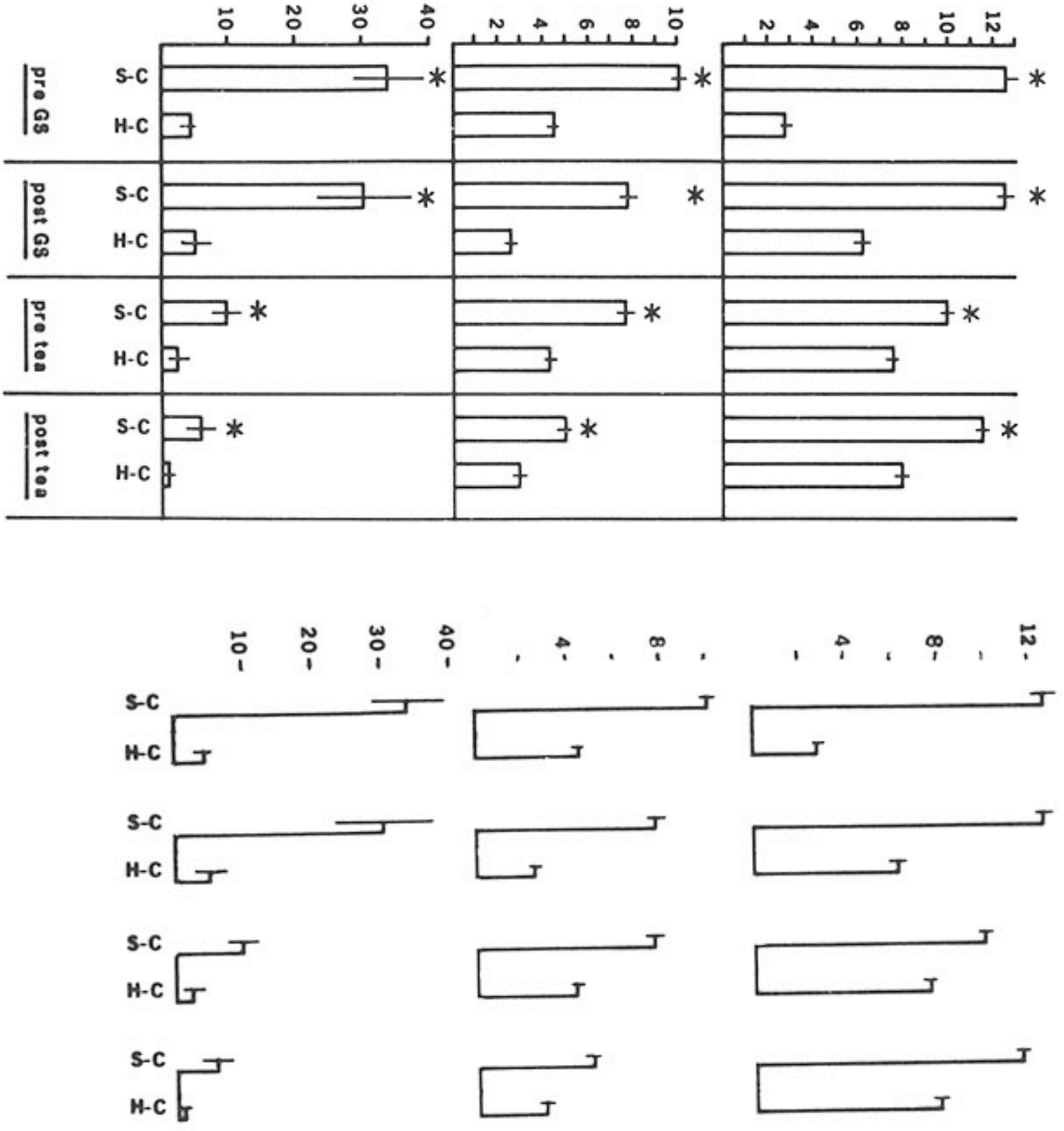
Another published version of the same data drove the share of data-ink up to about 0.7, an improvement:

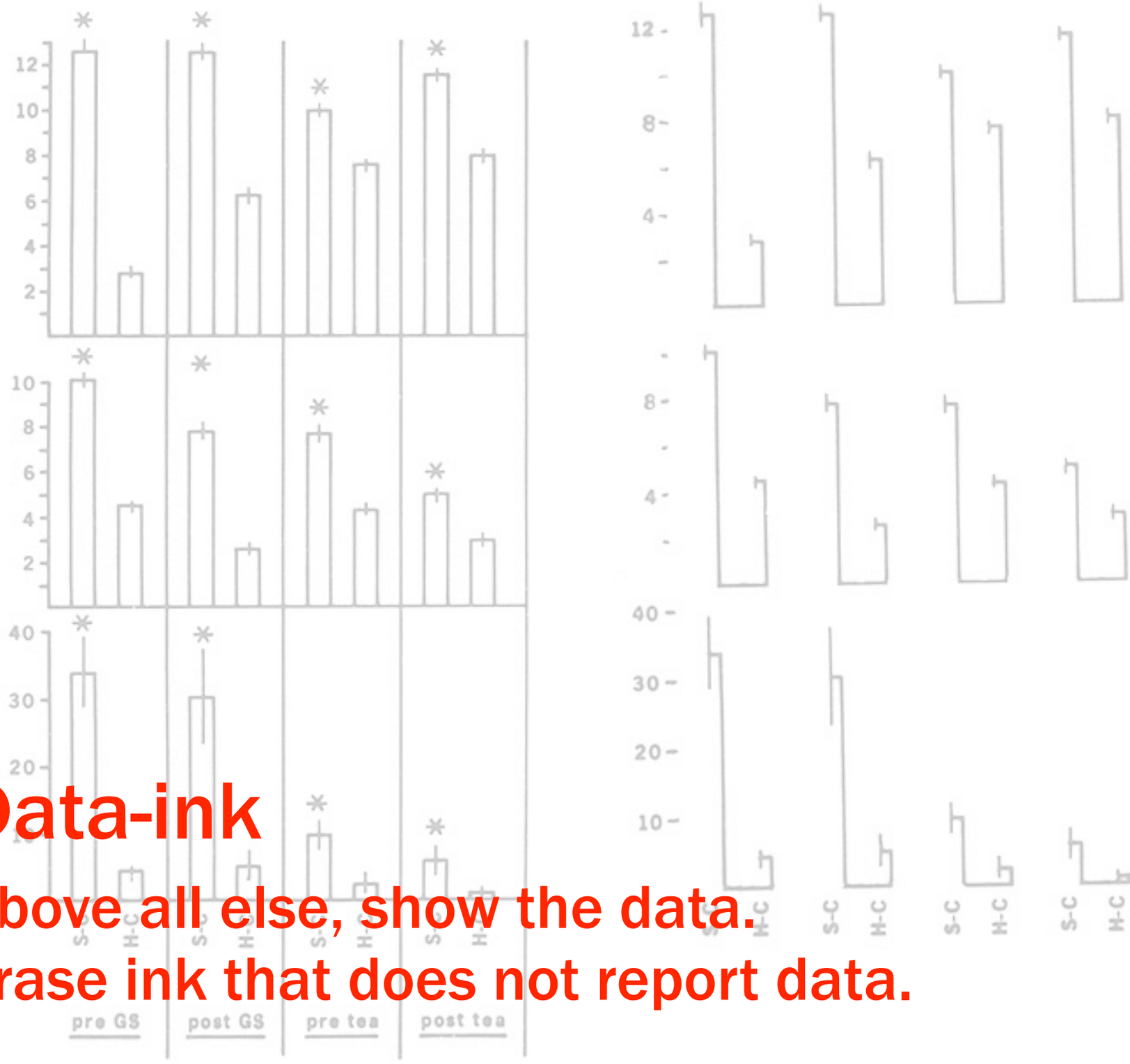


Relationship of Actual Rates of Registration to Predicted Rates (104 cities 1960).

But a third reprint publication of the same figure forgot to plot the points and simply retraced the grid lines from the original, including the excess strip of grid along the top and right margins. The resulting figure achieves a graphical absolute zero, a null data-ink ratio:




pre GS
post GS
pre tea
post tea
S-C
H-C
2
4
6
8
10
12
10
20
30
40



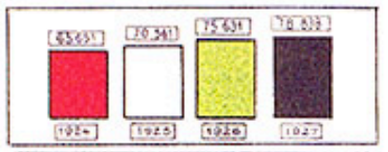
Data-ink

Above all else, show the data.
Erase ink that does not report data.

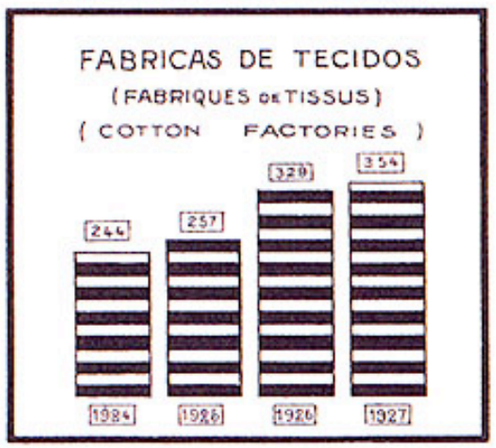
TECIDOS DE ALGODÃO

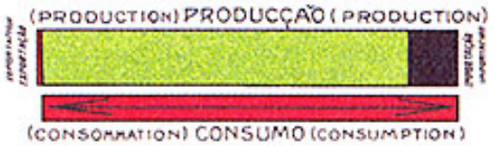
(COTONNADES) (COTTON TEXTILES)

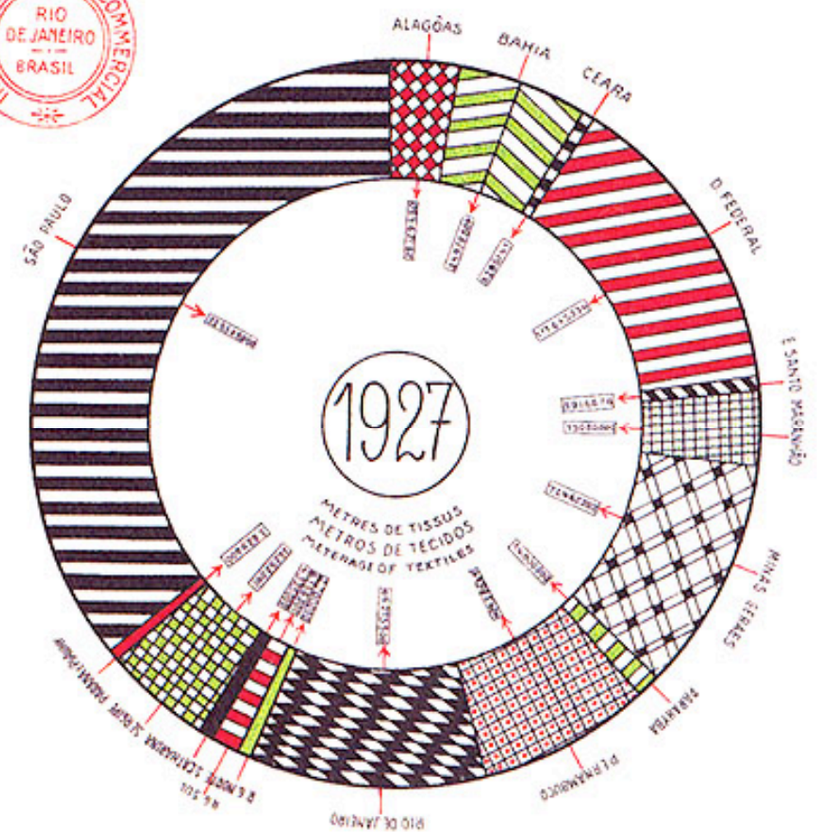
(FUSEAUX) FUZOS (SHUTTLES)

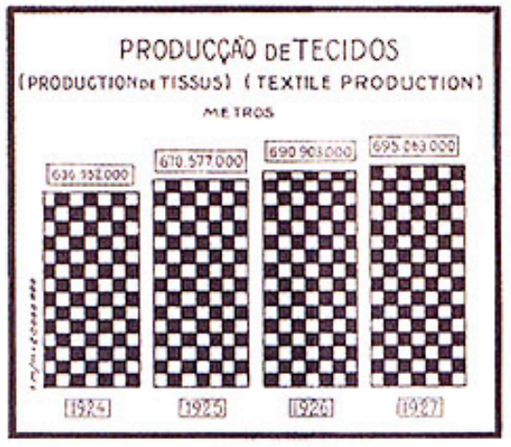


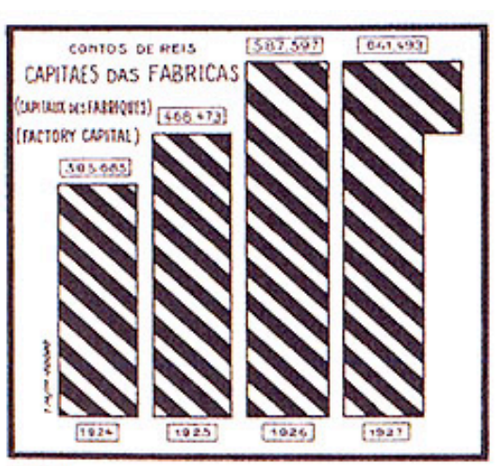
(MÉTIERS) TEARES (LOOMS)

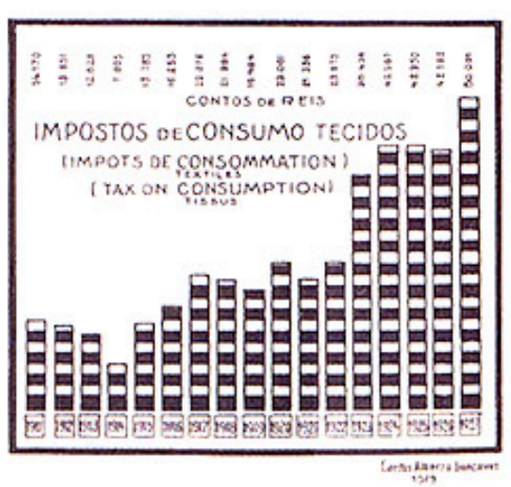


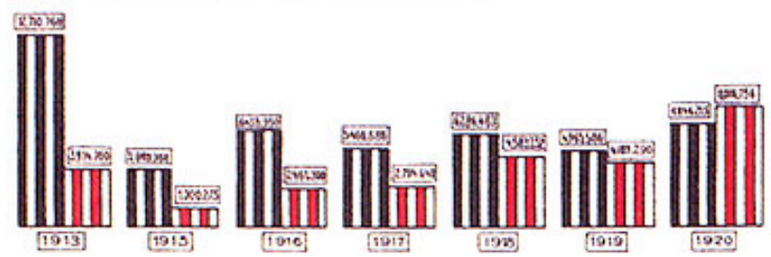






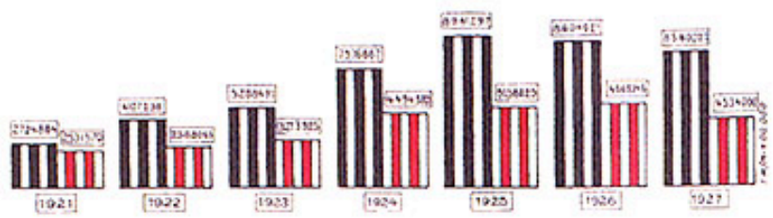


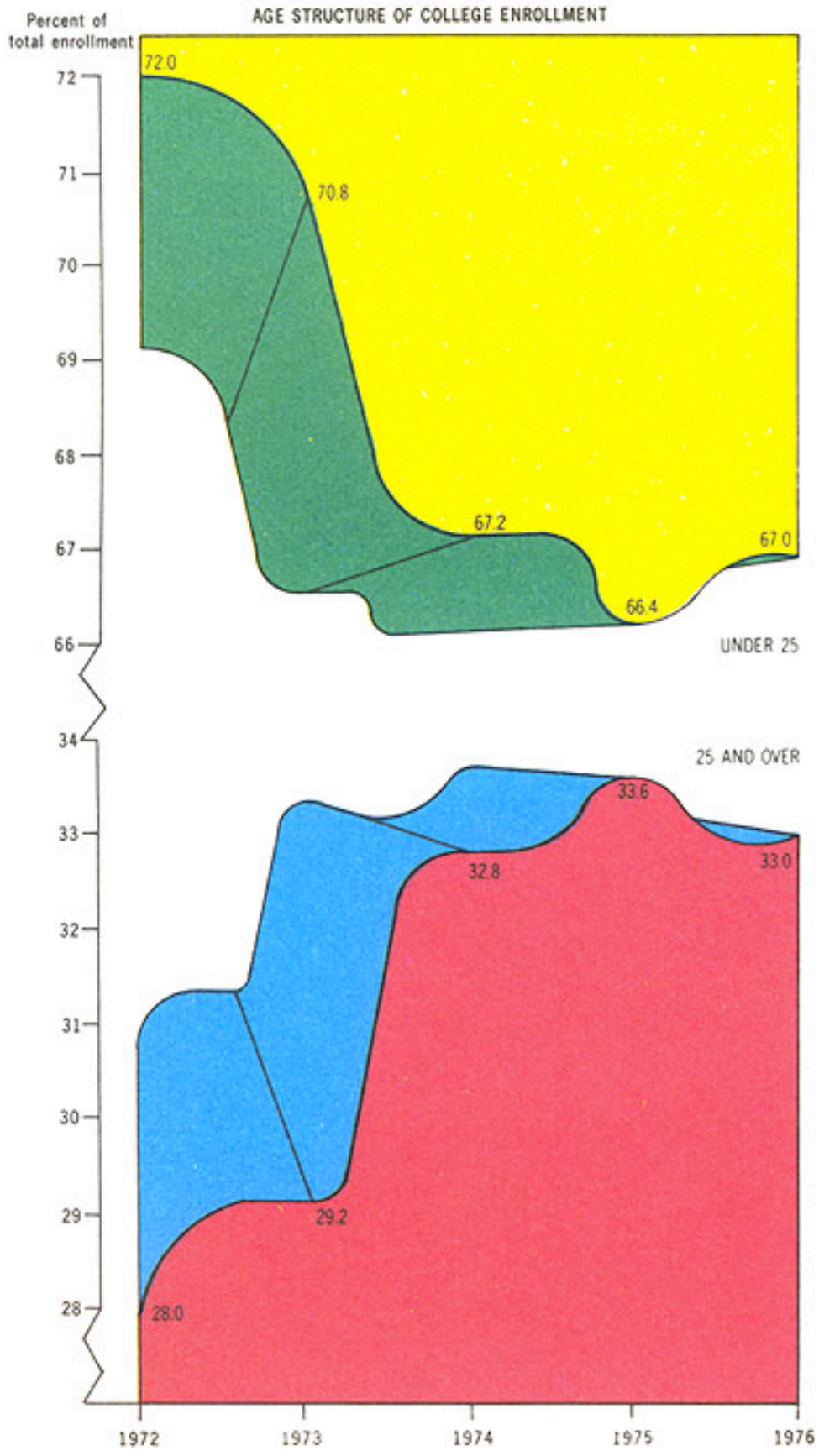


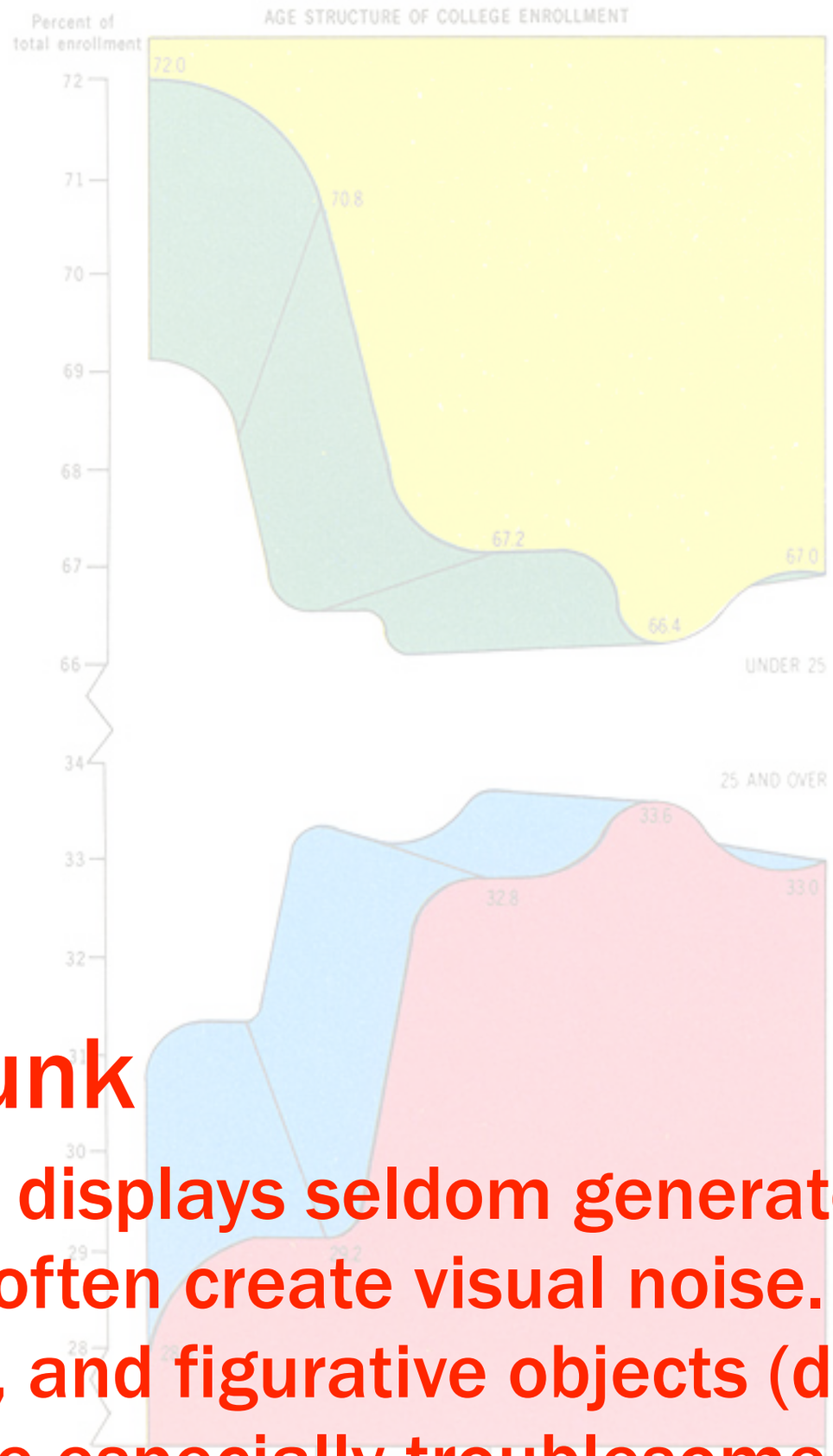


(IMPORTATION)
IMPORTAÇÃO

KILOGRAMMAS

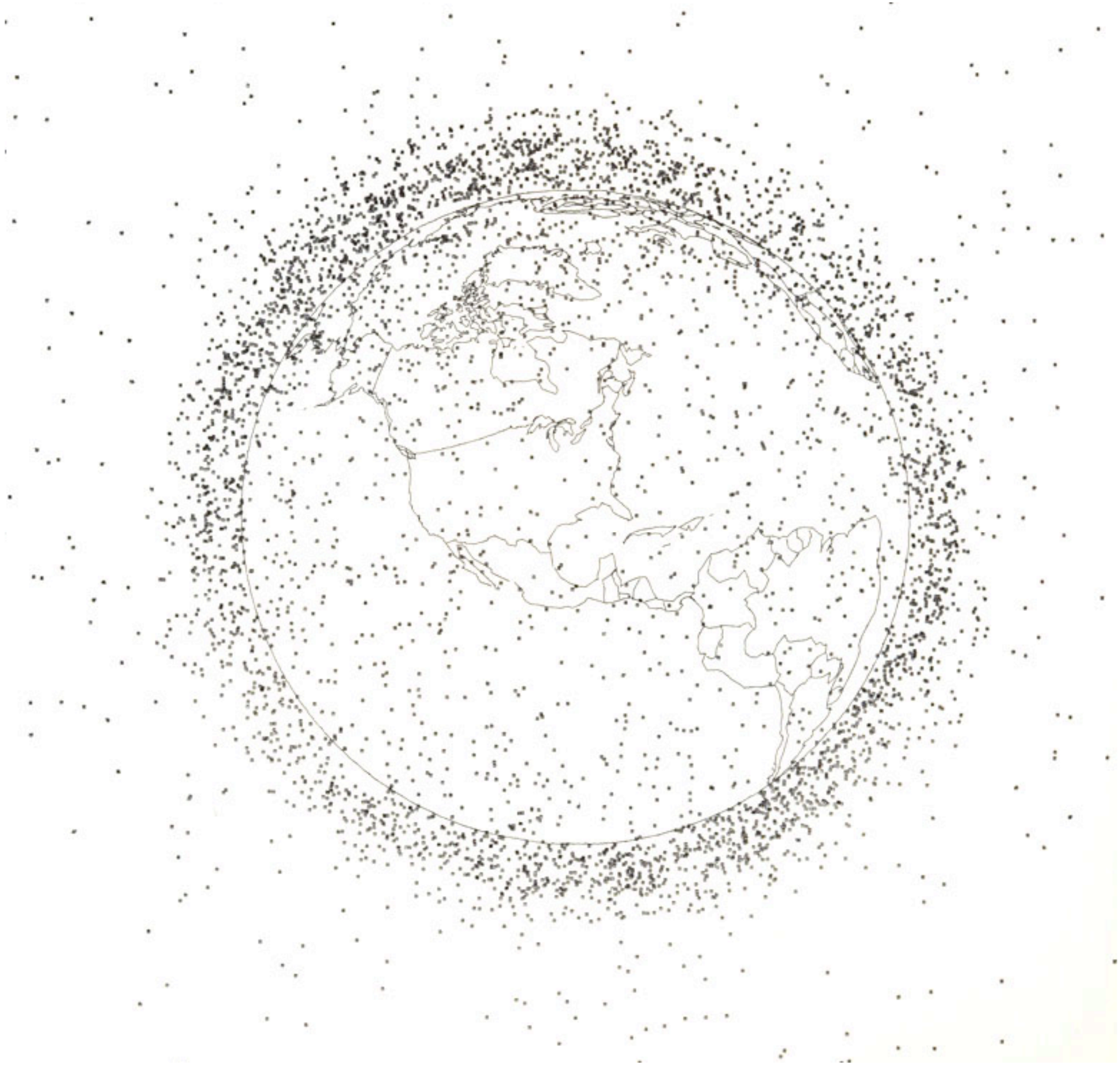


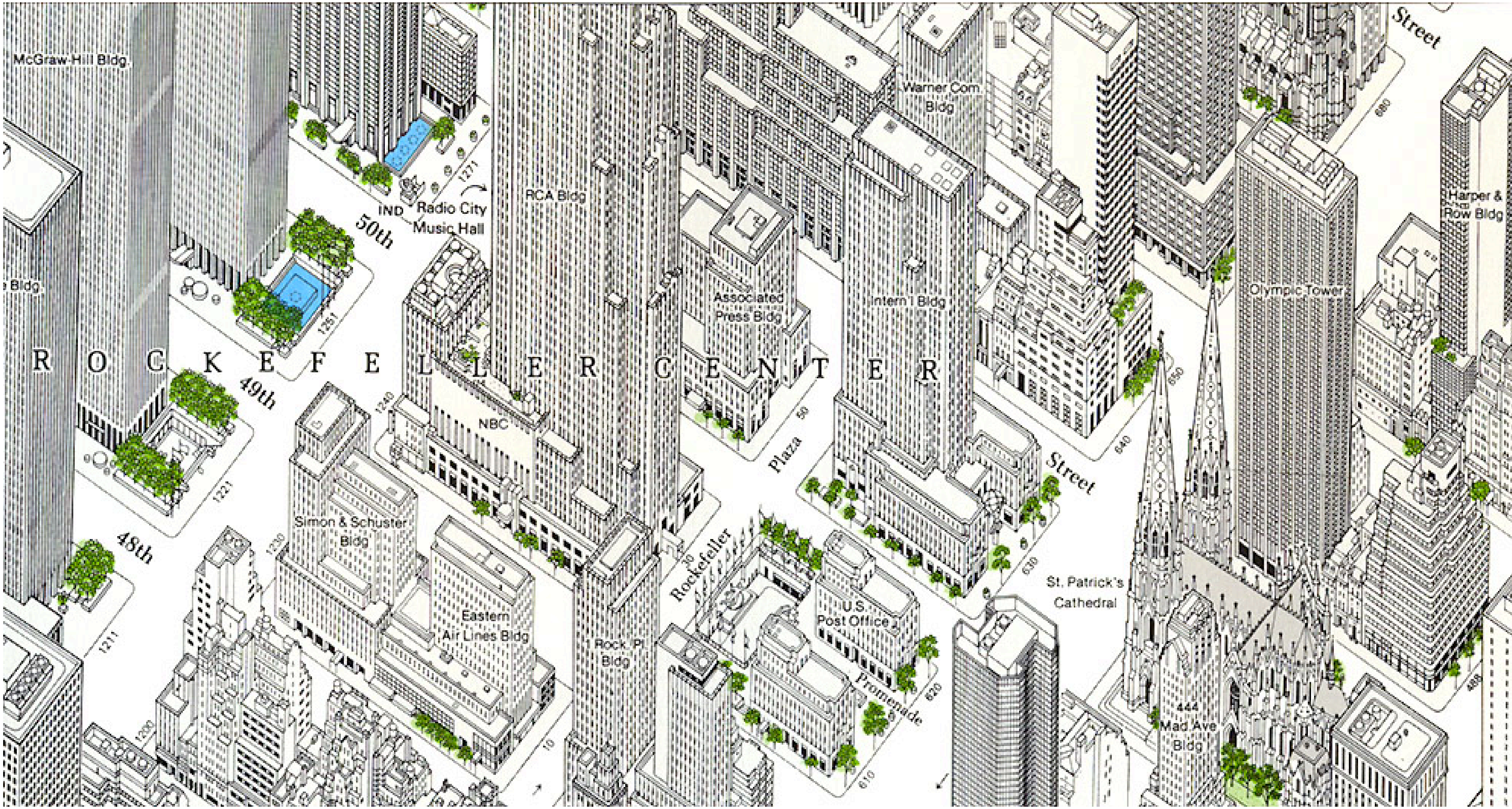

AGE STRUCTURE OF COLLEGE ENROLLMENT
Percent of total enrollment
72
71
70
69
68
67
66
34
33
32
31
30
29
28
72.0
70.8
67.2
66.4
67.0
UNDER 25
25 AND OVER
33.6
32.8
33.0
29.2
28.0
1972
1973
1974
1975
1976



Chartjunk

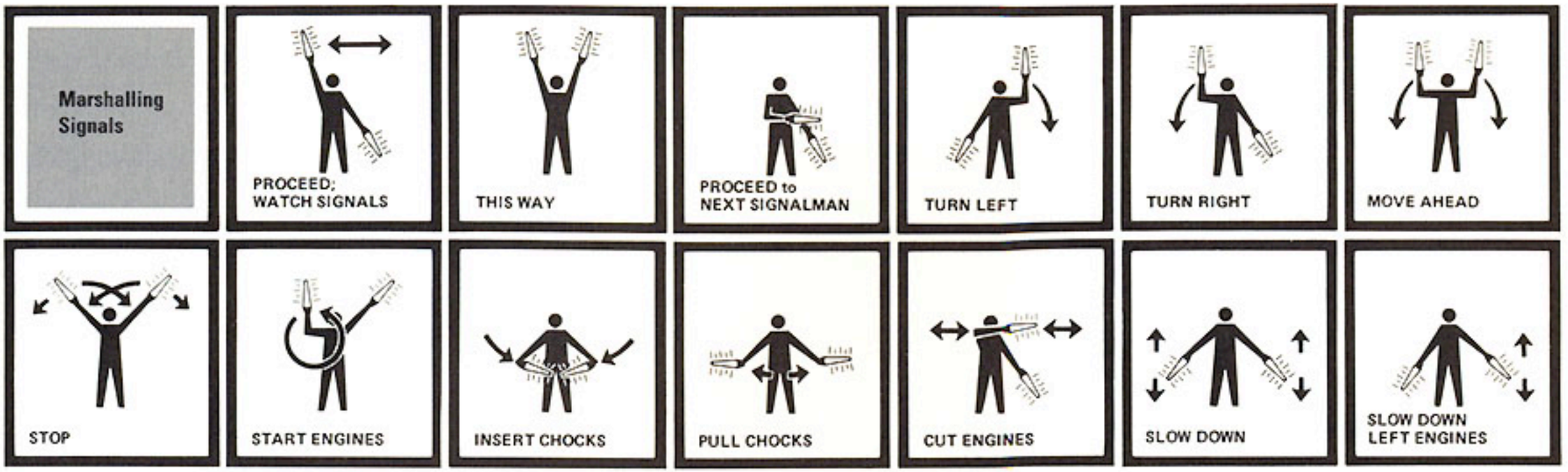
Inventive displays seldom generate interest, but they often create visual noise. Grids, hatching, and figurative objects (ducks) tend to be especially troublesome.

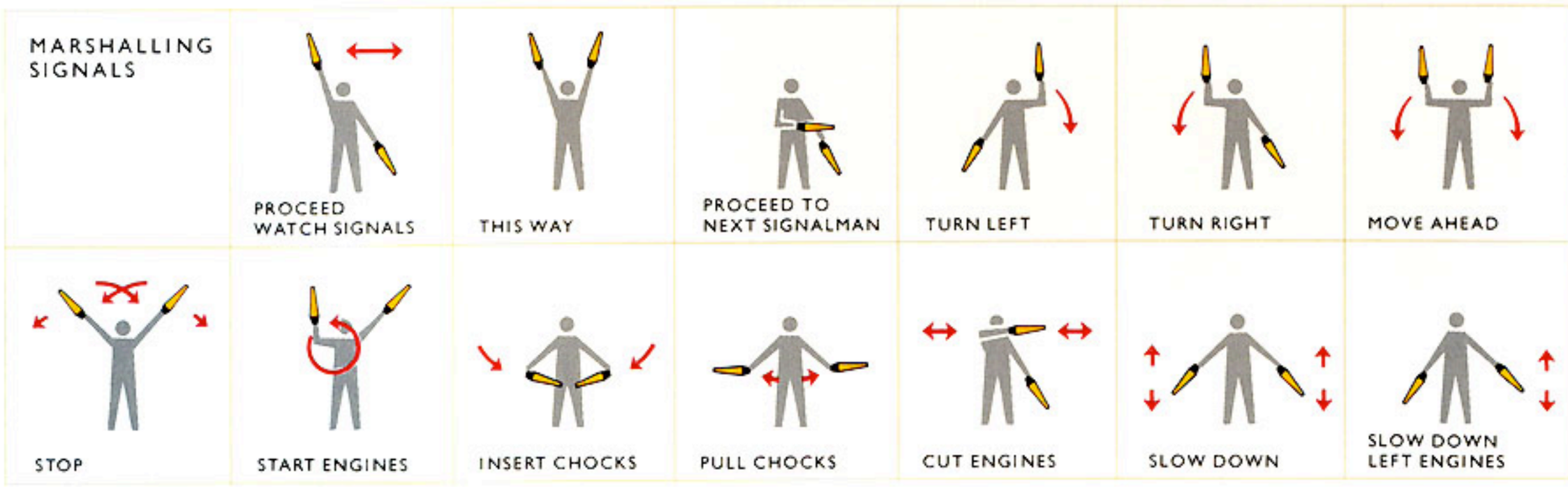


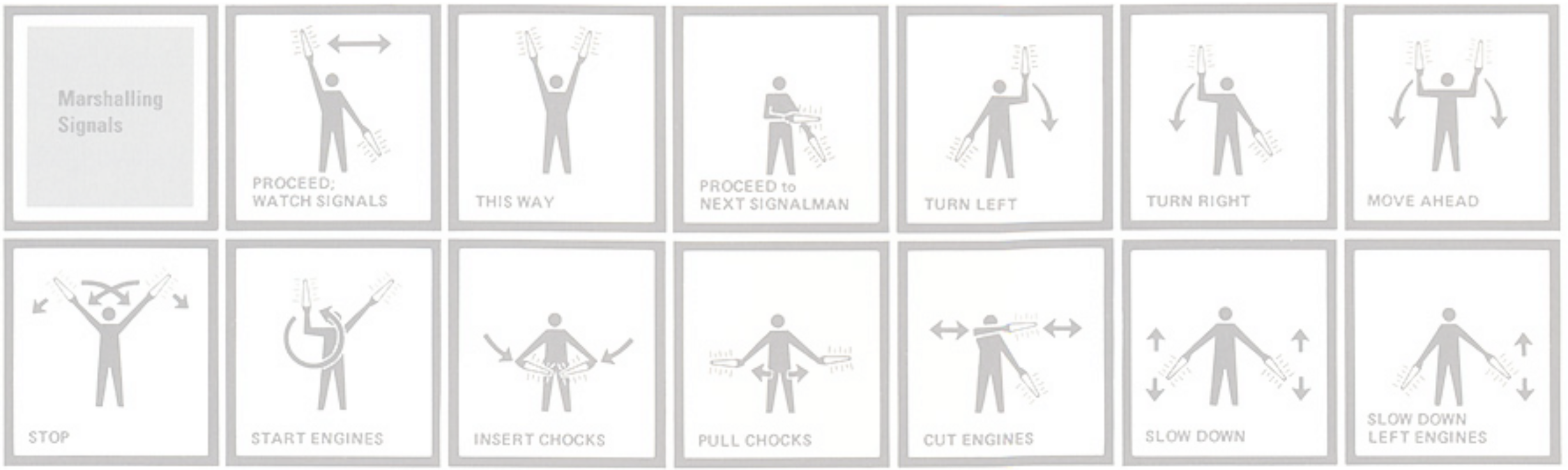

McGraw-Hill Bldg.
IND
Radio City
Music Hall
RCA Bldg
Warner Com.
Bldg
Harper &
Row Bldg
50th
Street
Associated
Press Bldg
Intern'l Bldg
Olympic Tower
R O C K E F E L L E R C E N T E R
49th
NBC
Plaza
Street
48th
Simon & Schuster
Bldg
Rockefeller
St. Patrick's
Cathedral
U.S.
Post Office
Eastern
Air Lines Bldg
1 Rock. Pl.
Bldg
Promenade
444
Mad. Ave
Bldg

Micro-macro

Graphics should be readable in whole images and in parts, and that should help manage levels of detail.

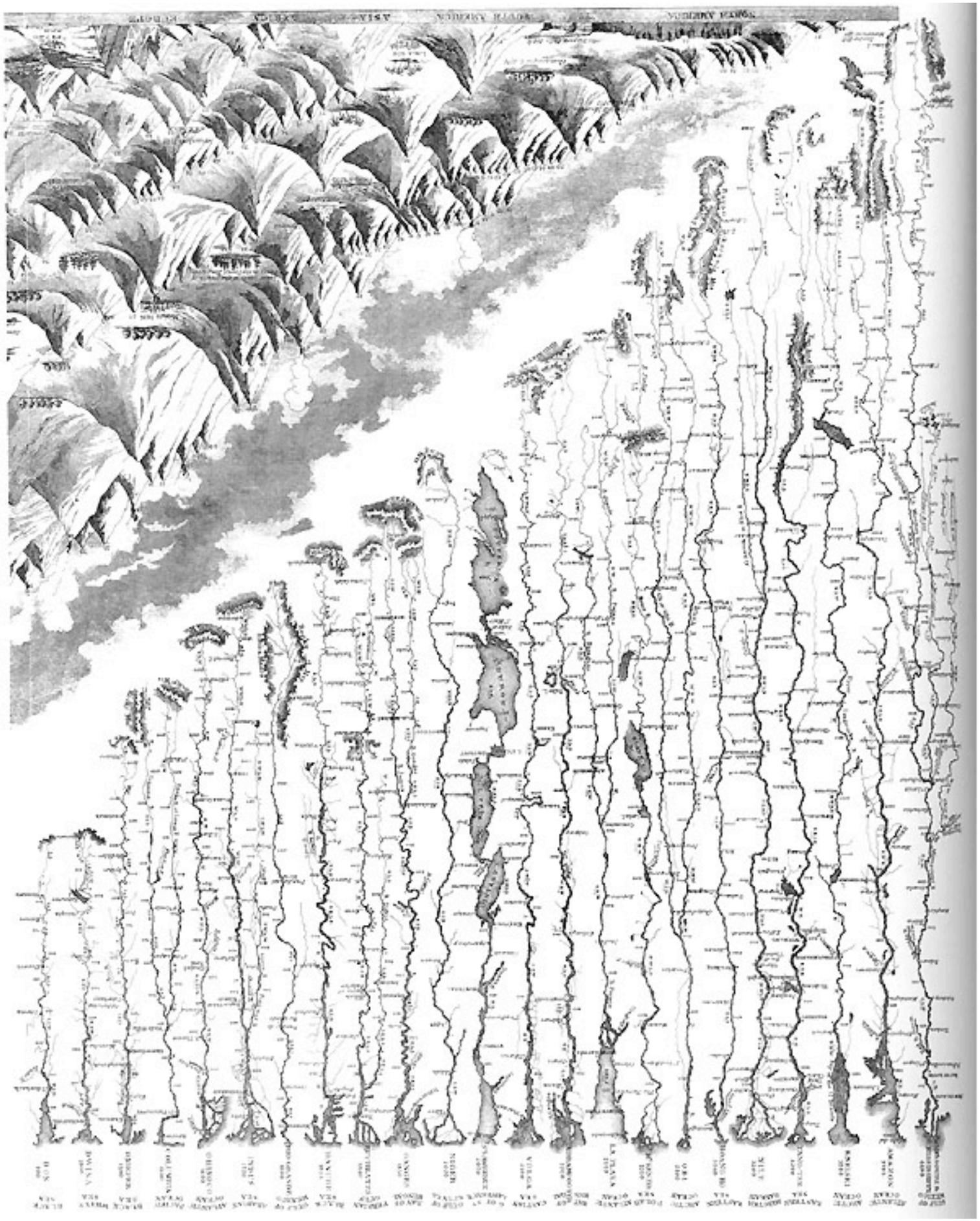

Marshalling Signals
PROCEED; WATCH SIGNALS
THIS WAY
PROCEED to NEXT SIGNALMAN
TURN LEFT
TURN RIGHT
MOVE AHEAD
STOP
START ENGINES
INSERT CHOCKS
PULL CHOCKS
CUT ENGINES
SLOW DOWN
SLOW DOWN LEFT ENGINES

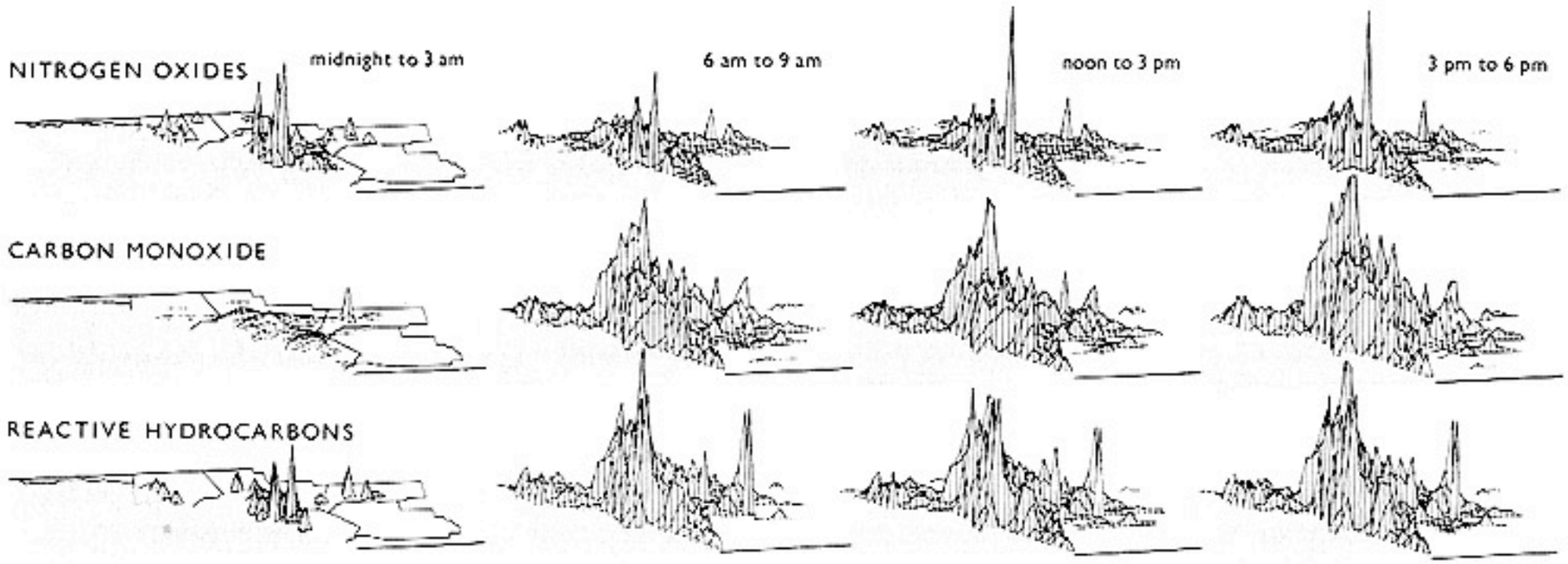

MARSHALLING SIGNALS
PROCEED WATCH SIGNALS
THIS WAY
PROCEED TO NEXT SIGNALMAN
TURN LEFT
TURN RIGHT
MOVE AHEAD
STOP
START ENGINES
INSERT CHOCKS
PULL CHOCKS
CUT ENGINES
SLOW DOWN
SLOW DOWN LEFT ENGINES

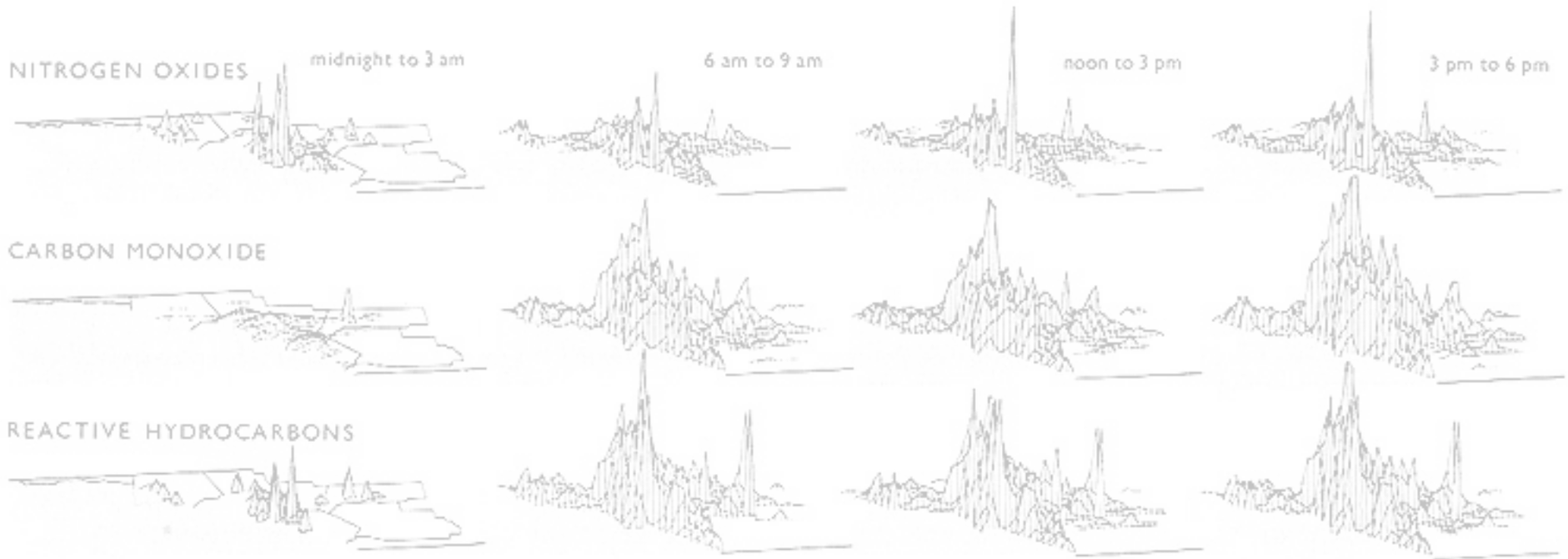


Layering

Reveal the complexity of data, and don’t blame it for any confusion. Use graphic devices to separate categories. Give layers hierarchy and levels of detail.

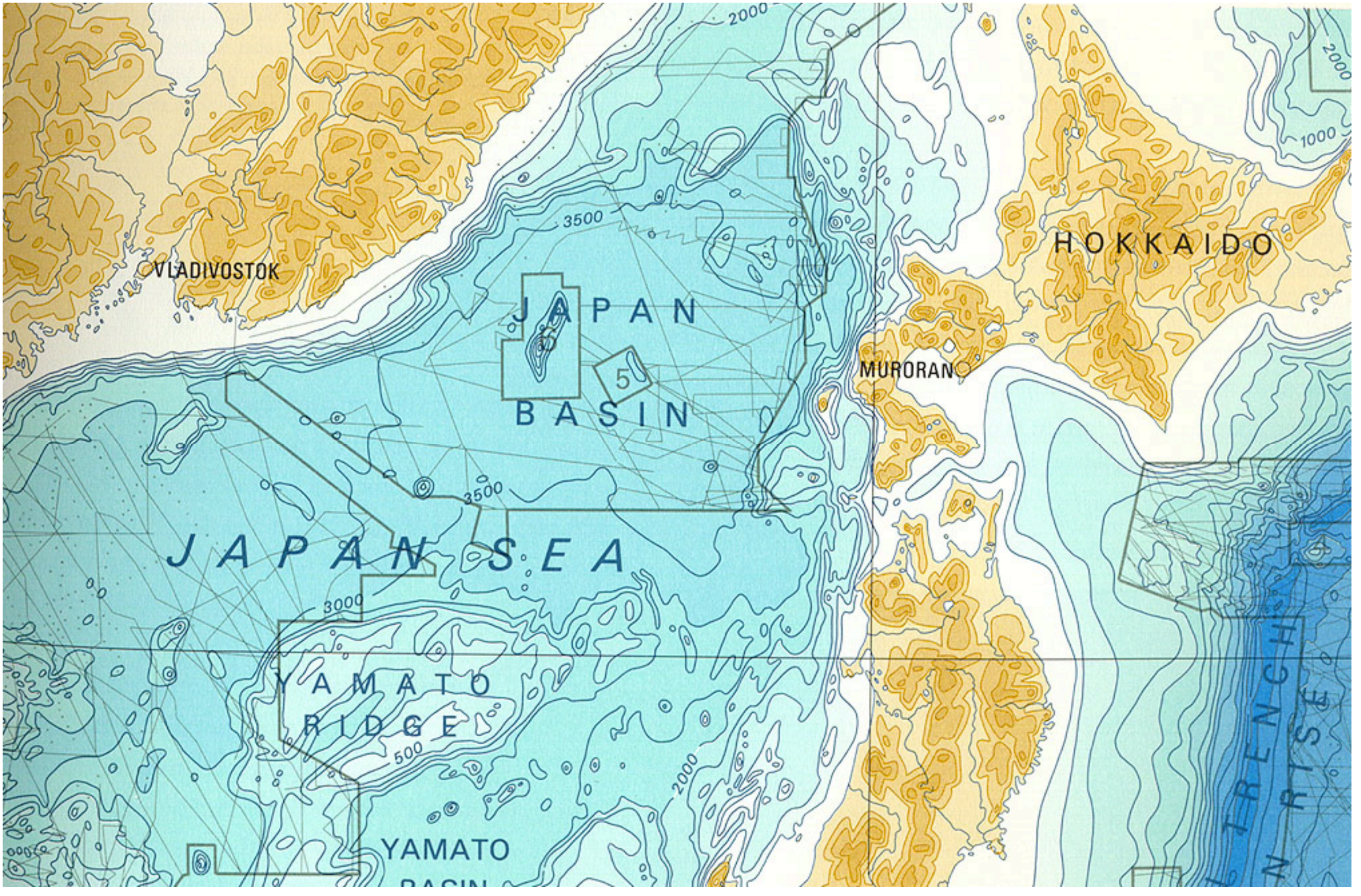


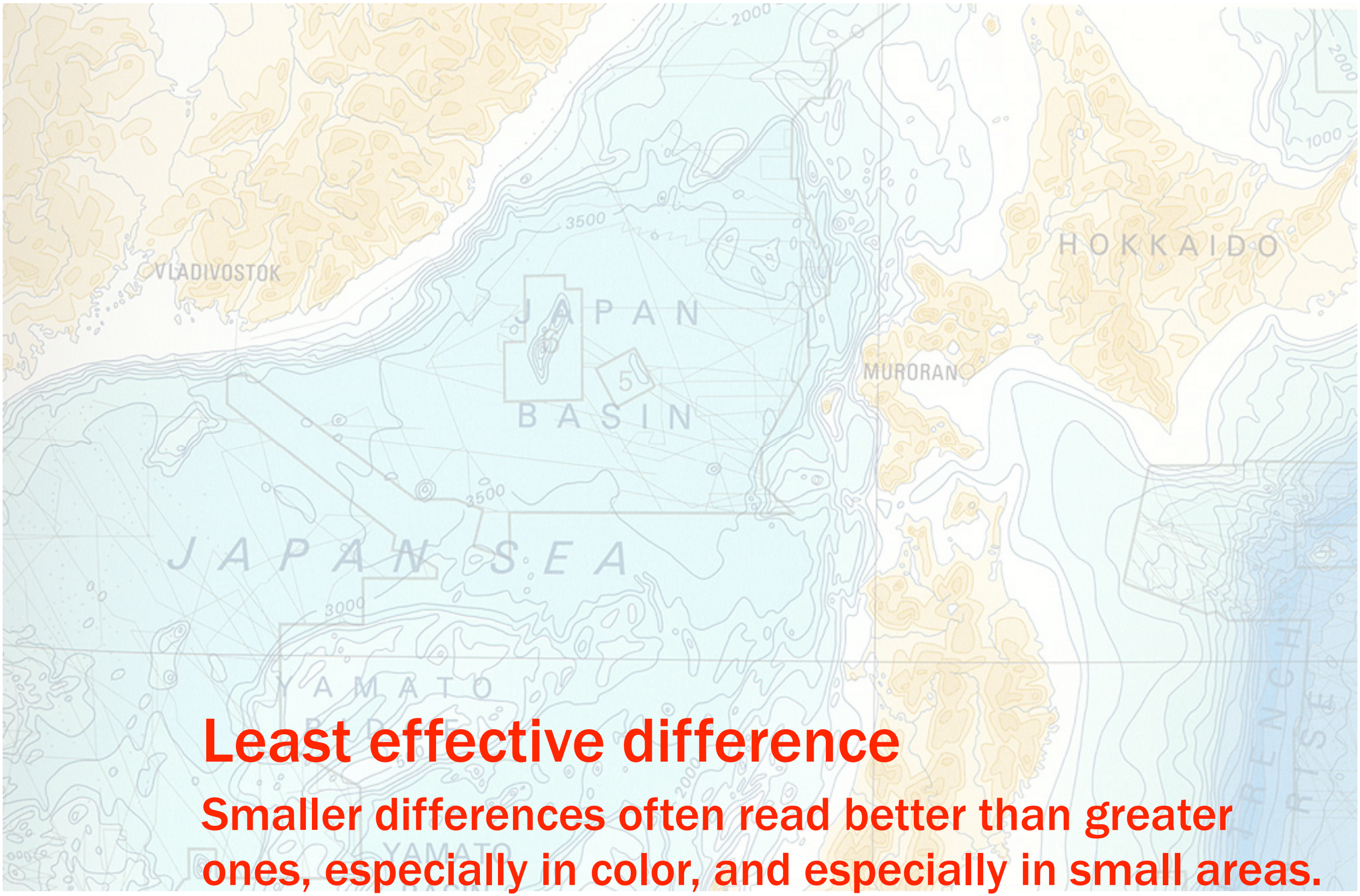

midnight to 3 am
6 am to 9 am
noon to 3 pm
3 pm to 6 pm
NITROGEN OXIDES
CARBON MONOXIDE
REACTIVE HYDROCARBONS



Small multiples

High-quality information graphics portray many numbers per square inch. Small multiple, comparative images work especially well for this.

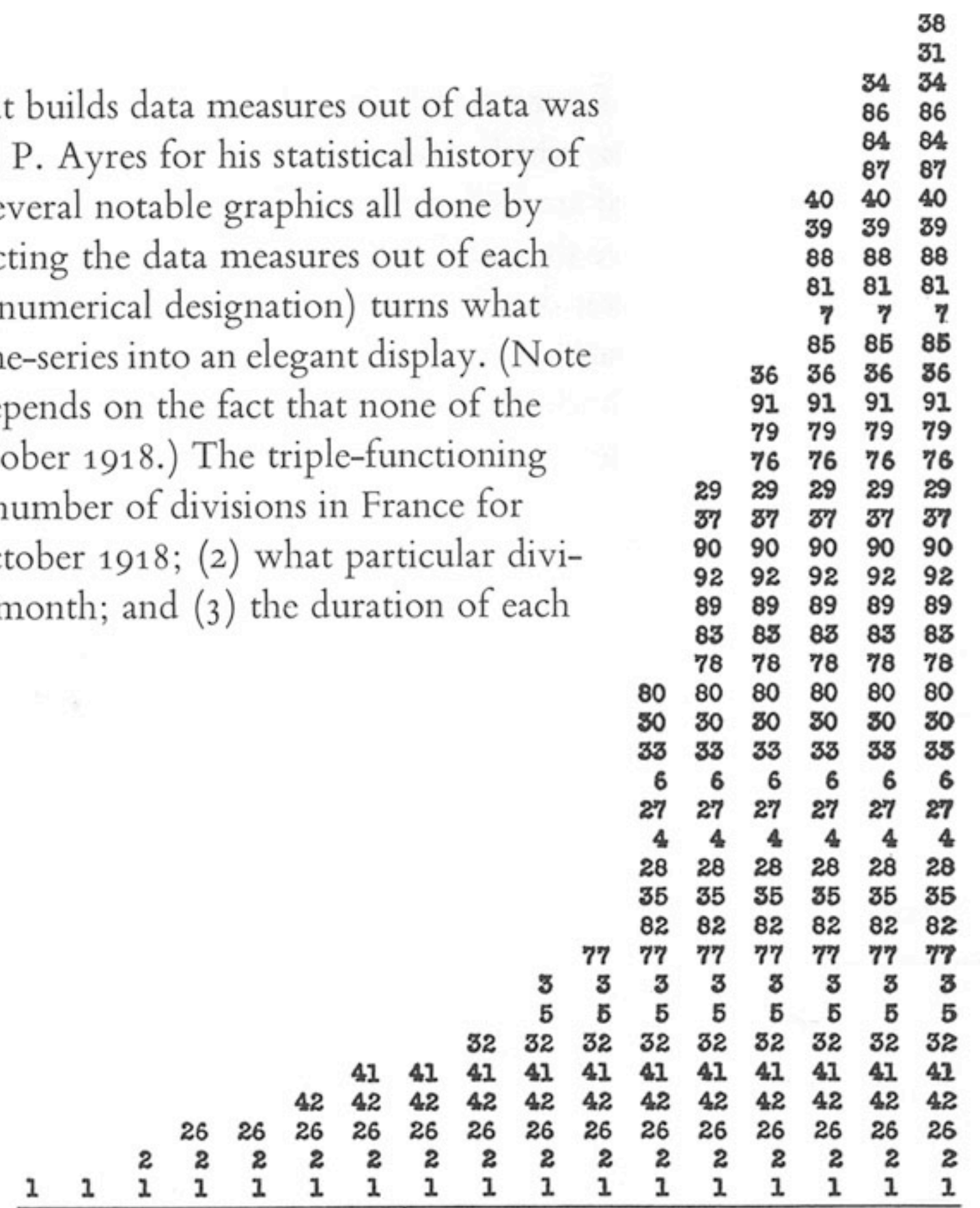

2000
3500
VLADIVOSTOK
JAPAN
BASIN
5
MURORAN
HOKKAIDO
1000
2000
3500
JAPAN SEA
3000
YAMATO
RIDGE
500
2000
YAMATO
TRENCH
NORTH RISE



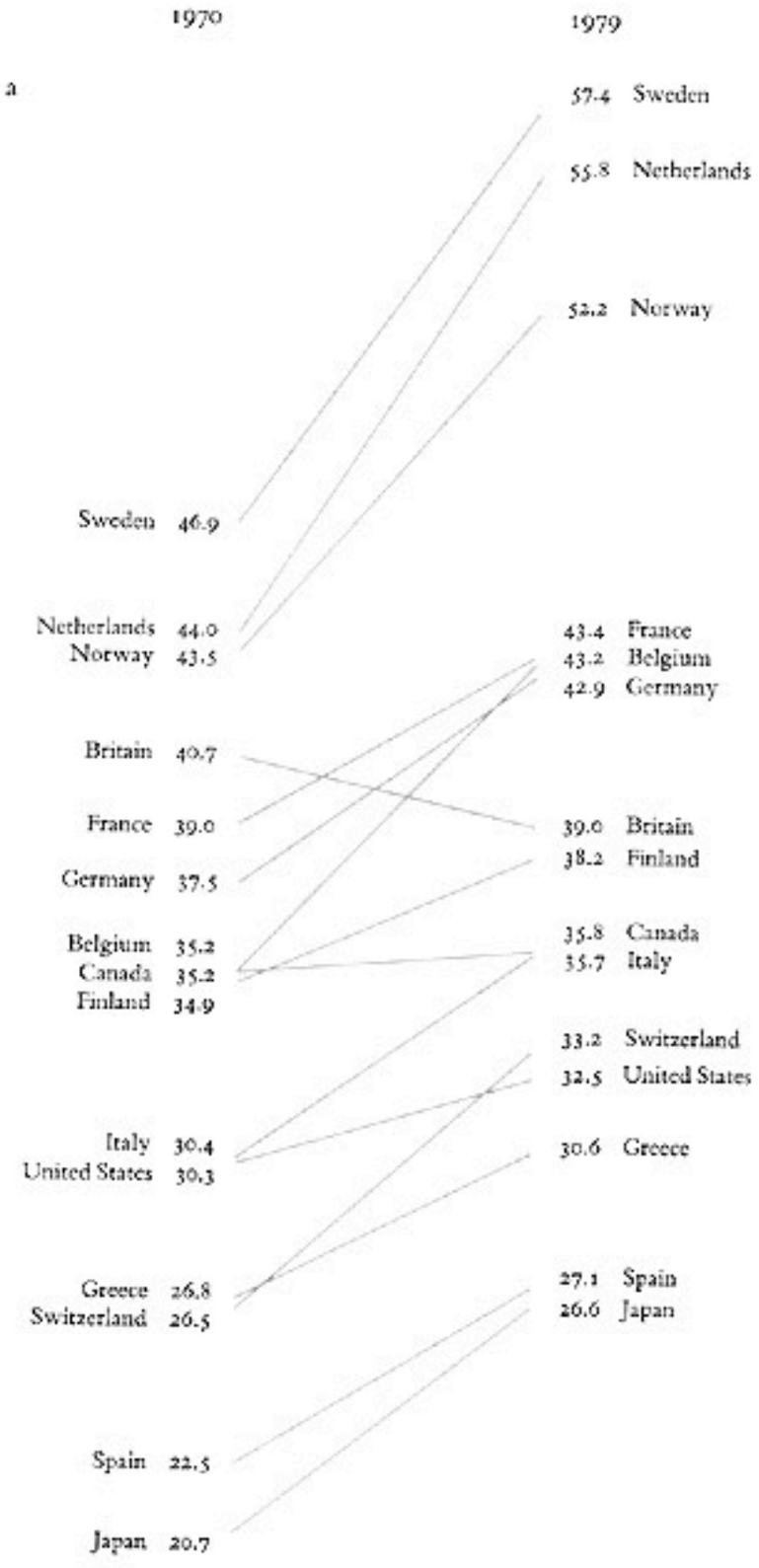
Least effective difference

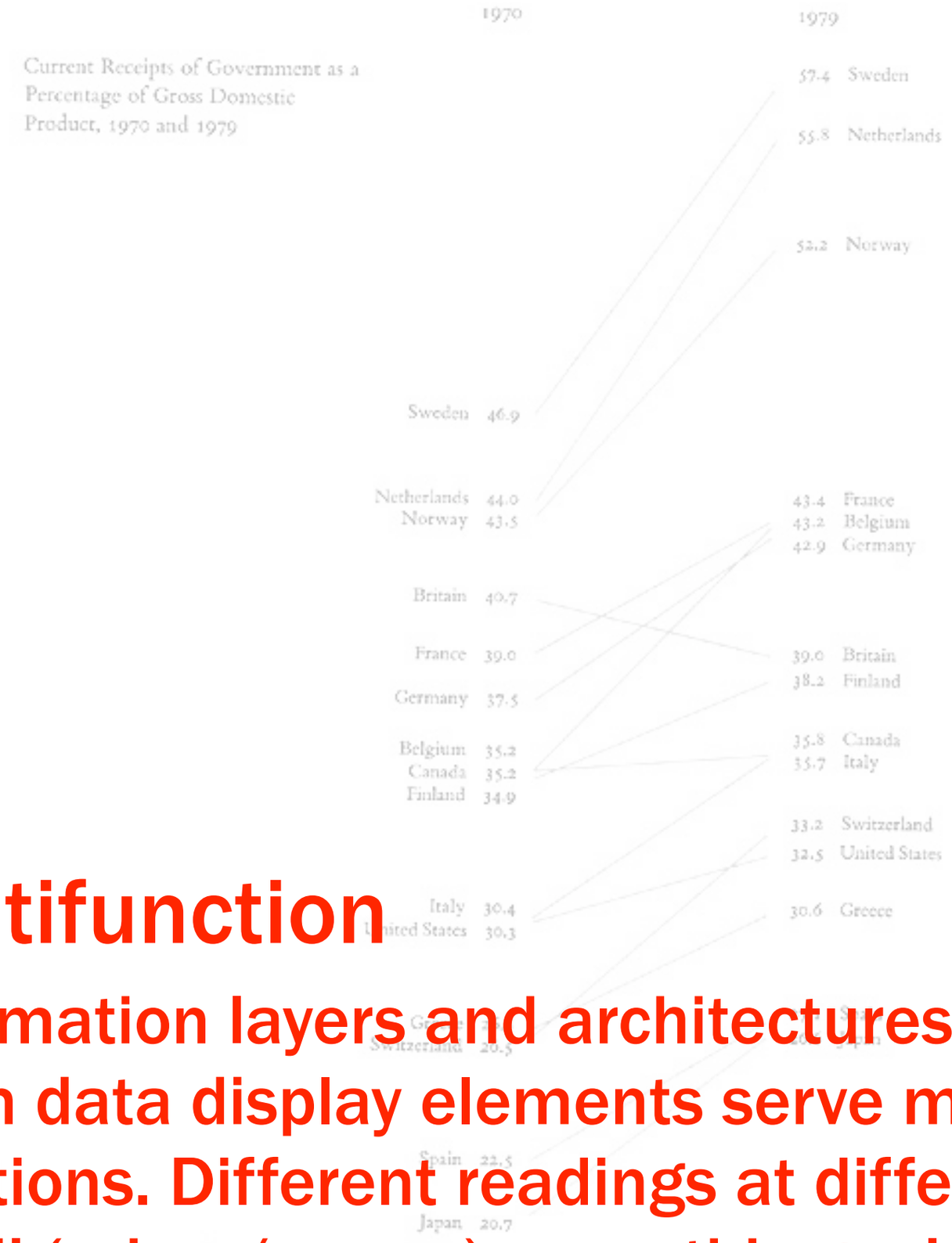
Smaller differences often read better than greater ones, especially in color, and especially in small areas.

A distinguished graphic that builds data measures out of data was designed by Colonel Leonard P. Ayres for his statistical history of World War I, a book with several notable graphics all done by typewriter and rule. Constructing the data measures out of each American division's name (a numerical designation) turns what might have been a routine time-series into an elegant display. (Note that the cumulative design depends on the fact that none of the divisions returned before October 1918.) The triple-functioning data measure shows: (1) the number of divisions in France for each month, June 1917 to October 1918; (2) what particular divisions were in France in each month; and (3) the duration of each division's presence in France.



Current Receipts of Government as a Percentage of Gross Domestic Product, 1970 and 1979

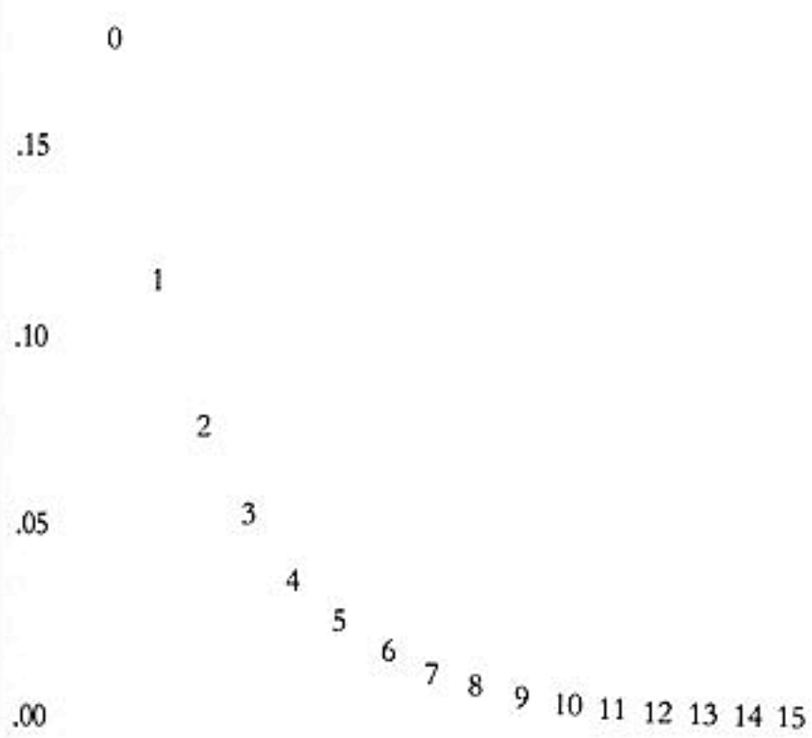




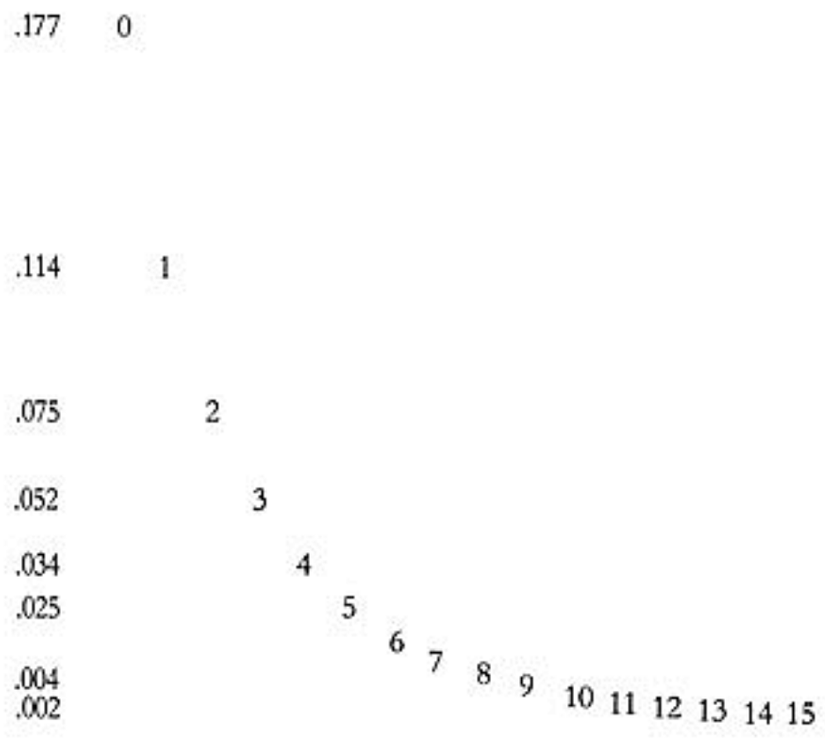
Multifunction

Information layers and architectures emerge best when data display elements serve multiple functions. Different readings at different levels of detail (micro/macro) serve this goal well.

The grid increments of the X-axis are relocated upward to mark the path of the data:

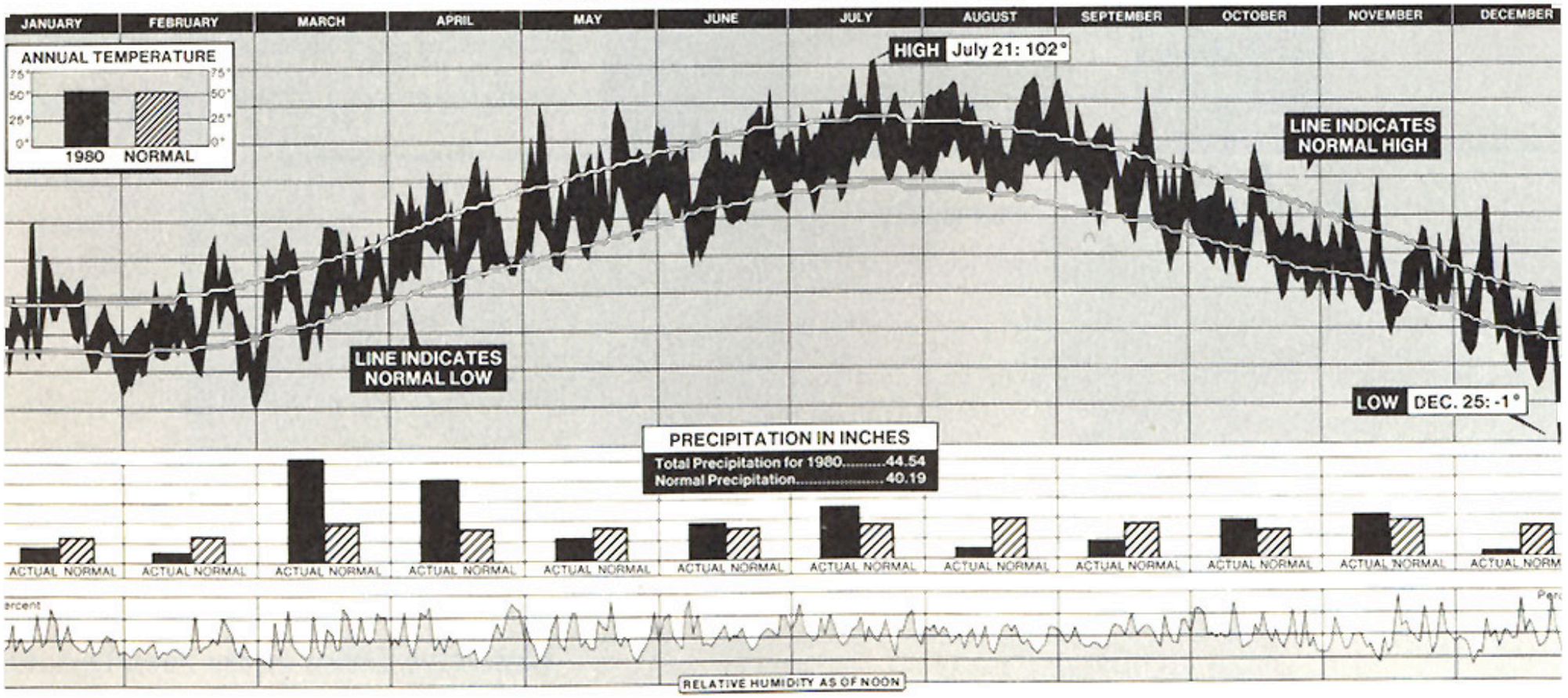


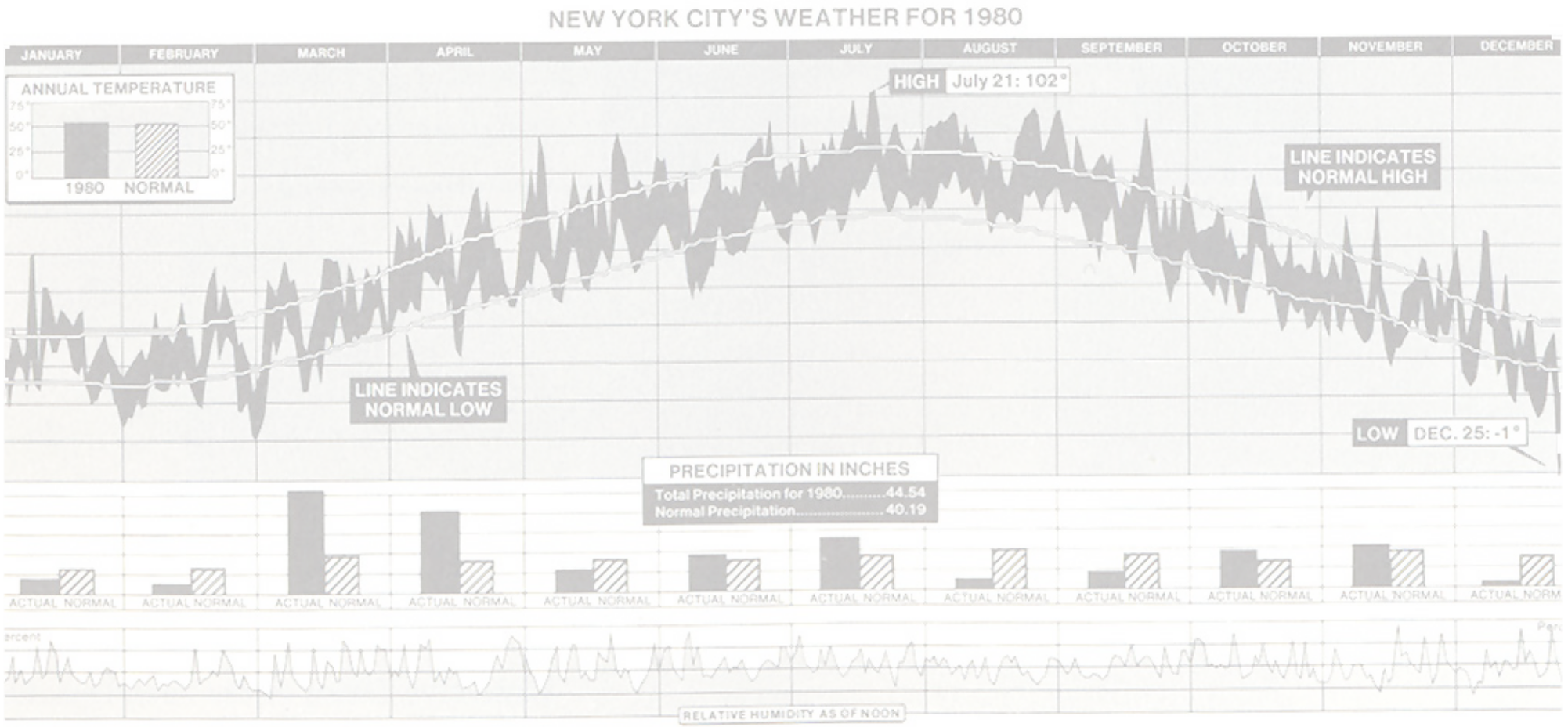
And since the issue in this display is the probability at each integer value, the round-number Y-scale is replaced by exact values:



The Y-scale now resembles the dashes of the dot-dash-plot, with the vertical column of data-positioned numbers serving as the dashes to indicate the marginal distribution.

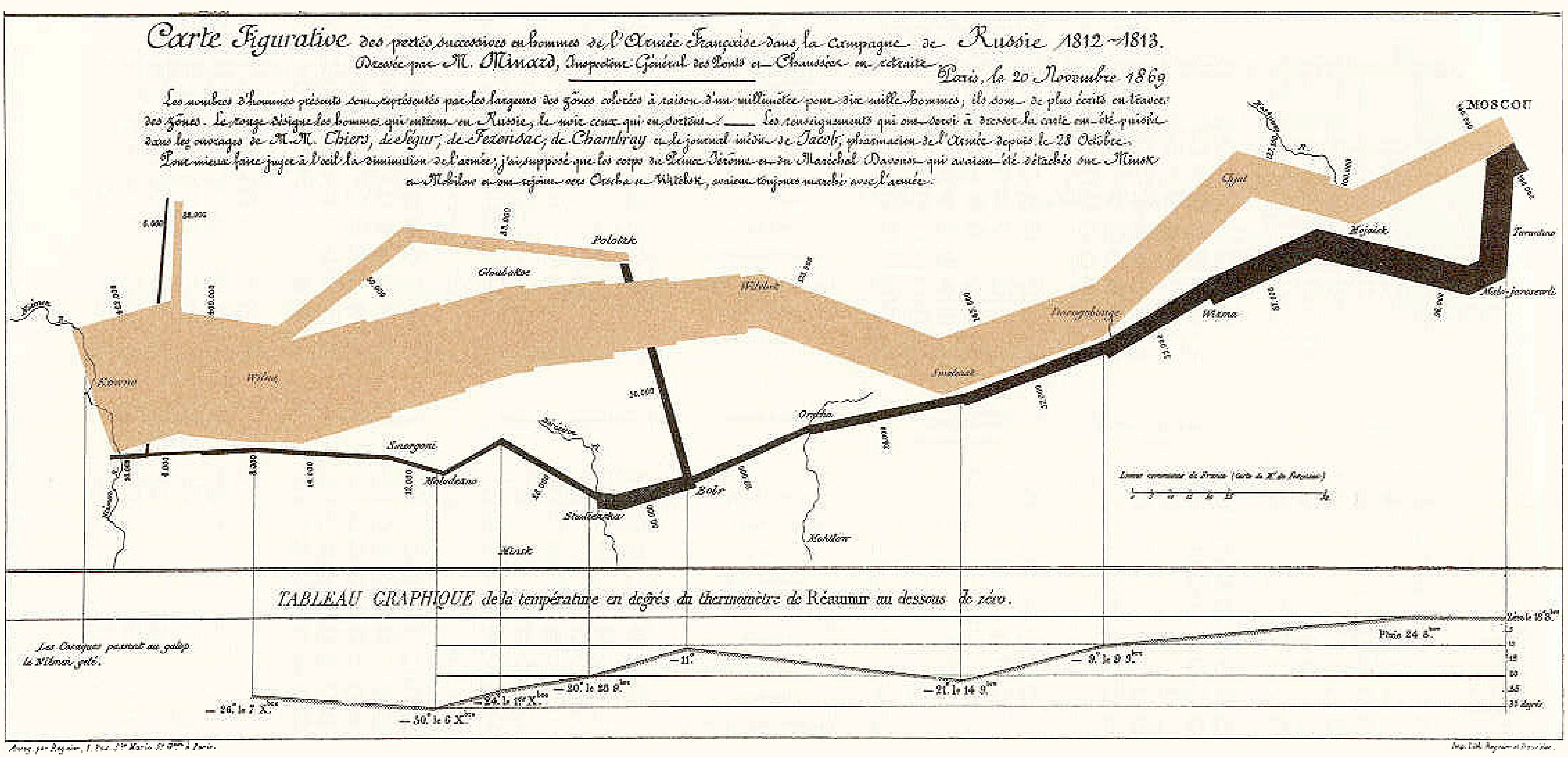
NEW YORK CITY'S WEATHER FOR 1980





Parallelism

Isomorphism and visual juxtapositions reveal connections..


Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812–1813.
Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite.
Paris, le 20 Novembre 1869.
Les nombres d'hommes présents sont représentés par les largeurs des zônes colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zônes. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. — Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.
Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davoust qui avaient été détachés sur Minsk et Mohilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.
MOSCOU
Polotzk
Gloubokoe
Witebsk
Kowno
Wilna
Smolensk
Dorogobouge
Wiazma
Chjat
Mojaisk
Tarantino
Malo-jarosewli
Orscha
Bobr
Studienska
Minsk
Mohilow
Smorgoni
Molodexno
TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.
Les Cosaques passent au galop le Niémen gelé.
Zéro le 18 8.bre
Pluie 24 8.bre
— 9.° le 9 9.bre
— 21.° le 14 9.bre
— 11.°
— 20.° le 28 9.bre
— 24.° le 1.er X.bre
— 30.° le 6 X.bre
— 26.° le 7 X.bre
35 degrés

Epilogue: Designs for the Display of Information

Design is choice. The theory of the visual display of quantitative information consists of principles that generate design options and that guide choices among options. The principles should not be applied rigidly or in a peevish spirit; they are not logically or mathematically certain; and it is better to violate any principle than to place graceless or inelegant marks on paper. Most principles of design should be greeted with some skepticism, for word authority can dominate our vision, and we may come to see only through the lenses of word authority rather than with our own eyes.

What is to be sought in designs for the display of information is the clear portrayal of complexity. Not the complication of the simple; rather the task of the designer is to give visual access to the subtle and the difficult—that is,

the revelation of the complex.

(Exercise: redesigning train schedules)

New Jersey Transit, *Northeastern Corridor Timetable* (Newark, 1985).

Train No.	3701	XM 3301	3801	A 67	3 3803	3 3201	A3 51	.3 3703	3 3807	3 3203	A3 61	3 3809	A3 47	3 3901	3 3811	3 3903	3 3813	3205	3815	3817	3819	3207	3821	3823	3825	.3209	3827	3829	3831
New York, N.Y.	A.M. 12.10	A.M. 12.40	A.M. 1.30	A.M. 3.52	A.M. 4.50	A.M. 6.10	A.M. 6.25	A.M. 6.35	A.M. 6.50	A.M. 7.10	A.M. 7.30	A.M. 7.33	A.M. 7.45	A.M. 7.50	A.M. 8.05	A.M. 8.25	A.M. 8.40	A.M. 8.50	A.M. 9.10	A.M. 9.40	A.M. 10.10	A.M. 10.25	A.M. 10.40	A.M. 11.10	A.M. 11.40	A.M. 11.50	P.M. **12.10**	P.M. **12.40**	P.M. **1.10**
Newark, N.J. P	12.24	12.55	1.44	4.07	5.04	6.24	6.38	6.49	7.04	7.24	7.45	7.47	7.59	8.04	8.19	8.39	8.54	9.04	9.24	9.54	10.24	10.39	10.54	11.24	11.54	**12.04**	**12.24**	**12.54**	**1.24**
North Elizabeth	....	....	....	....	....	....	....	....	....	7.30	....	....	....	8.10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Elizabeth	12.31	1.03	1.51	....	5.11	6.31	....	6.56	7.11	7.32	....	7.54	....	8.13	8.26	8.46	9.01	9.11	9.31	10.01	10.31	10.46	11.01	11.31	**12.01**	**12.11**	**12.31**	**1.01**	**1.31**
Linden	12.36	....	1.56	....	5.16	6.36	....	7.01	7.15	7.37	....	7.59	....	8.18	8.31	8.51	9.06	....	9.36	10.06	10.36	....	11.06	11.36	**12.06**	....	**12.36**	**1.06**	**1.36**
North Rahway	....	....	....	....	....	....	....	7.03	....	7.39	....	....	....	8.20	8.33	8.54	....	....	....	....	....	....	....	....	....	....	....	....	....
Rahway	12.40	1.11	2.00	....	5.20	6.40	....	7.06	7.20	7.42	....	8.03	....	8.24	8.36	8.57	9.10	9.18	9.40	10.10	10.40	10.53	11.10	11.40	**12.10**	**12.18**	**12.40**	**1.10**	**1.40**
Metro Park (Iselin)	12.44	....	2.04	4.26	5.24	....	6.56	7.10	7.25	....	8.04	8.07	8.15	....	8.40	....	9.14	....	9.44	10.14	10.44	....	11.14	11.44	**12.14**	....	**12.44**	**1.14**	**1.44**
Metuchen	12.48	....	2.08	....	5.28	....	....	7.14	7.29	....	....	8.11	....	....	8.44	....	9.18	....	9.48	10.18	10.48	....	11.18	11.48	**12.18**	....	**12.48**	**1.18**	**1.48**
Edison	12.51	....	2.11	....	....	....	....	7.17	7.32	....	....	8.14	....	....	8.47	....	9.21	....	....	10.21	....	....	11.21	....	**12.21**	....	....	**1.21**	....
New Brunswick	12.55	....	2.15	....	5.35	....	7.05	7.21	7.35	....	....	8.18	8.25	....	8.50	....	9.25	....	9.54	10.25	10.54	....	11.25	11.54	**12.25**	....	**12.54**	**1.25**	**1.54**
Jersey Avenue	1.02	....	2.18	....	....	....	....	7.28	....	....	....	8.21	....	....	....	....	9.28	....	....	10.28	....	....	11.28	....	**12.28**	....	....	**1.28**	....
Princeton Jct. S	....	....	2.31	....	5.50	....	7.19	....	7.50	....	....	8.34	8.41	....	9.05	....	9.41	....	10.09	10.41	11.09	....	11.41	**12.09**	**12.41**	....	**1.09**	**1.41**	**2.09**
Trenton, N.J.	....	....	2.42	4.58	6.03	....	7.28	....	8.01	....	8.31	8.44	8.52	....	9.16	....	9.52	....	10.1$	10.52	11.19	....	11.52	**12.19**	**12.52**	....	**1.22**	**1.52**	**2.20**

A redesign calms the dominating grid, moves the New York departure times to the very top, de-emphasizes less important data, and adds new information. A separating line is formed by tiny leader dots, which read as gray, making a distinction but not a barricade:

	am																							
New York, NY	12.10	12.40	1.30	3.52	4.50	6.10	6.25	6.35	6.50	7.10	7.30	7.33	7.45	7.50	8.05	8.25	8.40	8.50	9.10	9.40	10.10	10.25	10.40	11.10	1
Newark, NJ[P]	12.24	12.55	1.44	4.07	5.04	6.24	6.38	6.49	7.04	7.24	7.45	7.47	7.59	8.04	8.19	8.39	8.54	9.04	9.24	9.54	10.24	10.39	10.54	11.24	1
North Elizabeth										7.30				8.10											
Elizabeth	12.31	1.03	1.51		5.11	6.31		6.56	7.11	7.32		7.54		8.13	8.26	8.46	9.01	9.11	9.31	10.01	10.31	10.46	11.01	11.31	1
Linden	12.36		1.56		5.16	6.36		7.01	7.15	7.37		7.59		8.18	8.31	8.51	9.06		9.36	10.06	10.36		11.06	11.36	1
North Rahway								7.03		7.39				8.20	8.33	8.54									
Rahway	12.40	1.11	2.00		5.20	6.40		7.06	7.20	7.42		8.03		8.24	8.36	8.57	9.10	9.18	9.40	10.10	10.40	10.53	11.10	11.40	1
Metro Park (Iselin)	12.44		2.04	4.26	5.24		6.56	7.10	7.25		8.04	8.07	8.15		8.40		9.14		9.44	10.14	10.44		11.14	11.44	1
Metuchen	12.48		2.08		5.28			7.14	7.29			8.11			8.44		9.18		9.48	10.18	10.48		11.18	11.48	1
Edison	12.51		2.11					7.17	7.32			8.14			8.47		9.21			10.21			11.21		1
New Brunswick	12.55		2.15		5.35		7.05	7.21	7.35			8.18	8.25		8.50		9.25		9.54	10.25	10.54		11.25	11.54	1
Jersey Avenue	1.02		2.18					7.28				8.21					9.28			10.28			11.28		1
Princeton Junction[S]			2.31		5.50		7.19		7.50			8.34	8.41		9.05		9.41		10.09	10.41	11.09		11.41	12.09	1
Trenton, NJ			2.42	4.58	6.03		7.28		8.01		8.31	8.44	8.52		9.16		9.52		10.19	10.52	11.19		11.52	12.19	1
TRAIN NUMBER	3701	3301	3601	67	3603	3201	51	3703	3807	3203	61	3809	47	3901	3811	3903	3813	3205	3815	3817	3819	3207	3821	3823	
NOTES		XM		⇤	3	3	⇤3	3	3	3	⇤3	3	⇤3	3	3	3	3								

NEW YORK TO NEW HAVEN

MONDAY TO FRIDAY, EXCEPT HOLIDAYS

Leave New York	Arrive New Haven	Leave New York	Arrive New Haven	Leave New York	Arrive New Haven
AM	AM	PM	PM	PM	PM
12:35	2:18	2:05	3:45	ϒ 6:25	8:19
5:40	7:44	3:05	4:45	ϒ 7:05	8:56
7:05	8:45	ϒ 4:01	5:45	ϒ 8:05	9:45
8:05	9:45	4:41	6:25	ϒ 9:05	10:50
9:05	10:45	ϒ 4:59	6:53	10:05	11:45
10:05	11:45	XY 5:02E	6:33	11:20	1:05
11:05	12:45	XY 5:20	7:08	12:35	2:18
12:05	1:45	X 5:42	7:26	.....	.....
1:05	2:45	XY 6:07E	7:46	.....	.....
PM	PM	PM	PM	PM	PM

SATURDAY, SUNDAY & HOLIDAYS

AM	AM	PM	PM	PM	PM
12:35	2:18	2:05	3:45	7:05	8:45
5:40	7:37	S 3:05	S 4:45	H 8:05	H 9:45
8:05	9:45	4:05	5:45	9:05	10:45
10:05	11:47	5:05	6:48	11:20	1:00
12:05	1:45	6:05	7:48	12:35	2:18
PM	PM	PM	PM	AM	AM

The service shown herein is operated by Metro-North Commuter R.R.

REFERENCE NOTES
Economy **off-peak** tickets are **not** valid on trains in shaded areas.
Check displays in G.C.T. for departure tracks.
E-Express
X-Does not stop at 125th Street.
S-Saturdays and Washington's Birthday only.
H-Sundays and Holidays only.
ϒ-Snack and Beverage Service.
HOLIDAYS-New Year's Day, Washington's Birthday, Memorial Day, Independence Day, Labor Day, Thanksgiving and Christmas.

Bold sans serif capitals weak in distinguishing between two directions:
NEW HAVEN TO NEW YORK NEW YORK TO NEW HAVEN

Column headings repeated 3 times and 24 AM's and PM's shown due to folded sequence of times. The eye must trace a serpentine path in tracking the day's schedule; and another serpentine for weekends:

Poor column break, leaving last peak-hour train as a widow in this column.

Too much separation between leave/arrive times for the same train.

Too little separation between these unrelated columns.

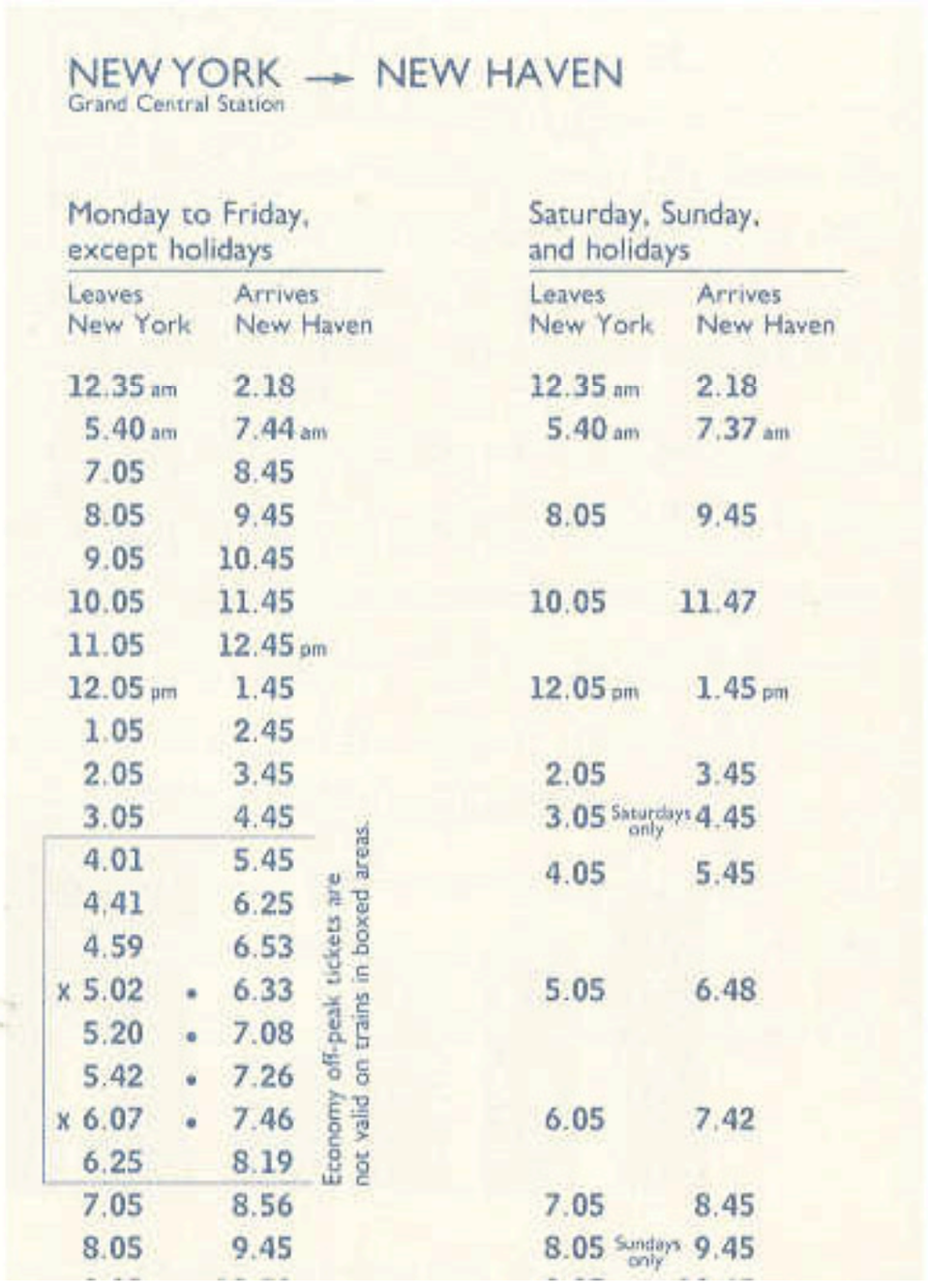
Most frequently used part of schedule (showing rush-hour trains) is the most cluttered part, with a murky screen tint and heavy-handed symbols.

Rules segregate what should be together; a total of 41 inches (104 cm) of rules are drawn for this small table.

Wasted space in headings cramps the times (over-tight leading, in particular). Well-designed schedules use a visually less-active dot between hours and minutes rather than a colon.

Ambiguity in coding; both X and E suggest an express train, or even E for Economy.

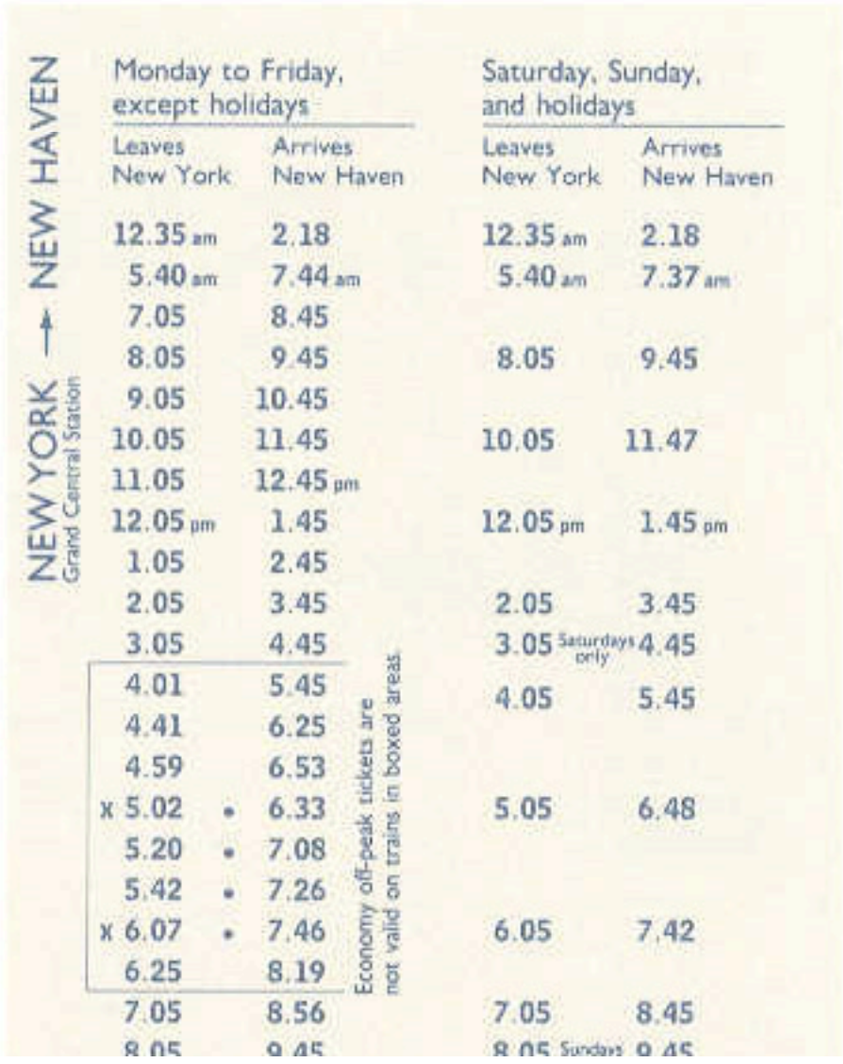
At any rate, the redesign below eliminates all the assorted convolutions from the modern-day schedule and yields a graceful but unceremonious layout. The numbers, no longer serpentined, are now set in Matthew Carter's Bell Centennial, a telephone-book typeface designed for clarity of reading in tight spaces (such as the convenient pocket schedule).[5]



NEW YORK → NEW HAVEN
Grand Central Station

Monday to Friday, except holidays		Saturday, Sunday, and holidays	
Leaves New York	Arrives New Haven	Leaves New York	Arrives New Haven
12.35 am	2.18	12.35 am	2.18
5.40 am	7.44 am	5.40 am	7.37 am
7.05	8.45		
8.05	9.45	8.05	9.45
9.05	10.45		
10.05	11.45	10.05	11.47
11.05	12.45 pm		
12.05 pm	1.45	12.05 pm	1.45 pm
1.05	2.45		
2.05	3.45	2.05	3.45
3.05	4.45	3.05 Saturdays only	4.45
4.01	5.45	4.05	5.45
4.41	6.25		
4.59	6.53		
x 5.02 •	6.33	5.05	6.48
5.20 •	7.08		
5.42 •	7.26		
x 6.07 •	7.46	6.05	7.42
6.25	8.19		
7.05	8.56	7.05	8.45
8.05	9.45	8.05 Sundays only	9.45

Economy off-peak tickets are not valid on trains in boxed areas.



NEW YORK → NEW HAVEN
Grand Central Station

Monday to Friday, except holidays		Saturday, Sunday, and holidays	
Leaves New York	Arrives New Haven	Leaves New York	Arrives New Haven
12.35 am	2.18	12.35 am	2.18
5.40 am	7.44 am	5.40 am	7.37 am
7.05	8.45		
8.05	9.45	8.05	9.45
9.05	10.45		
10.05	11.45	10.05	11.47
11.05	12.45 pm		
12.05 pm	1.45	12.05 pm	1.45 pm
1.05	2.45		
2.05	3.45	2.05	3.45
3.05	4.45	3.05 Saturdays only	4.45
4.01	5.45	4.05	5.45
4.41	6.25		
4.59	6.53		
x 5.02 •	6.33	5.05	6.48
5.20 •	7.08		
5.42 •	7.26		
x 6.07 •	7.46	6.05	7.42
6.25	8.19		
7.05	8.56	7.05	8.45
8.05	9.45	8.05 Sundays only	9.45

Economy off-peak tickets are not valid on trains in boxed areas.