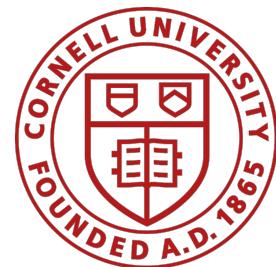


# **DIMENSIONALITY & VISUALIZATION**

– Multidimensional Scaling and Related Approaches –



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Moontae Lee

INFO3300: Data-driven Web Pages (4/20/2018)

O	28 <b>Ni</b> [Ar]4s <sup>2</sup> 3d <sup>8</sup> nickel 58.69	29 <b>Cu</b> [Ar]4s <sup>1</sup> 3d <sup>10</sup> copper 63.55	30 <b>Zn</b> [Ar]4s <sup>2</sup> 3d <sup>10</sup> zinc 65.39	31 <b>Ga</b> [Ar]4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>1</sup> gallium 69.72	32 <b>Ge</b> [Ar]4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>2</sup> germanium 72.58	33 <b>As</b> [Ar]4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>3</sup> arsenic 74.92	34 <b>Se</b> [Ar]4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>4</sup> selenium 78.96	35 <b>Br</b> [Ar]4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>5</sup> bromine 79.90	36 <b>Ru</b> [Ar]4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>6</sup> ruthenium 82.91
Rh	46 <b>Pd</b> [Kr]4d <sup>10</sup> palladium 106.4	47 <b>Ag</b> [Kr]5s <sup>1</sup> 4d <sup>10</sup> silver 107.9	48 <b>Cd</b> [Kr]5s <sup>2</sup> 4d <sup>10</sup> cadmium 112.4	49 <b>In</b> [Kr]5s <sup>2</sup> 4d <sup>10</sup> 5p <sup>1</sup> indium 114.8	50 <b>Tin</b> [Kr]5s <sup>2</sup> 4d <sup>10</sup> 5p <sup>2</sup> tin 118.7	51 <b>Sb</b> [Kr]5s <sup>2</sup> 4d <sup>10</sup> 5p <sup>3</sup> antimony 121.8	52 <b>Te</b> [Kr]5s <sup>2</sup> 4d <sup>10</sup> 5p <sup>4</sup> tellurium 127.6	53 <b>I</b> [Kr]5s <sup>2</sup> 4d <sup>10</sup> 5p <sup>5</sup> iodine 127.9	54 <b>Xe</b> [Kr]5s <sup>2</sup> 4d <sup>10</sup> 5p <sup>6</sup> xenon 131.3
Pt	78 <b>Au</b> [Xe]2f <sup>14</sup> 5d <sup>10</sup>	79 <b>Hg</b> [Xe]6s <sup>2</sup> 4f <sup>14</sup> 5d <sup>10</sup>	80 <b>Tl</b> [Xe]6s <sup>2</sup> 4f <sup>14</sup> 5d <sup>10</sup> 6p <sup>1</sup>	81 <b>Pb</b> [Xe]6s <sup>2</sup> 4f <sup>14</sup> 5d <sup>10</sup> 6p <sup>2</sup>	82 <b>Bi</b> [Xe]6s <sup>2</sup> 4f <sup>14</sup> 5d <sup>10</sup> 6p <sup>3</sup>	83 <b>Po</b> [Xe]6s <sup>2</sup> 4f <sup>14</sup> 5d <sup>10</sup> 6p <sup>4</sup>	84 <b>At</b> [Xe]6s <sup>2</sup> 4f <sup>14</sup> 5d <sup>10</sup> 6p <sup>5</sup>	85 <b>Rn</b> [Xe]6s <sup>2</sup> 4f <sup>14</sup> 5d <sup>10</sup> 6p <sup>6</sup>	86 <b>Og</b> [Xe]6s <sup>2</sup> 4f <sup>14</sup> 5d <sup>10</sup> 6p <sup>7</sup>

1	Hydrogen	H	1.00794
2	Helium	He	4.002602
3	Lithium	Li	6.941
4	Beryllium	Be	9.012182
5	Boron	B	10.811
6	Carbon	C	12.011
7	Nitrogen	N	14.00674
8	Oxygen	O	15.9994
9	Fluorine	F	18.9984032
10	Neon	Ne	20.1797
11	Sodium	Na	22.989768
12	Magnesium	Mg	24.3050
13	Aluminum	Al	26.981539
14	Silicon	Si	28.0855
15	Phosphorus	P	30.973762
16	Sulfur	S	32.066
17	Chlorine	Cl	35.4527
18	Argon	Ar	39.948
19	Potassium	K	39.0983
20	Calcium	Ca	40.078
21	Scandium	Sc	44.955910
22	Titanium	Ti	47.867
23	Vanadium	V	50.9415
24	Chromium	Cr	51.9961
25	Manganese	Mn	54.93805
26	Iron	Fe	55.845
27	Cobalt	Co	58.93320
28	Nickel	Ni	58.6934
29	Copper	Cu	63.546
30	Zinc	Zn	65.39
31	Gallium	Ga	69.723
32	Germanium	Ge	72.61

55	Cesium	Cs	132.90543
56	Barium	Ba	137.327
57	Lanthanum	La	138.9055
58	Cerium	Ce	140.115
59	Praseodymium	Pr	140.90765
60	Neodymium	Nd	144.24
61	Promethium	Pm	144.9127*
62	Samarium	Sm	150.36
63	Europium	Eu	151.965
64	Gadolinium	Gd	157.25
65	Terbium	Tb	158.92534
66	Dysprosium	Dy	162.50
67	Holmium	Ho	164.93032
68	Erbium	Er	167.26
69	Thulium	Tm	168.93421
70	Ytterbium	Yb	173.04
71	Lutetium	Lu	174.967
72	Hafnium	Hf	178.49
73	Tantalum	Ta	180.9479
74	Tungsten	W	183.84
75	Rhenium	Re	186.207
76	Osmium	Os	190.23
77	Iridium	Ir	192.217
78	Platinum	Pt	195.08
79	Gold	Au	196.96654
80	Mercury	Hg	200.59
81	Thallium	Tl	204.3833
82	Lead	Pb	207.2
83	Bismuth	Bi	208.98037
84	Polonium	Po	208.9824*
85	Astatine	At	209.9871*
86	Radon	Rn	222.0176*

Atomic Number → **1**  
 Symbol → **H**  
 1.008 ← Atomic Mass  
 Hydrogen ← Name

1 <b>H</b> 1.008 Hydrogen	2 <b>He</b> 4.002602 Helium
3 <b>Li</b> 6.94 Lithium	4 <b>Be</b> 9.0121831 Beryllium
11 <b>Na</b> 22.98976928 Sodium	12 <b>Mg</b> 24.305 Magnesium
19 <b>K</b> 39.0983 Potassium	20 <b>Ca</b> 40.078 Calcium
21 <b>Sc</b> 44.95908 Scandium	22 <b>Ti</b> 47.867 Titanium
23 <b>V</b> 50.9415 Vanadium	24 <b>Cr</b> 51.9961 Chromium
25 <b>Mn</b> 54.938044 Manganese	26 <b>Fe</b> 55.845 Iron
27 <b>Co</b> 58.933194 Cobalt	28 <b>Ni</b> 58.6934 Nickel
29 <b>Cu</b> 63.546 Copper	30 <b>Zn</b> 65.38 Zinc
31 <b>Ga</b> 69.723 Gallium	32 <b>Ge</b> 72.630 Germanium
33 <b>As</b> 74.921595 Arsenic	34 <b>Se</b> 78.971 Selenium
35 <b>Br</b> 79.904 Bromine	36 <b>Kr</b> 83.798 Krypton
37 <b>Rb</b> 85.4678 Rubidium	38 <b>Sr</b> 87.62 Strontium
39 <b>Y</b> 88.90584 Yttrium	40 <b>Zr</b> 91.224 Zirconium
41 <b>Nb</b> 92.90637 Niobium	42 <b>Mo</b> 95.95 Molybdenum
43 <b>Tc</b> 98 Technetium	44 <b>Ru</b> 101.07 Ruthenium
45 <b>Rh</b> 102.90550 Rhodium	46 <b>Pd</b> 106.42 Palladium
47 <b>Ag</b> 107.8682 Silver	48 <b>Cd</b> 112.414 Cadmium
49 <b>In</b> 114.818 Indium	50 <b>Sn</b> 118.710 Tin
51 <b>Sb</b> 121.760 Antimony	52 <b>Te</b> 127.60 Tellurium
53 <b>I</b> 126.90447 Iodine	54 <b>Xe</b> 131.293 Xenon
55 <b>Cs</b> 132.90545196 Caesium	56 <b>Ba</b> 137.327 Barium
57 <b>/</b> 71 Hafnium	72 <b>Hf</b> 178.49 Hafnium
73 <b>Ta</b> 180.94788 Tantalum	74 <b>W</b> 183.84 Tungsten
75 <b>Re</b> 186.207 Rhenium	76 <b>Os</b> 190.23 Osmium
77 <b>Ir</b> 192.217 Iridium	78 <b>Pt</b> 195.084 Platinum
79 <b>Au</b> 196.966569 Gold	80 <b>Hg</b> 200.592 Mercury
81 <b>Tl</b> 204.38 Thallium	82 <b>Pb</b> 207.2 Lead
83 <b>Bi</b> 208.98040 Bismuth	84 <b>Po</b> 209 Polonium
85 <b>At</b> 210 Astatine	86 <b>Rn</b> 222 Radon
87 <b>Fr</b> 223 Francium	88 <b>Ra</b> 226 Radium
89 <b>/</b> 103 Rutherfordium	104 <b>Rf</b> 267 Rutherfordium
105 <b>Db</b> 268 Dubnium	106 <b>Sg</b> 269 Seaborgium
107 <b>Bh</b> 270 Bohrium	108 <b>Hs</b> 269 Hassium
109 <b>Mt</b> 278 Meitnerium	110 <b>Ds</b> 281 Darmstadtium
111 <b>Rg</b> 281 Roentgenium	112 <b>Cn</b> 285 Copernicium
113 <b>Uut</b> 286 Ununtrium	114 <b>Fl</b> 289 Flerovium
115 <b>Uup</b> 289 Ununpentium	116 <b>Lv</b> 293 Livermorium
117 <b>Uus</b> 294 Ununseptium	118 <b>Uuo</b> 294 Ununoctium

Lanthanide Series	57 <b>La</b> 138.90547 Lanthanum	58 <b>Ce</b> 140.116 Cerium	59 <b>Pr</b> 140.90766 Praseodymium	60 <b>Nd</b> 144.242 Neodymium	61 <b>Pm</b> 145 Promethium	62 <b>Sm</b> 150.36 Samarium	63 <b>Eu</b> 151.964 Europium	64 <b>Gd</b> 157.25 Gadolinium	65 <b>Tb</b> 158.92535 Terbium	66 <b>Dy</b> 162.500 Dysprosium	67 <b>Ho</b> 164.93033 Holmium	68 <b>Er</b> 167.259 Erbium	69 <b>Tm</b> 168.93422 Thulium	70 <b>Yb</b> 173.054 Ytterbium	71 <b>Lu</b> 174.9668 Lutetium
Actinide Series	89 <b>Ac</b> 227 Actinium	90 <b>Th</b> 232.0377 Thorium	91 <b>Pa</b> 231.03588 Protactinium	92 <b>U</b> 238.02891 Uranium	93 <b>Np</b> 237 Neptunium	94 <b>Pu</b> 244 Plutonium	95 <b>Am</b> 243 Americium	96 <b>Cm</b> 247 Curium	97 <b>Bk</b> 247 Berkelium	98 <b>Cf</b> 251 Californium	99 <b>Es</b> 252 Einsteinium	100 <b>Fm</b> 257 Fermium	101 <b>Md</b> 258 Mendelevium	102 <b>No</b> 259 Nobelium	103 <b>Lr</b> 266 Lawrencium

# Better visualization?

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18											
1	<b>H</b> Hydrogen 1.008	<b>He</b> Helium 4.0026	<b>Li</b> Lithium 6.94	<b>Be</b> Beryllium 9.0122	<b>B</b> Boron 10.81	<b>C</b> Carbon 12.011	<b>N</b> Nitrogen 14.007	<b>O</b> Oxygen 15.999	<b>F</b> Fluorine 18.998	<b>Ne</b> Neon 20.180	<b>Ar</b> Argon 39.948	<b>K</b> Potassium 39.098	<b>Ca</b> Calcium 40.078	<b>Sc</b> Scandium 44.956	<b>Ti</b> Titanium 54.938	<b>V</b> Vanadium 51.996	<b>Mn</b> Manganese 54.938	<b>Cr</b> Chromium 55.845	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933	<b>Ni</b> Nickel 58.693	<b>Cu</b> Copper 63.546	<b>Zn</b> Zinc 65.38	<b>Ga</b> Gallium 69.723	<b>Ge</b> Germanium 72.630	<b>As</b> Arsenic 74.922	<b>Se</b> Selenium 78.971	<b>Br</b> Bromine 79.904	<b>Kr</b> Krypton 83.798
2	<b>Li</b> Lithium 6.94	<b>Be</b> Beryllium 9.0122	<b>Hg</b> Mercury (200)	<b>H</b> Hydrogen 1.008	<b>Rf</b> Rutherfordium (261)	<b>Solid</b>	<b>Liquid</b>	<b>Gas</b>	<b>Alkali metals</b>	<b>Alkaline earth metals</b>	<b>Lanthanoids (Lanthanides)</b>	<b>Actinoids (Actinides)</b>	<b>Metals</b>	<b>Post-transition metals</b>	<b>Transition metals</b>	<b>Nonmetals</b>	<b>Metalloids</b>	<b>Noble gases</b>	<b>Pnictogens</b>	<b>Chalcogens</b>	<b>Halogens</b>								
3	<b>Na</b> Sodium 22.990	<b>Mg</b> Magnesium 24.305	<b>Rb</b> Rubidium 85.468	<b>Sr</b> Strontium 87.62	<b>Sc</b> Scandium 44.956	<b>Ti</b> Titanium 54.938	<b>V</b> Vanadium 51.996	<b>Mn</b> Manganese 54.938	<b>Cr</b> Chromium 55.845	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933	<b>Ni</b> Nickel 58.693	<b>Cu</b> Copper 63.546	<b>Zn</b> Zinc 65.38	<b>Ga</b> Gallium 69.723	<b>Ge</b> Germanium 72.630	<b>As</b> Arsenic 74.922	<b>Se</b> Selenium 78.971	<b>Br</b> Bromine 79.904	<b>Kr</b> Krypton 83.798									
4	<b>Ca</b> Calcium 40.078	<b>Sc</b> Scandium 44.956	<b>Sc</b> Scandium 44.956	<b>Ti</b> Titanium 54.938	<b>Ti</b> Titanium 54.938	<b>Sc</b> Scandium 44.956	<b>V</b> Vanadium 51.996	<b>V</b> Vanadium 51.996	<b>Cr</b> Chromium 55.845	<b>Mn</b> Manganese 54.938	<b>Cr</b> Chromium 55.845	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933	<b>Ni</b> Nickel 58.693	<b>Cu</b> Copper 63.546	<b>Zn</b> Zinc 65.38	<b>Ga</b> Gallium 69.723	<b>Ge</b> Germanium 72.630	<b>As</b> Arsenic 74.922	<b>Se</b> Selenium 78.971	<b>Br</b> Bromine 79.904	<b>Kr</b> Krypton 83.798					
5	<b>Rb</b> Rubidium 85.468	<b>Sr</b> Strontium 87.62	<b>Zr</b> Zirconium 88.906	<b>Yttrium Nb</b> Yttrium 91.224 Niobium 92.906	<b>Sc</b> Scandium 44.956	<b>Ti</b> Titanium 54.938	<b>Ti</b> Titanium 54.938	<b>Sc</b> Scandium 44.956	<b>Tc</b> Technetium (98)	<b>Ru</b> Ruthenium 101.07	<b>Tc</b> Technetium (98)	<b>Ru</b> Ruthenium 101.07	<b>Co</b> Cobalt 58.933	<b>Rh</b> Rhodium 102.91	<b>Co</b> Cobalt 58.933	<b>Rh</b> Rhodium 102.91	<b>Pd</b> Palladium 106.42	<b>Ag</b> Silver 107.87	<b>Pd</b> Palladium 106.42	<b>Ag</b> Silver 107.87	<b>Cd</b> Cadmium 112.41	<b>In</b> Indium 114.82	<b>Sn</b> Tin 118.71	<b>Sb</b> Antimony 121.76	<b>Te</b> Tellurium 127.60	<b>I</b> Iodine 126.90	<b>Xe</b> Xenon 131.29		
6	<b>Cs</b> Caesium 132.91	<b>Ba</b> Barium 137.33	<b>Hf</b> Hafnium 178.49	<b>Ta</b> Tantalum 180.95	<b>W</b> Tungsten 183.84	<b>Re</b> Rhenium 186.21	<b>Os</b> Osmium 190.23	<b>Ir</b> Iridium 192.22	<b>Pt</b> Platinum 195.08	<b>Os</b> Osmium 190.23	<b>Ir</b> Iridium 192.22	<b>Pt</b> Platinum 195.08	<b>Gold Au</b> Gold 196.97	<b>Platinum Pt</b> Platinum 200.59	<b>Ir</b> Iridium 192.22	<b>Pt</b> Platinum 195.08	<b>Au</b> Gold 196.97	<b>Hg</b> Mercury 204.38	<b>Pt</b> Thallium 204.38	<b>Pb</b> Lead 207.2	<b>Bi</b> Bismuth (209)	<b>Po</b> Polonium (210)	<b>At</b> Astatine (222)	<b>Rn</b> Radon (222)	<b>Fr</b> Francium (223)				
7	<b>Fr</b> Francium (223)	<b>Ra</b> Radium (226)	<b>Rf</b> Rutherfordium (261)	<b>Db</b> Dubnium (262)	<b>Sg</b> Seaborgium (263)	<b>Bh</b> Bohrium (263)	<b>Hs</b> Hassium (263)	<b>Mt</b> Meitnerium (263)	<b>Ds</b> Darmstadtium (264)	<b>Rg</b> Roentgenium (263)	<b>Mt</b> Meitnerium (263)	<b>Ds</b> Darmstadtium (264)	<b>Cn</b> Copernicium (263)	<b>Nh</b> Nihonium (263)	<b>Fl</b> Flerovium (263)	<b>Mc</b> Moscovium (263)	<b>Lv</b> Livermoresium (263)	<b>Ts</b> Tennessine (263)	<b>Og</b> Oganesson (263)	<b>Fr</b> Francium (223)									
8	<b>Fr</b> Francium (223)	<b>Ra</b> Radium (226)	<b>Rf</b> Rutherfordium (261)	<b>Db</b> Dubnium (262)	<b>Sg</b> Seaborgium (263)	<b>Bh</b> Bohrium (263)	<b>Hs</b> Hassium (263)	<b>Mt</b> Meitnerium (263)	<b>Ds</b> Darmstadtium (264)	<b>Rg</b> Roentgenium (263)	<b>Mt</b> Meitnerium (263)	<b>Ds</b> Darmstadtium (264)	<b>Cn</b> Copernicium (263)	<b>Nh</b> Nihonium (263)	<b>Fl</b> Flerovium (263)	<b>Mc</b> Moscovium (263)	<b>Lv</b> Livermoresium (263)	<b>Ts</b> Tennessine (263)	<b>Og</b> Oganesson (263)	<b>Fr</b> Francium (223)									

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.



# What about dynamic?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																
1 <b>H</b> Hydrogen 1.008	2 <b>He</b> Helium 4.0026	3 <b>Li</b> Lithium 6.94	4 <b>Be</b> Beryllium 9.0122	5 <b>B</b> Boron 10.81	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.007	8 <b>O</b> Oxygen 15.999	9 <b>F</b> Fluorine 18.998	10 <b>Ne</b> Neon 20.180	11 <b>Na</b> Sodium 22.990	12 <b>Mg</b> Magnesium 24.305	13 <b>Al</b> Aluminum 26.982	14 <b>Si</b> Silicon 28.085	15 <b>P</b> Phosphorus 30.974	16 <b>S</b> Sulfur 32.06	17 <b>Cl</b> Chlorine 35.45	18 <b>Ar</b> Argon 39.948																
Atomic Sym Name Weight	Solid	Metals	Nonmetals	1200																													
3 <b>Li</b> Lithium 6.94	4 <b>Be</b> Beryllium 9.0122	5 <b>B</b> Boron 10.81	6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.007	8 <b>O</b> Oxygen 15.999	9 <b>F</b> Fluorine 18.998	10 <b>Ne</b> Neon 20.180	11 <b>Na</b> Sodium 22.990	12 <b>Mg</b> Magnesium 24.305	13 <b>Al</b> Aluminum 26.982	14 <b>Si</b> Silicon 28.085	15 <b>P</b> Phosphorus 30.974	16 <b>S</b> Sulfur 32.06	17 <b>Cl</b> Chlorine 35.45	18 <b>Ar</b> Argon 39.948	19 <b>K</b> Potassium 39.098	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.956	22 <b>Ti</b> Titanium 47.867	23 <b>V</b> Vanadium 50.942	24 <b>Cr</b> Chromium 51.996	25 <b>Mn</b> Manganese 54.938	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.933	28 <b>Ni</b> Nickel 58.693	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.630	33 <b>As</b> Arsenic 74.922	34 <b>Se</b> Selenium 78.971	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.798
4 <b>Rb</b> Rubidium 85.468	5 <b>Sr</b> Strontium 87.62	6 <b>Sc</b> Scandium 44.956	7 <b>Ti</b> Titanium 47.867	8 <b>V</b> Vanadium 50.942	9 <b>Cr</b> Chromium 51.996	10 <b>Mn</b> Manganese 54.938	11 <b>Fe</b> Iron 55.845	12 <b>Co</b> Cobalt 58.933	13 <b>Ni</b> Nickel 58.693	14 <b>Cu</b> Copper 63.546	15 <b>Zn</b> Zinc 65.38	16 <b>Ga</b> Gallium 69.723	17 <b>Ge</b> Germanium 72.630	18 <b>As</b> Arsenic 74.922	19 <b>Se</b> Selenium 78.971	20 <b>Br</b> Bromine 79.904	21 <b>Kr</b> Krypton 83.798																
5 <b>Cs</b> Caesium 132.91	6 <b>Ba</b> Barium 137.33	7 <b>Sc</b> Scandium 44.956	8 <b>Ti</b> Titanium 47.867	9 <b>V</b> Vanadium 50.942	10 <b>Cr</b> Chromium 51.996	11 <b>Mn</b> Manganese 54.938	12 <b>Fe</b> Iron 55.845	13 <b>Co</b> Cobalt 58.933	14 <b>Ni</b> Nickel 58.693	15 <b>Cu</b> Copper 63.546	16 <b>Zn</b> Zinc 65.38	17 <b>Ga</b> Gallium 69.723	18 <b>Ge</b> Germanium 72.630	19 <b>As</b> Arsenic 74.922	20 <b>Se</b> Selenium 78.971	21 <b>Br</b> Bromine 79.904	22 <b>Kr</b> Krypton 83.798																
6 <b>Rb</b> Rubidium 85.468	7 <b>Sr</b> Strontium 87.62	8 <b>Sc</b> Scandium 44.956	9 <b>Ti</b> Titanium 47.867	10 <b>V</b> Vanadium 50.942	11 <b>Cr</b> Chromium 51.996	12 <b>Mn</b> Manganese 54.938	13 <b>Fe</b> Iron 55.845	14 <b>Co</b> Cobalt 58.933	15 <b>Ni</b> Nickel 58.693	16 <b>Cu</b> Copper 63.546	17 <b>Zn</b> Zinc 65.38	18 <b>Ga</b> Gallium 69.723	19 <b>Ge</b> Germanium 72.630	20 <b>As</b> Arsenic 74.922	21 <b>Se</b> Selenium 78.971	22 <b>Br</b> Bromine 79.904	23 <b>Kr</b> Krypton 83.798																
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## Implications

**Good visualization helps better understanding  
large complex data.**

## Implications

Good visualization helps better understanding  
large complex data.

succinct

## Implications

Good visualization helps better understanding  
large complex data.

succinct

transparent

## Implications

Good visualization helps better understanding  
large complex data.

succinct

transparent

comparative

## Implications

Good visualization helps better understanding  
large complex data.

succinct

transparent

comparative

coherent

# Even better

Good visualization helps better understanding  
large complex data.

succinct

transparent

comparative

coherent

beautiful

creative

## Failure modes

If you tried very hard but frustrated,

## Failure modes

If you tried very hard but frustrated, then check

Readability: too much content? busy?

Usability: inform useful knowledge?

Accessibility, Creativity, and Complexity

# Scientific Research Method



# David's mindmap



# David's mindmap



Based on your observations.

# David's mindmap



Based on your observations.

By picking the data of your interest.

# David's mindmap



Based on your observations.

By picking the data of your interest.

That your data can answer.

# David's mindmap



Based on your observations.

By picking the data of your interest.

That your data can answer.

Via various data-science tools.

Regression, Distributions  
Stochastic Gradient Descent,  
Clustering, Reduction

# David's mindmap



Based on your observations.

By picking the data of your interest.

That your data can answer.

Via various data-science tools.

Regression, Distributions  
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Based on your visualization!

# David's mindmap



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By picking the data of your interest.

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Regression, Distributions  
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Based on your visualization!

You learned Javascript and D3!

# David's mindmap



Based on your observations.

By picking the data of your interest.

That your data can answer.

Via various data-science tools.

Regression, Distributions  
Stochastic Gradient Descent,  
Clustering, Reduction

Based on your visualization!

You learned Javascript and D3!

Based on comments and feedback.

**He is ambitious!**



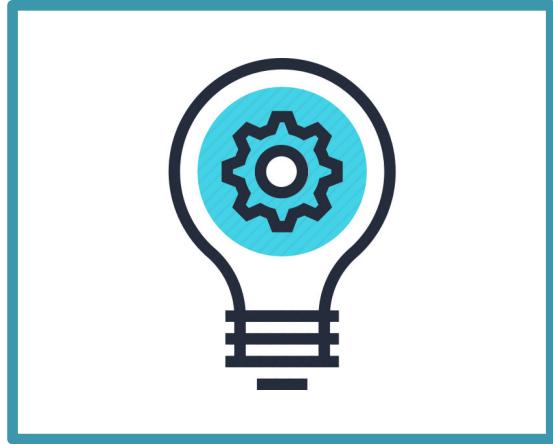


- 1. Critical ingredient of readability?**

---
- 2. Can visualization inspire new/better models?**



- 1. Must be human interpretable  
(even if the data is complex & high-dimension)**



**1. Must be human interpretable  
(even if the data is complex & high-dimension)**

---

**2. Yes!**

## Cognitive limit

**Only 2D (or 3D at most) figures are readable.**

## Cognitive limit

Only 2D (or 3D at most) figures are readable.

---

What if with more than 2 feature variables?  
(Estimate housing price by {size, distance, area, ...})

## Cognitive limit

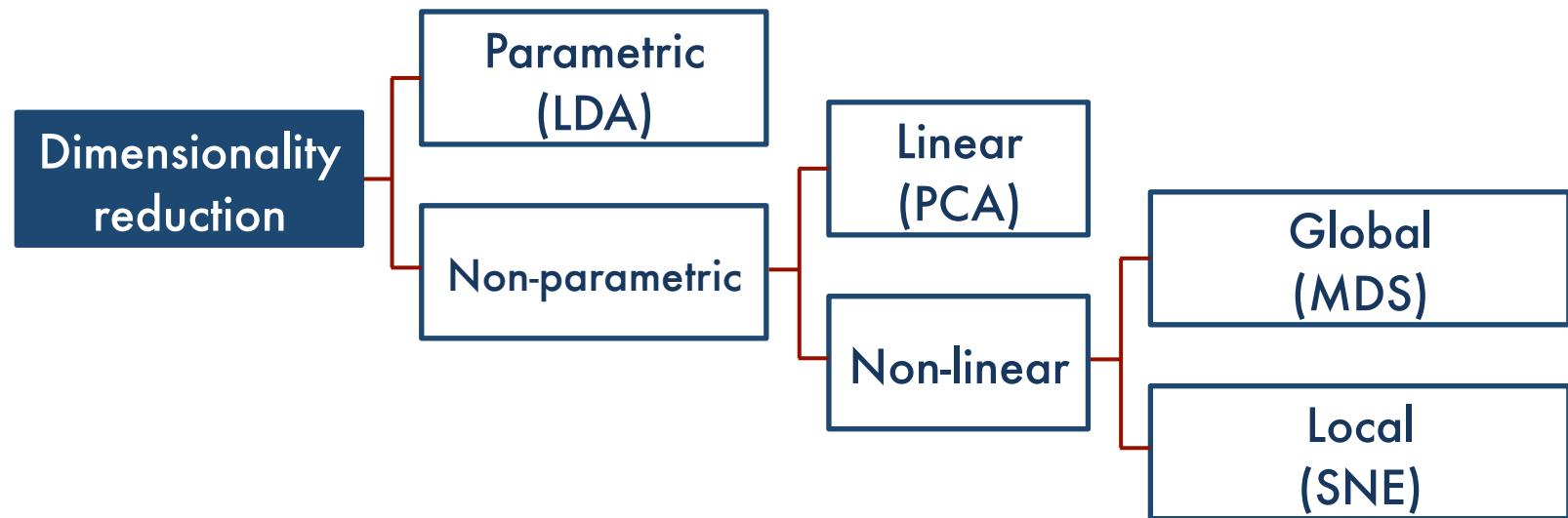
Only 2D (or 3D at most) figures are readable.

---

What if with more than 2 feature variables?  
(Estimate housing price by {size, distance, area, ...})

Dimensionality reduction!

# Map of the tools



## Common assumptions

NOT that complex (in reality)!

NOT that complicated (in details)!

## Common assumptions

NOT that complex (in reality)!



- Looking complex, but lies in much simple space.
- That space gives better representations.

NOT that complicated (in details)!

## Common assumptions

NOT that complex (in reality)!



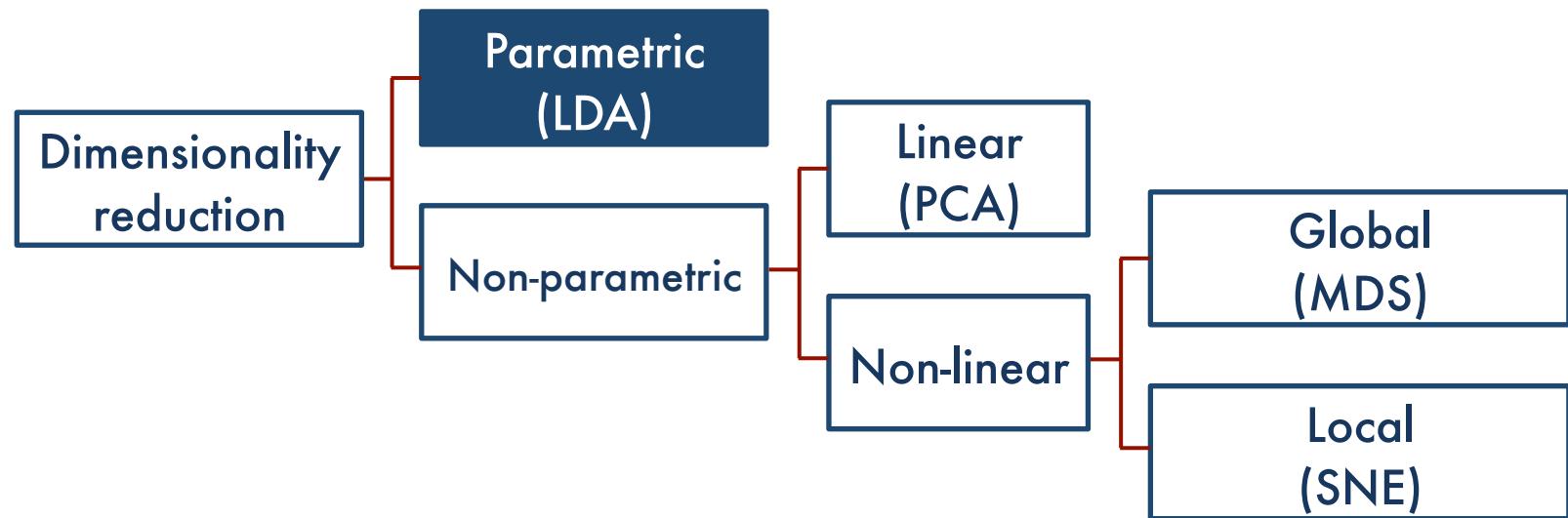
- Looking complex, but lies in much simple space.
- That space gives better representations.

NOT that complicated (in details)!

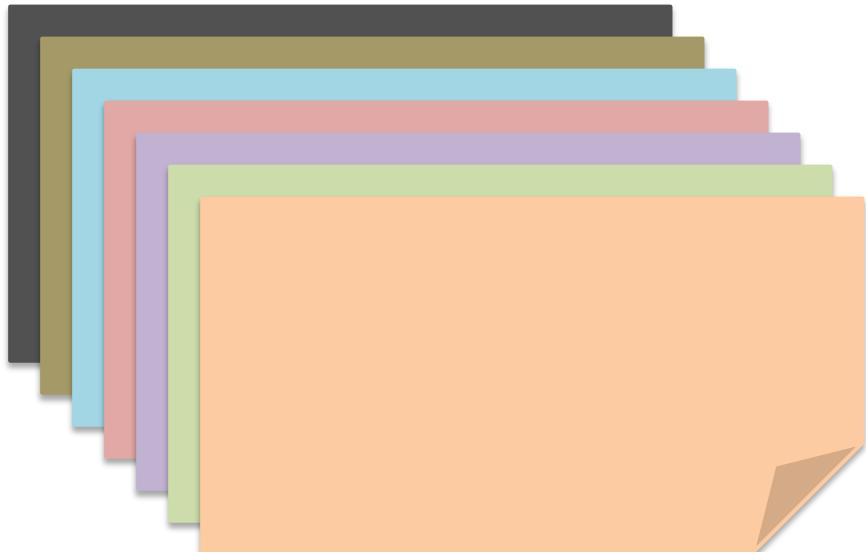


- Most information is pairwise between data points.
- In particular, by pairwise distances.

# Map of the tools



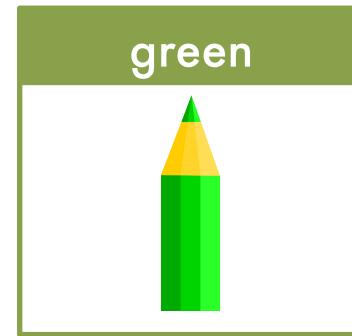
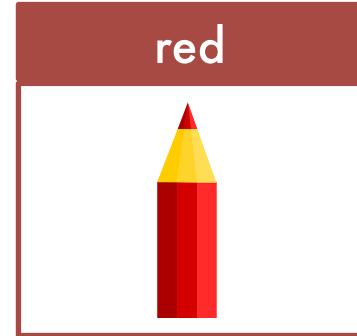
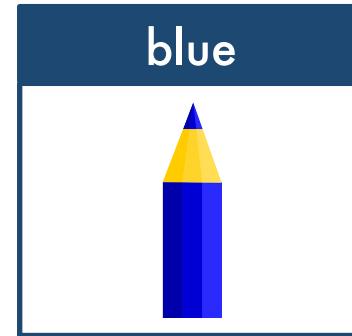
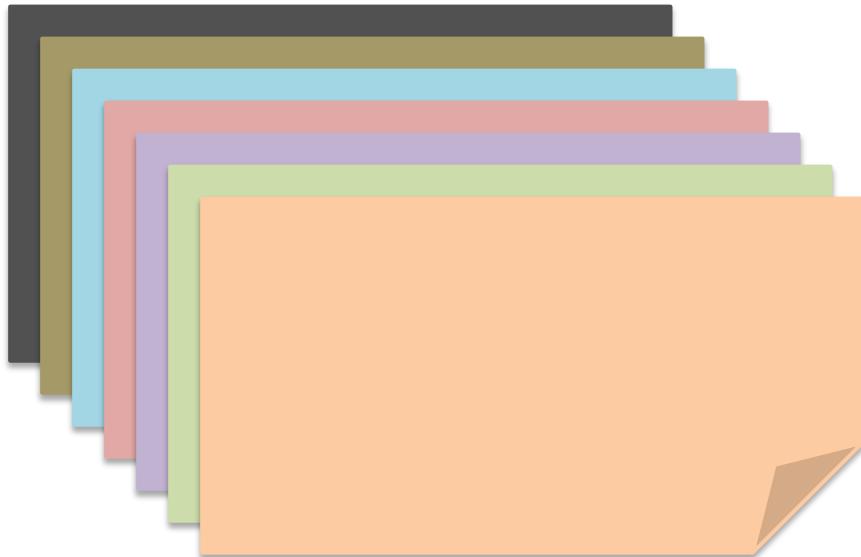
# Motivation: coloring



---

$2^{24}$  sheets with different colors

# Motivation: coloring



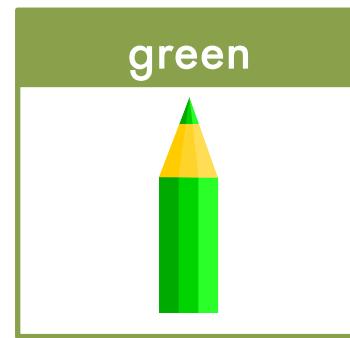
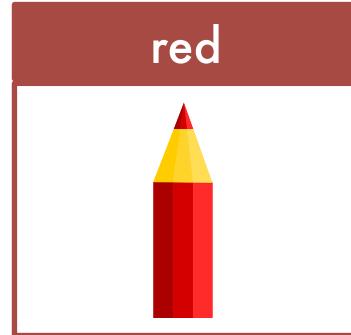
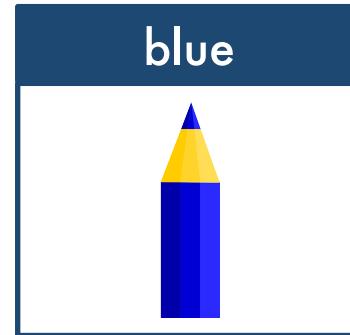
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Bring basis pencils

# Motivation: coloring

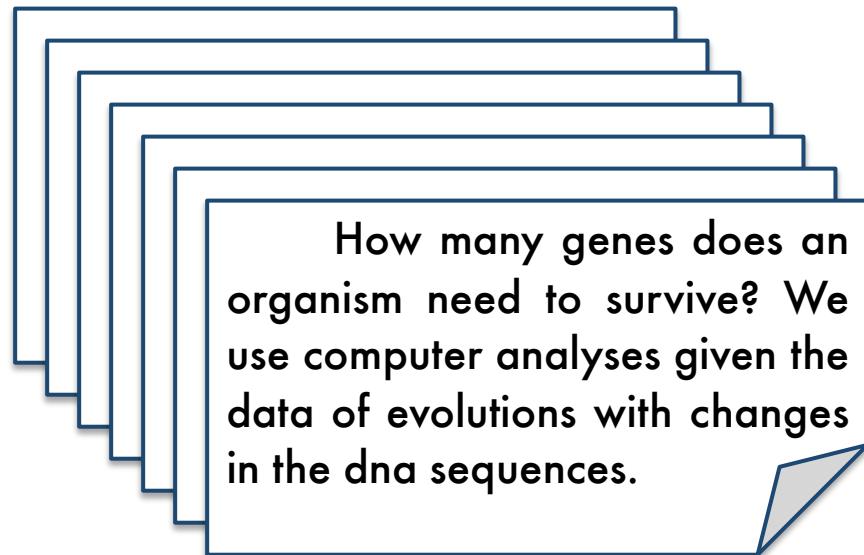


(R=255, G=199, B=143)



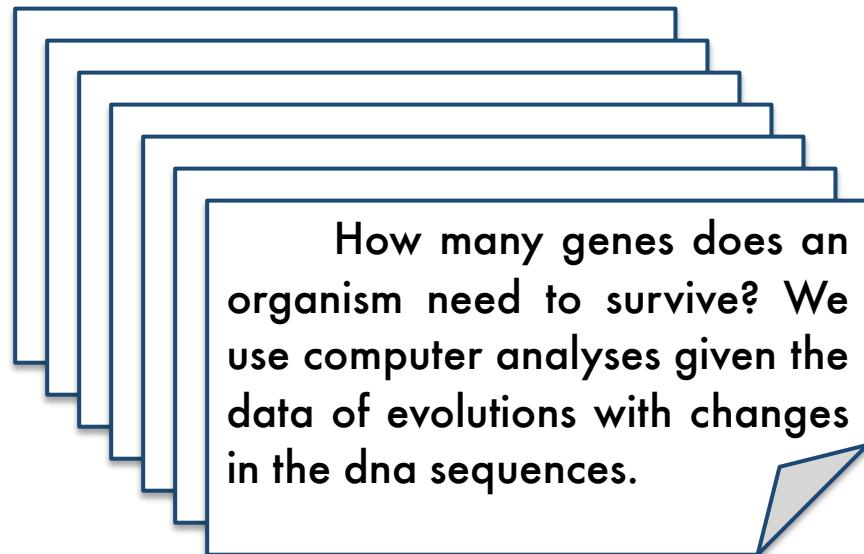
Bring basis pencils

# Topic modeling



17,000 Articles from the journal "Science"

# Topic modeling



17,000 Articles from the journal "Science"



user input: 4 topics

# Topic modeling

How many genes does an organism need to survive? We use computer analyses given the data of evolutions with changes in the dna sequences.

b <sub>1</sub> : biology	
dna	0.04
genes	0.02
data	0.01
...	...

b <sub>2</sub> : life	
evolution	0.08
life	0.03
brain	0.01
...	...

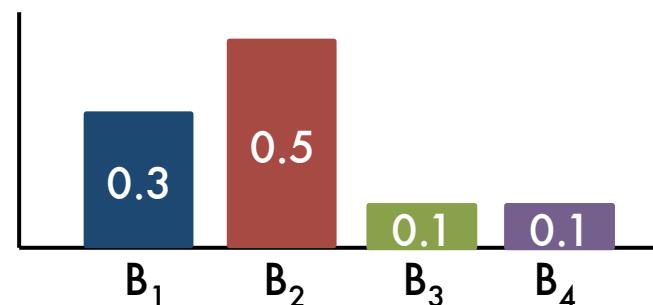
b <sub>3</sub> : neuro	
neuron	0.06
brain	0.05
dna	0.01
...	...

b <sub>4</sub> : computer	
computer	0.07
data	0.04
evolution	0.02
...	...

Learn topics

# Topic modeling

How many genes does an organism need to survive? We use computer analyses given the data of evolutions with changes in the dna sequences.



$b_1$ : biology	
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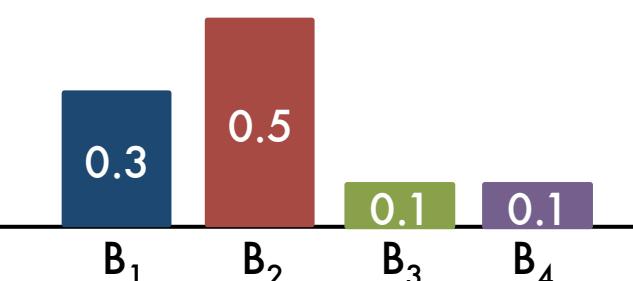
$b_3$ : neuro	
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dna	0.01
...	...

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computer	0.07
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evolution	0.02
...	...

Learn topic compositions

# Topic modeling

How many genes does an organism need to survive? We use computer analyses given the data of evolutions with changes in the dna sequences.



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genes	0.02
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brain	0.05
dna	0.01
...	...

$b_4$ : computer

computer	0.07
data	0.04
evolution	0.02
...	...

$$\text{document} = (0.3, 0.5, 0.1, 0.1) \in \mathbb{R}^4$$

# Topic modeling

Genetic algorithm was popular based on the biological models of evolution. Now deep learning imitates the structure of human brain: **neurons & synapses**.

**b<sub>1</sub>: biology**

dna	0.04
genes	0.02
data	0.01
...	...

**b<sub>2</sub>: life**

evolution	0.08
life	0.03
brain	0.01
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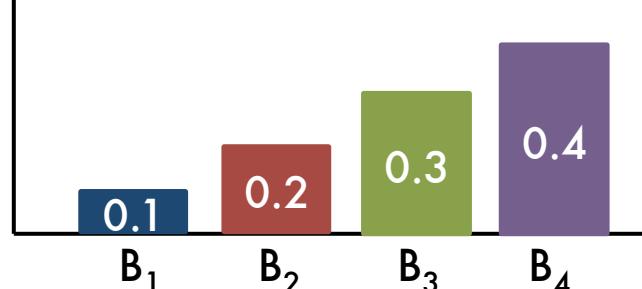
**b<sub>4</sub>: computer**

computer	0.07
data	0.04
evolution	0.02
...	...

# Topic modeling

Genetic algorithm was popular based on the biological models of evolution. Now deep learning imitates the structure of human brain: **neurons & synapses**.

In the and sequences.



b<sub>1</sub>: biology

dna	0.04
genes	0.02
data	0.01
...	...

b<sub>2</sub>: life

evolution	0.08
life	0.03
brain	0.01
...	...

b<sub>3</sub>: neuro

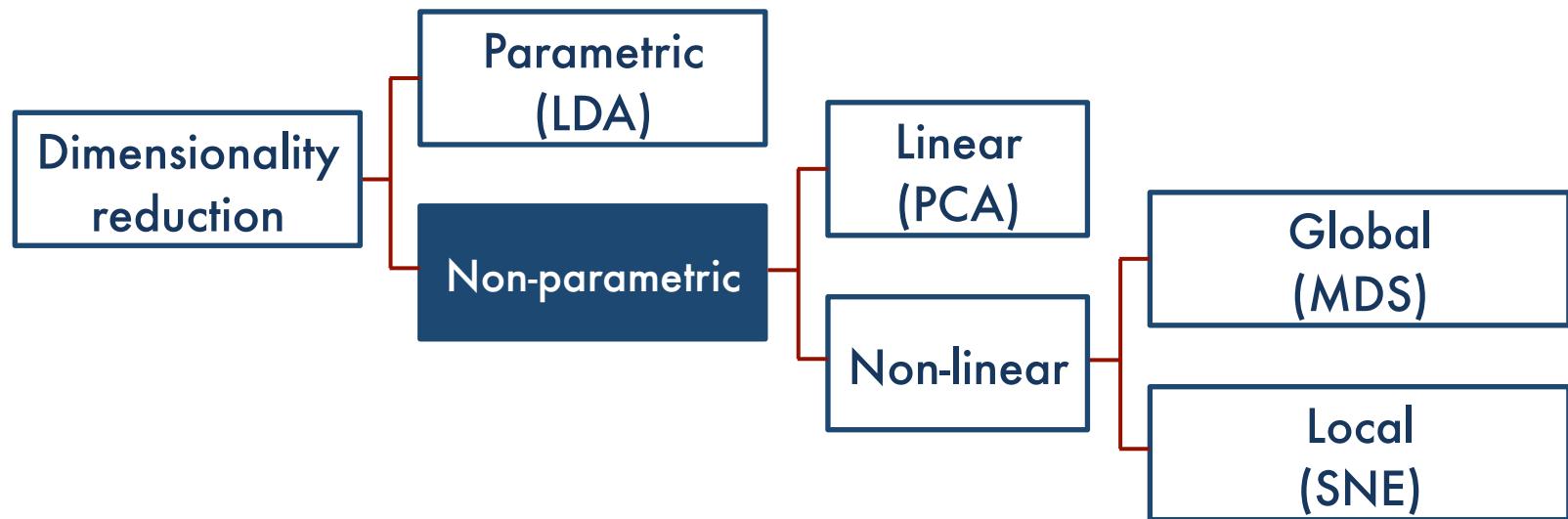
neuron	0.06
brain	0.05
dna	0.01
...	...

b<sub>4</sub>: computer

computer	0.07
data	0.04
evolution	0.02
...	...

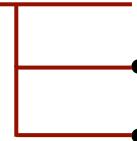
$$\text{document} = (0.1, 0.2, 0.3, 0.4) \in \mathbb{R}^4$$

# Map of the tools



# Non-parametric reduction

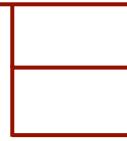
## Goals:



- Represent high-dim data in a low-dim space.
- Try to preserve certain properties in the original data.

# Non-parametric reduction

## Goals:



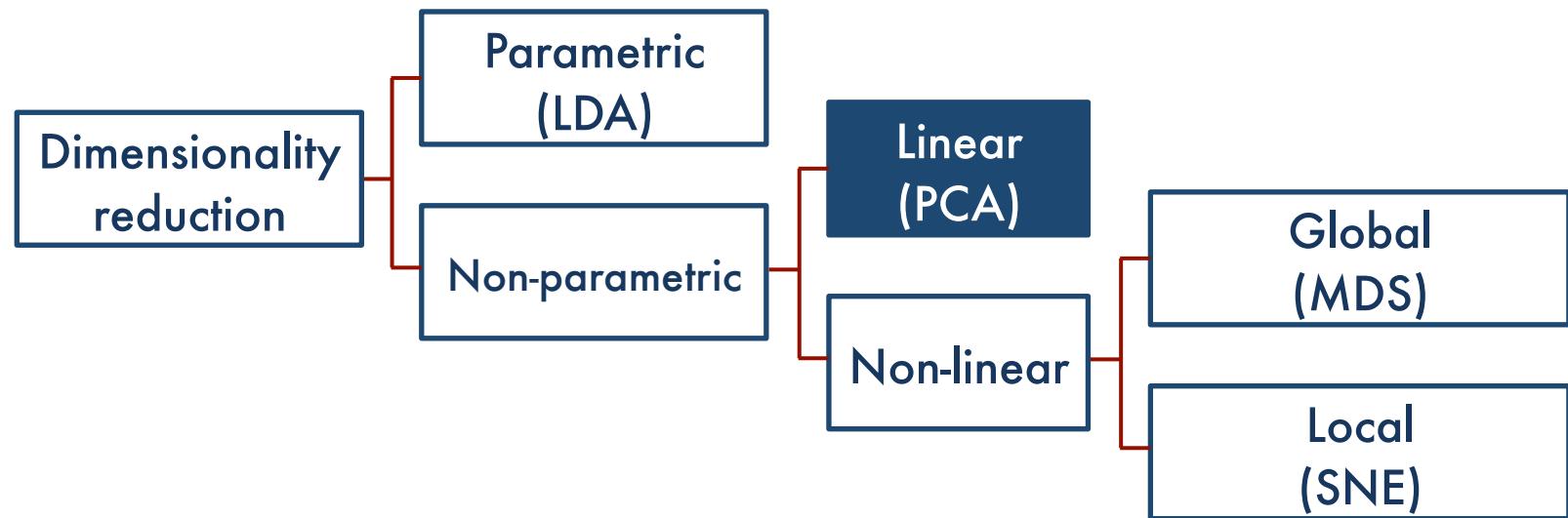
- Represent high-dim data in a low-dim space.
- Try to preserve certain properties in the original data.

## NOT interested in

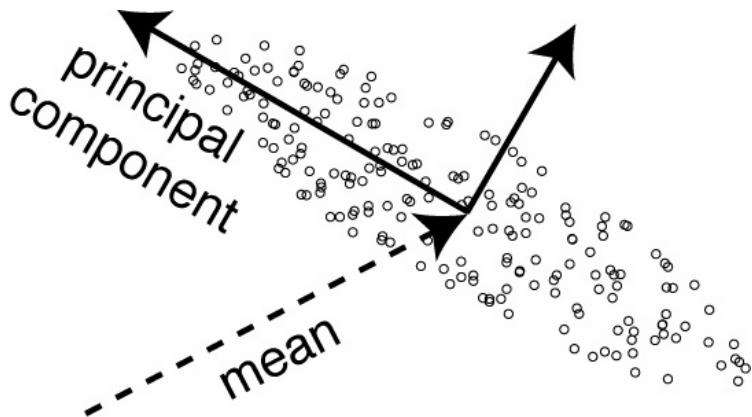


- Parametric encoding of high-to-low mapping.
- Parametric decoding of low-to-high reconstruction.

# Map of the tools

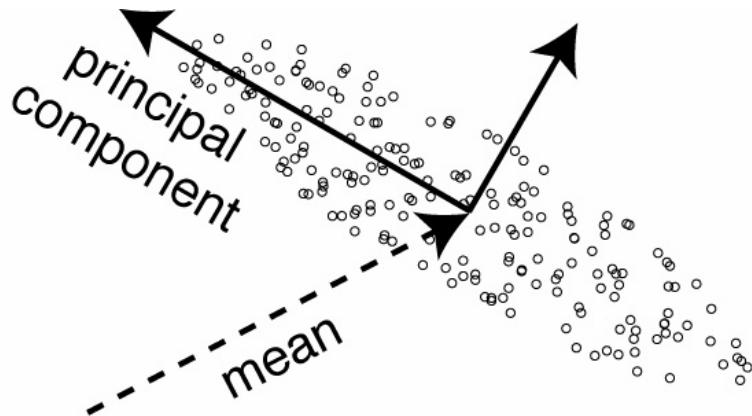


# Principal Component Analysis



- For each  $x$ ,  $y = f(x) = V^T x$  ( $V$ :  $n \times k$  linear transform)
- 1<sup>st</sup> PC: the direction with the maximum variance
- 2<sup>nd</sup> PC: the orthogonal direction to the 1<sup>st</sup> PC  
with the maximum residual variance.

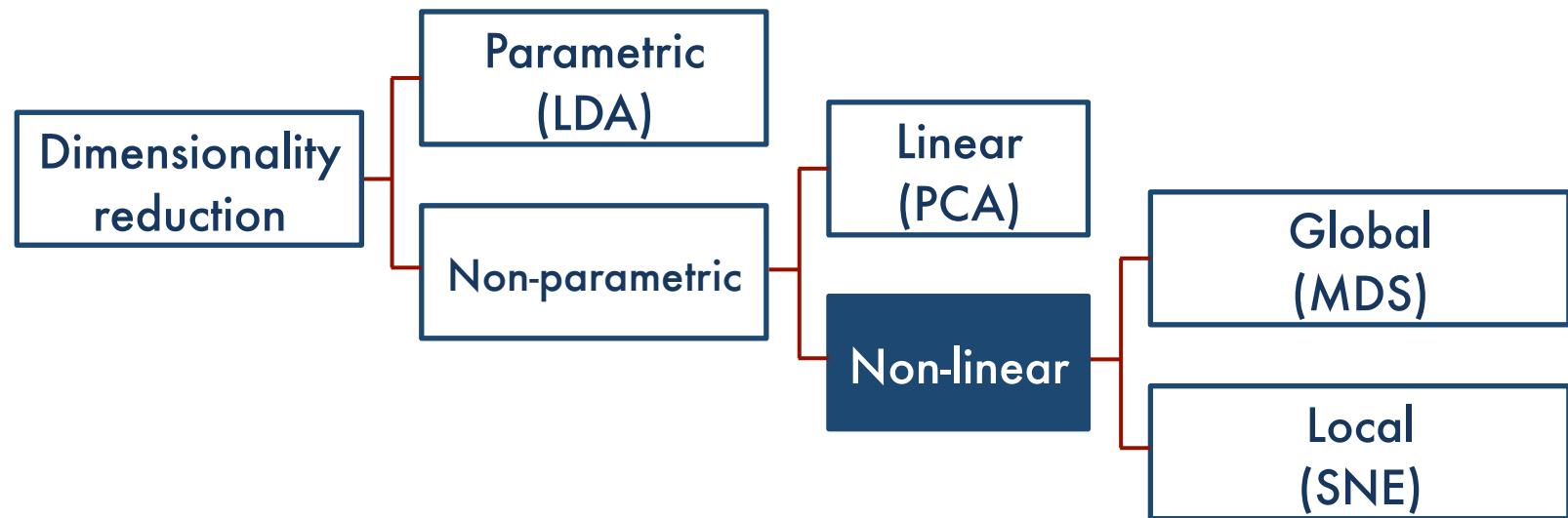
# Principal Component Analysis



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Original axes information will be lost!

# Map of the tools



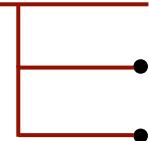
## Non-linear reduction

Global methods:

Local methods:

# Non-linear reduction

## Global methods:

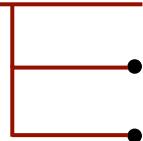


- All pairwise distances are equally important.
- Choose a low-dim space considering all pairs.

## Local methods:

# Non-linear reduction

## Global methods:



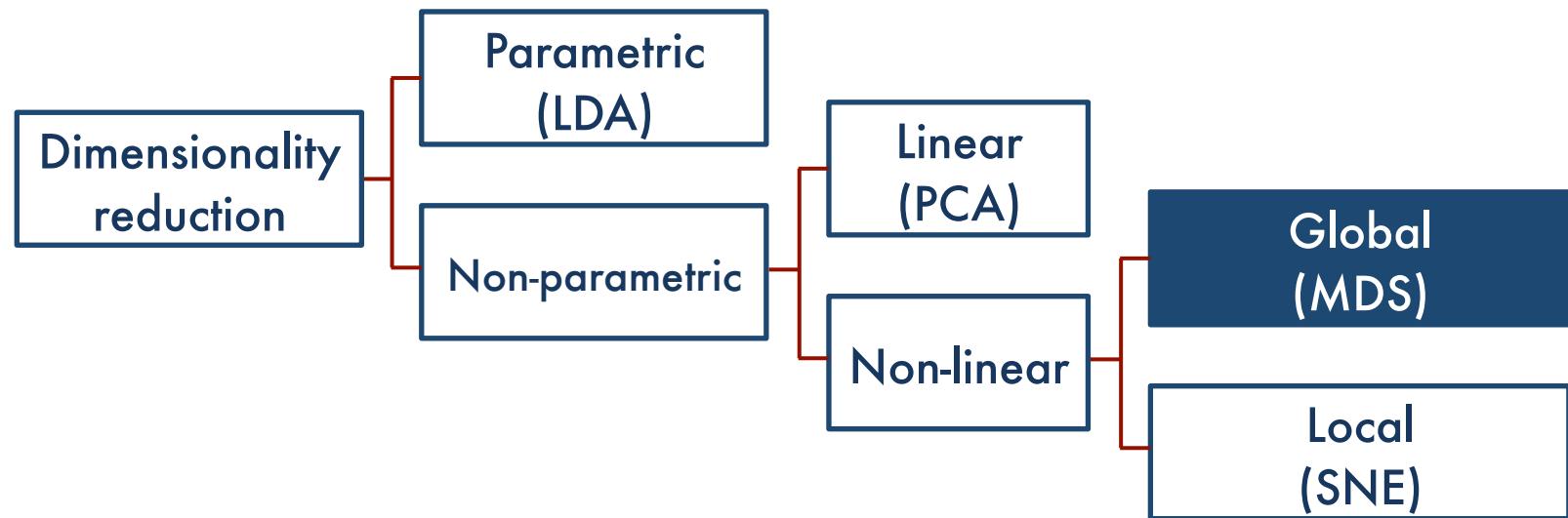
- All pairwise distances are equally important.
- Choose a low-dim space considering all pairs.

## Local methods:



- Only local pairwise distances are reliable.
- Put more weights on preserving local pairs.

# Map of the tools



# Multi-Dimensional Scaling

$$\min Cost = \sum_{i < j} (d_{ij} - \hat{d}_{ij})^2$$

$$d_{ij} = \|x_i - x_j\|^2$$

$$\hat{d}_{ij} = \|y_i - y_j\|^2$$

- $d_{ij}$ : the distance between i and j in the original space.
- $\hat{d}_{ij}$ : the distance between i and j in the new space.
- By minimizing cost, we preserve all pairwise distances.  
(penalized if two distances are different)

# Multi-Dimensional Scaling

$$\min Cost = \sum_{i < j} (d_{ij} - \hat{d}_{ij})^2$$

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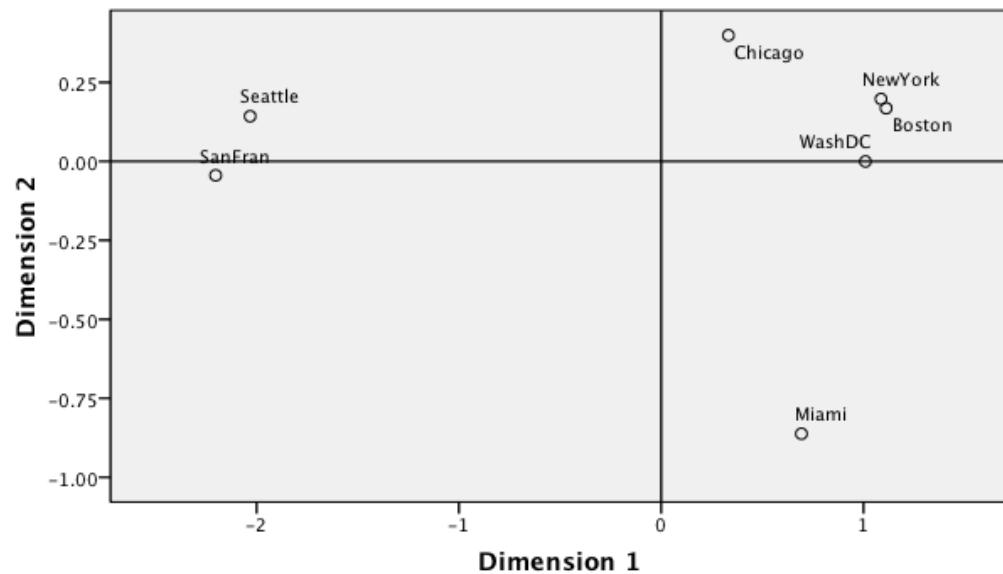
$$\hat{d}_{ij} = \|y_i - y_j\|^2$$

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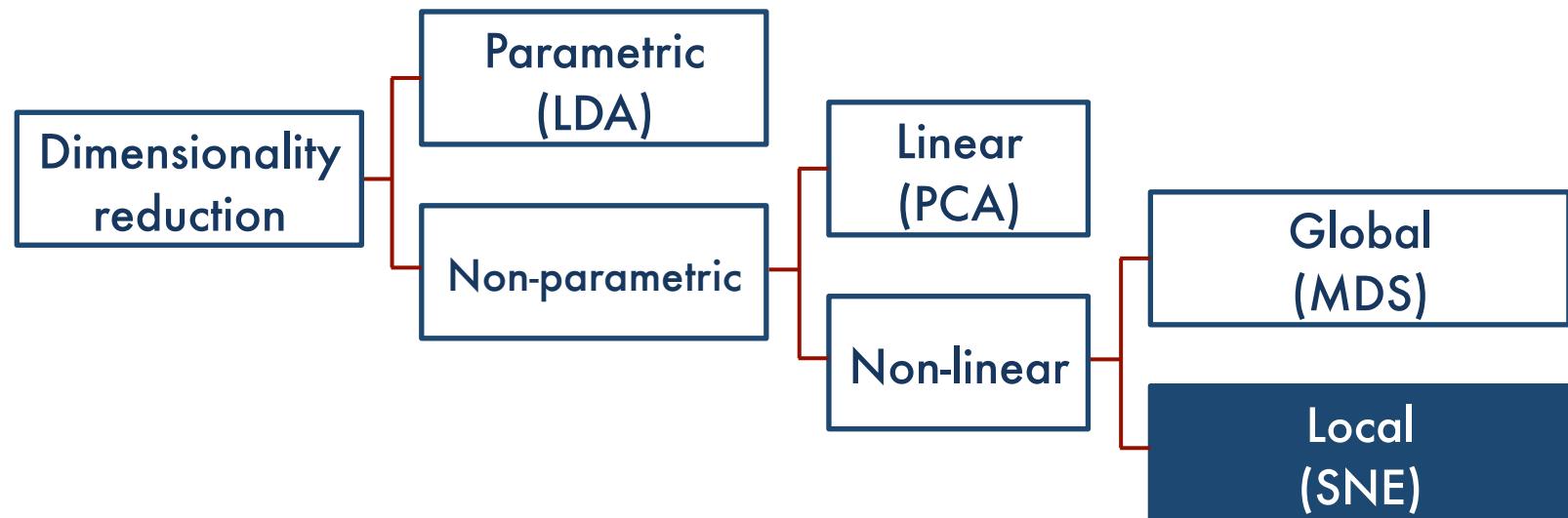
Too careful in far distant points!

# What are the dimensions?

	1	2	3	4	5	6	7	8	9
	BOST	NY	DC	MIAM	CHIC	SEAT	SF	LA	DENV
1	BOSTON	0	206	429	1504	963	2976	3095	2979
2	NY	206	0	233	1308	802	2815	2934	2786
3	DC	429	233	0	1075	671	2684	2799	2631
4	MIAMI	1504	1308	1075	0	1329	3273	3053	2687
5	CHICAGO	963	802	671	1329	0	2013	2142	2054
6	SEATTLE	2976	2815	2684	3273	2013	0	808	1131
7	SF	3095	2934	2799	3053	2142	808	0	379
8	LA	2979	2786	2631	2687	2054	1131	379	0
9	DENVER	1949	1771	1616	2037	996	1307	1235	1059



# Map of the tools



# Stochastic Neighbor Embedding

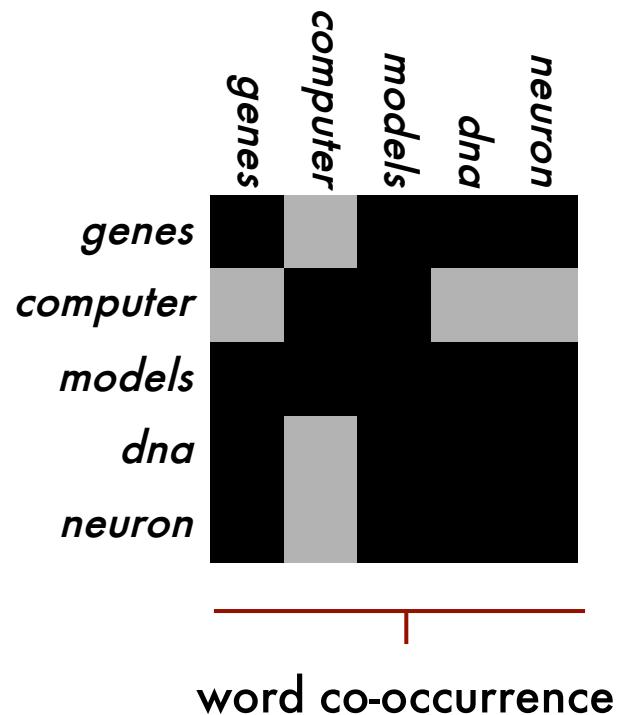
$$\min Cost = \sum_i KL(P_i \| Q_i) = \sum_i \sum_j p_{j|i} \log \frac{p_{j|i}}{q_{j|i}}$$

$$p_{j|i} = \frac{e^{-\|x_i - x_j\|^2 / 2\sigma_i^2}}{\sum_k e^{-\|x_i - x_k\|^2 / 2\sigma_i^2}} \quad q_{j|i} = \frac{e^{-\|y_i - y_j\|^2}}{\sum_k e^{-\|y_i - y_k\|^2}}$$

- Preserves local distances correctly > infinitesimal ones.
- Probabilistically decide the locality of pairwise distance.
- Define the similarity by probabilistic distance.  
(so called KL-divergence)

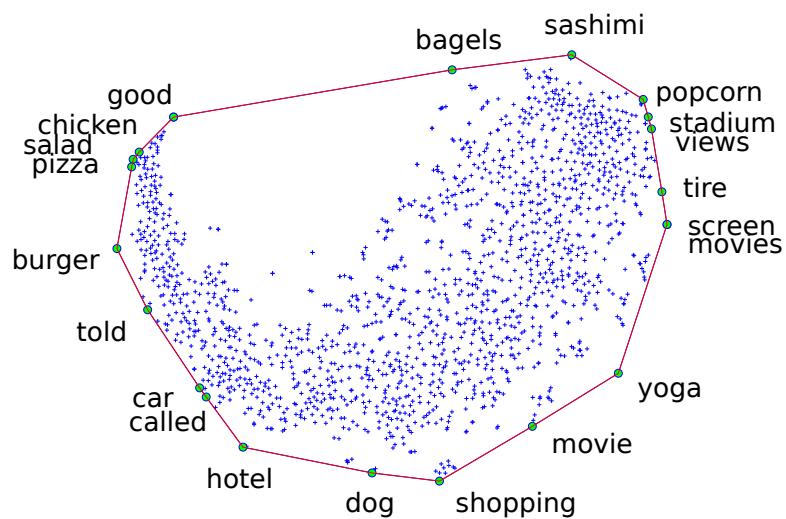
# Using t-SNE for topic modeling

Co-occurrence space & anchor words on Yelp [Moontae and David]



# Using t-SNE for topic modeling

## Co-occurrence space & anchor words on Yelp [Moontae and David]



# Better topics

# Better interpretability



**THANKS  
&  
ASK ME!**

If we still have a time...

Moderato e maestoso. ( $\text{♩} = 112$ )

*p*

*cresc.*

*f*

*dimin.*

*cresc.*

*f*

*dimin.*

Moderato e maestoso. ( $\text{♩} = 112$ )

*p*

*cresc.*

*dimin.*

*cresc.*

*f*

*dimin.*

Moderato e maestoso. ( $\text{♩} = 112$ )

The image shows three staves of piano sheet music. The top staff is in treble clef, C major, and common time. It starts with a dynamic *p*. The middle staff is in bass clef, G major, and common time. The bottom staff is in treble clef, G major, and common time. Red boxes highlight specific notes in each staff: a cluster of notes in the bass staff's first measure, a note in the bass staff's second measure, and a note in the treble staff's third measure.

*p*

*cresc.*

*dimin.*

*cresc.*

*f*

*dimin.*

Moderato e maestoso. ( $\text{♩} = 112$ )

The image shows three staves of piano sheet music. The top staff is in common time (indicated by a 'C') and has a tempo of  $\text{♩} = 112$ . The dynamic is *p* (piano). The middle staff is also in common time. The bottom staff is in common time. Red boxes highlight specific chords in each staff. In the first staff, a red box encloses the bass notes in measures 1 and 2. Another red box encloses a chord in measure 3. A third red box encloses a chord in measure 4. In the second staff, a red box encloses the bass notes in measure 1. Another red box encloses a chord in measure 2. In the third staff, a red box encloses a chord in measure 1. Measures 2 and 3 show a descending bass line. Measures 4 and 5 show a descending bass line.

Moderato e maestoso. ( $\text{♩} = 112$ )

The image shows three staves of piano sheet music. The top staff is in common time, C major, with a dynamic of *p*. The middle staff is in common time, G major. The bottom staff is in common time, A major. Red boxes highlight specific fingerings and dynamics across the three staves.

- Staff 1:** Fingerings 3-4-1-2 are shown under the bass notes. A red box highlights the first measure. In the second measure, fingerings 2-1-4 are shown above the notes, and fingerings 3-5 are shown below the notes. A red box highlights this measure. In the third measure, fingerings 4-3-5 are shown above the notes. The dynamic *cresc.* is indicated below the staff.
- Staff 2:** Fingerings 4-3-5 are shown above the notes in the first measure. A red box highlights this measure. In the second measure, fingerings 2-1-5 are shown above the notes, and fingerings 3-4 are shown below the notes. A red box highlights this measure. In the third measure, fingerings 5-4-2 are shown above the notes. The dynamic *f* is indicated below the staff.
- Staff 3:** Fingerings 4-5 are shown above the notes in the first measure. The dynamic *dimin.* is indicated below the staff. In the second measure, fingerings 3-2-5 are shown above the notes. The dynamic *cresc.* is indicated below the staff. In the third measure, fingerings 5-3-2-1 are shown above the notes. The dynamic *f* is indicated below the staff. In the fourth measure, fingerings 5-3-2 are shown above the notes. The dynamic *dimin.* is indicated below the staff.

The image shows three staves of musical notation, likely for a piano or harpsichord, with a red bar at the top. The notation uses a treble clef and a bass clef, with a key signature of four sharps. The music consists of six measures per staff.

**Staff 1:** Measures 1-3. The first measure starts with a dynamic *p*. Measure 2 begins with *f*. Measure 3 has a dynamic *dimin.*. Measure 4 begins with *p*. A red box highlights the eighth note in measure 4, which is followed by a dynamic *cresc.*

**Staff 2:** Measures 1-3. The first measure starts with *p*. Measures 2-3 have dynamics *v*, *v*, and *v* respectively. A red box highlights the eighth note in measure 3, which is followed by a dynamic *cresc.*

**Staff 3:** Measures 1-3. Measures 1-2 have dynamics *v* and *v* respectively. Measure 3 begins with *f*. A red box highlights the eighth note in measure 3, which is followed by a dynamic *cresc.*

The image displays three staves of musical notation, likely for a piano or harpsichord, with handwritten markings and colored boxes highlighting specific sections.

**Staff 1:** The first staff begins with a treble clef and a key signature of four sharps. It features several grace notes indicated by small numbers above the main notes. A dynamic marking *f* is present. The second measure starts with a bass clef. The third measure contains a dynamic marking *dimin.*. The fourth measure includes a dynamic marking *p*. The first measure of the second system is highlighted with a green box, and the last measure of the first system and the first measure of the second system are highlighted with red boxes.

**Staff 2:** The second staff begins with a treble clef and a key signature of four sharps. It features grace notes with small numbers. A dynamic marking *cresc.* is present at the end. The first measure of this staff is highlighted with a red box, and the first measure of the third staff is highlighted with a green box.

**Staff 3:** The third staff begins with a bass clef and a key signature of four sharps. It features grace notes with small numbers. The first measure of this staff is highlighted with a red box, and the second measure is highlighted with a green box.

The image displays three staves of musical notation, likely for a wind instrument, set against a white background. The notation is in common time and consists of two systems. The first system ends with a repeat sign and begins again below. The second system ends with a double bar line.

**Staff 1:**

- Measure 1: Treble clef, key signature of 4 sharps. Fingerings: 5, 2; 5, 2. Dynamic: *f*.
- Measure 2: Fingerings: 5, 2; 5, 2. Dynamic: *dimin.*
- Measure 3: Fingerings: 5, 1, 4, 2; 5, 1, 4, 2. Dynamic: *p*.
- Measure 4: Fingerings: 4, 5, 3; 4, 5, 3. Dynamic: *cresc.*

**Staff 2:**

- Measure 1: Treble clef, key signature of 4 sharps. Fingerings: 5, 1, 5; 4, 1, 5; 4, 2. Dynamic: *dimin.*
- Measure 2: Fingerings: 3, 1, 5, 4, 2, 4; 3, 2. Dynamic: *cresc.*

**Staff 3:**

- Measure 1: Treble clef, key signature of 4 sharps. Fingerings: 4, 2, 5, 5, 4; 5, 2. Dynamic: *f*.
- Measure 2: Fingerings: 5, 1, 4, 5, 4; 5, 1, 4, 5, 4.
- Measure 3: Fingerings: 4, 5, 3; 4, 5, 3.

**Annotations:**

- A large red rectangular box covers the entire width of the top staff, spanning from the beginning of the first measure to the end of the third measure.
- A green rectangular box highlights the first measure of the middle staff, containing fingerings 5, 1, 5 and 4, 1, 5.
- A red rectangular box highlights the first measure of the bottom staff, containing fingerings 4, 2, 5, 5, 4 and 5, 2.
- A green rectangular box highlights the first measure of the bottom staff, containing fingerings 5, 1, 4, 5, 4 and 5, 1, 4, 5, 4.
- A grey rectangular box highlights the second measure of the bottom staff, containing fingerings 5, 1, 4, 5, 4 and 5, 1, 4, 5, 4.