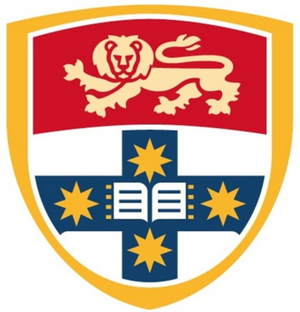
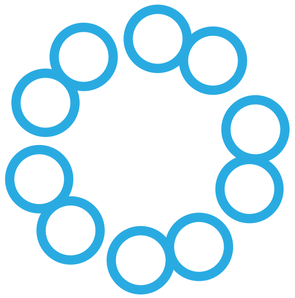


THE UNIVERSITY OF
SYDNEY



CANADA'S MICHAEL SMITH
GENOME
SCIENCES
CENTRE

ESSENTIALS OF DATA VISUALIZATION

THINKING ABOUT DRAWING DATA + COMMUNICATING SCIENCE

SCIENTIFIC AMERICAN GRAPHIC SCIENCE

visualization and design process

art direction

Jen Christiansen (Scientific American)

Let’s now look at the process of designing a visualization from scratch—from the encoding all the way to design.

This was a graphic I did for the June 2015 issue of Scientific American. It appeared on the Graphic Science page.

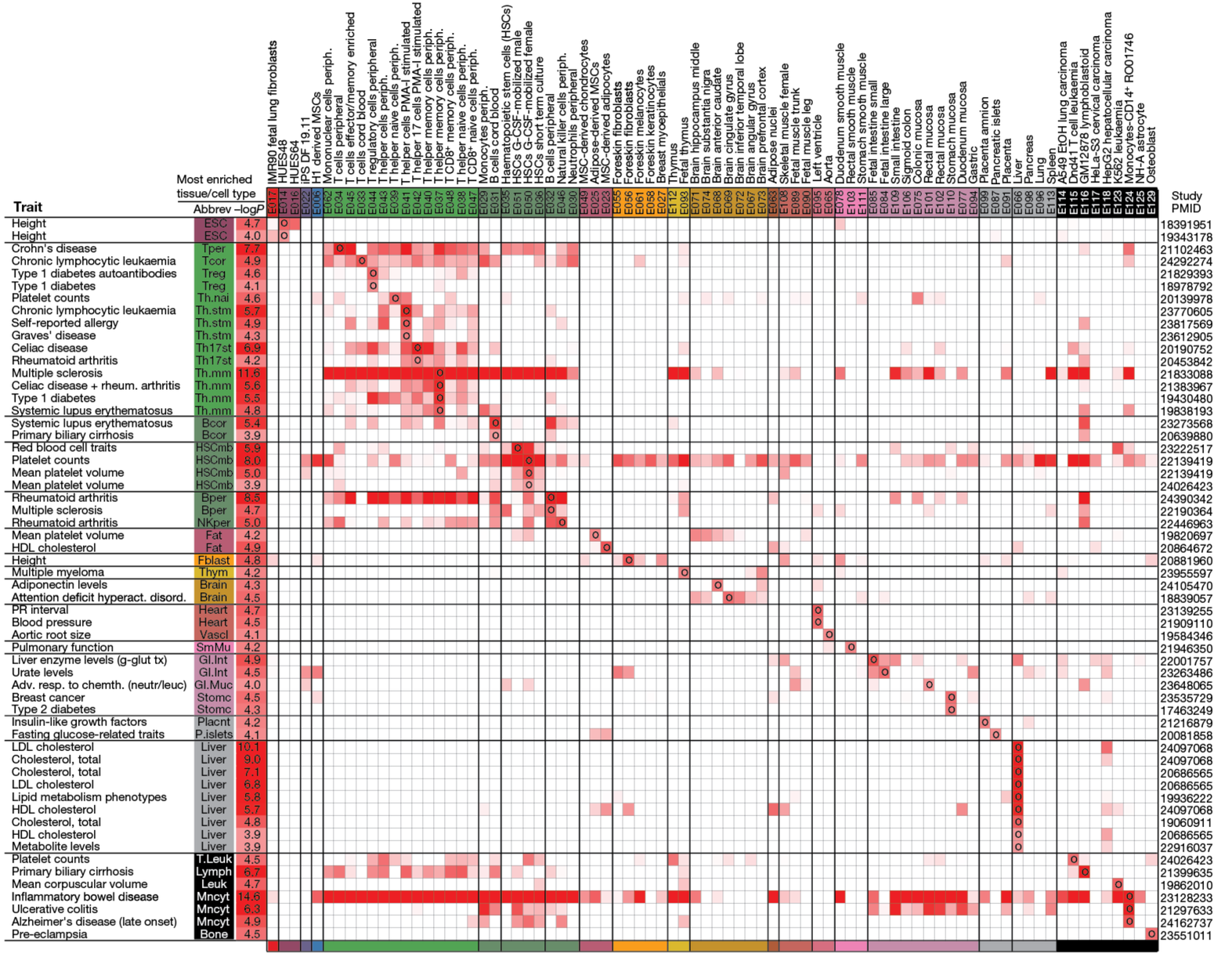
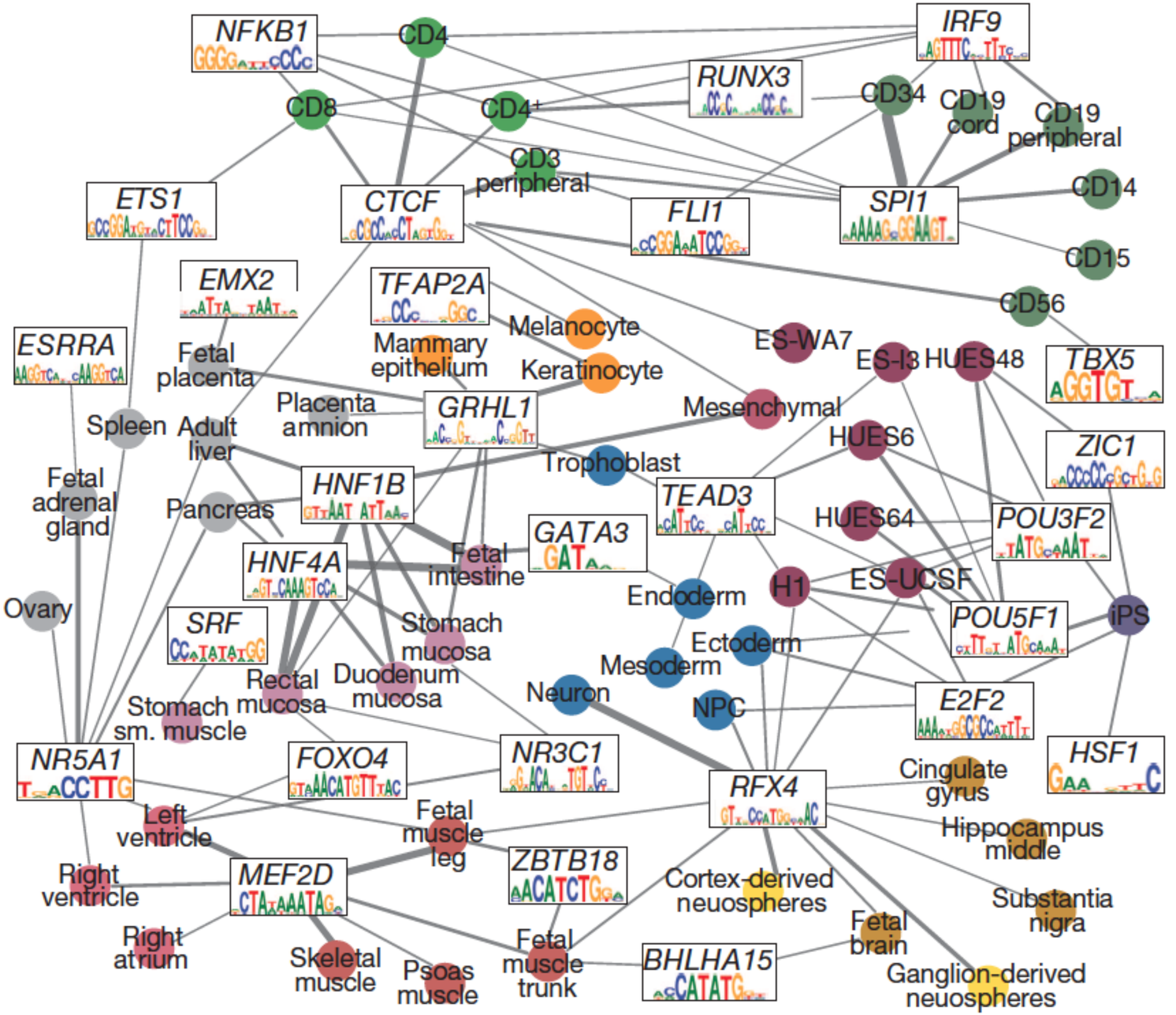
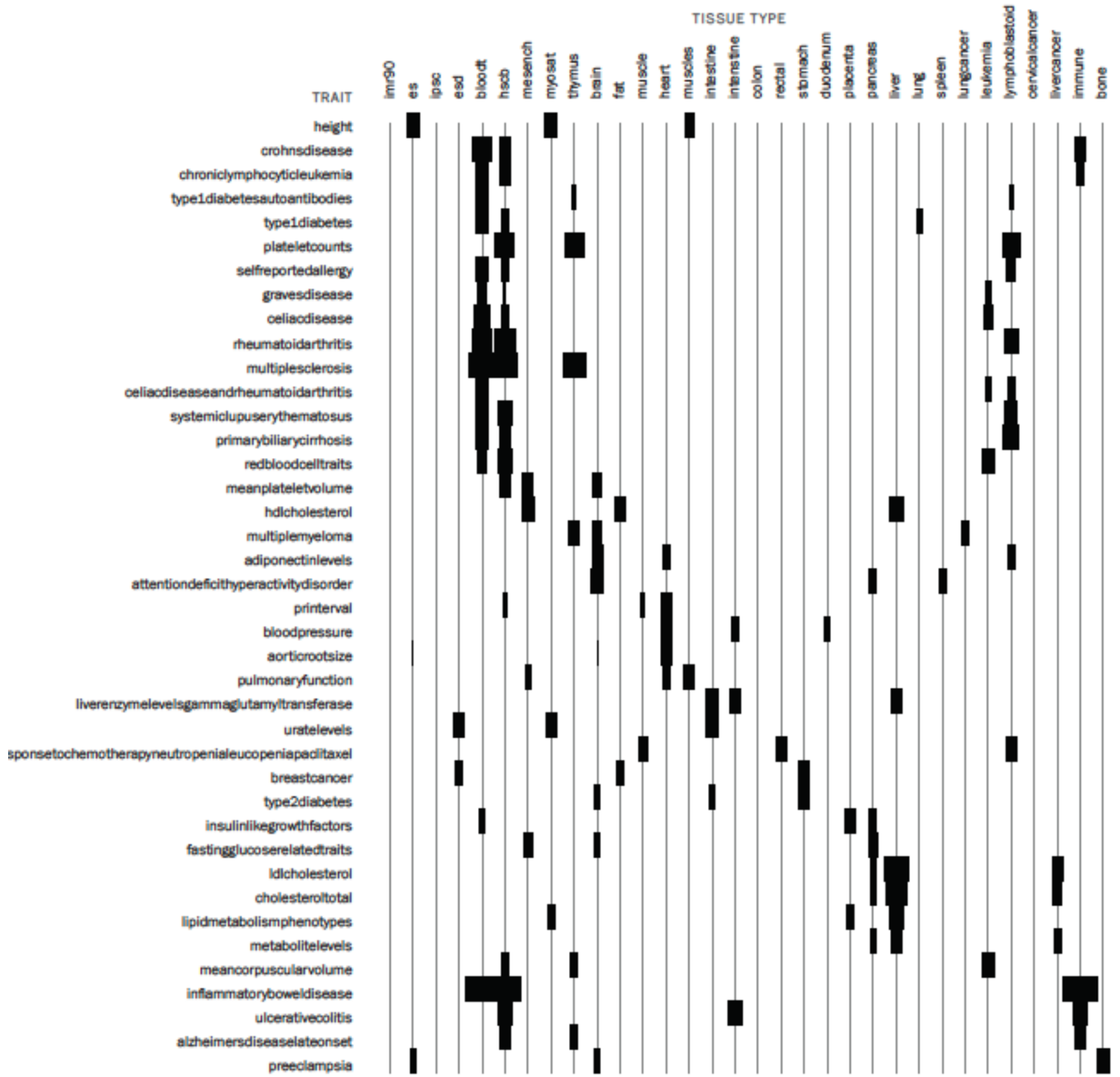


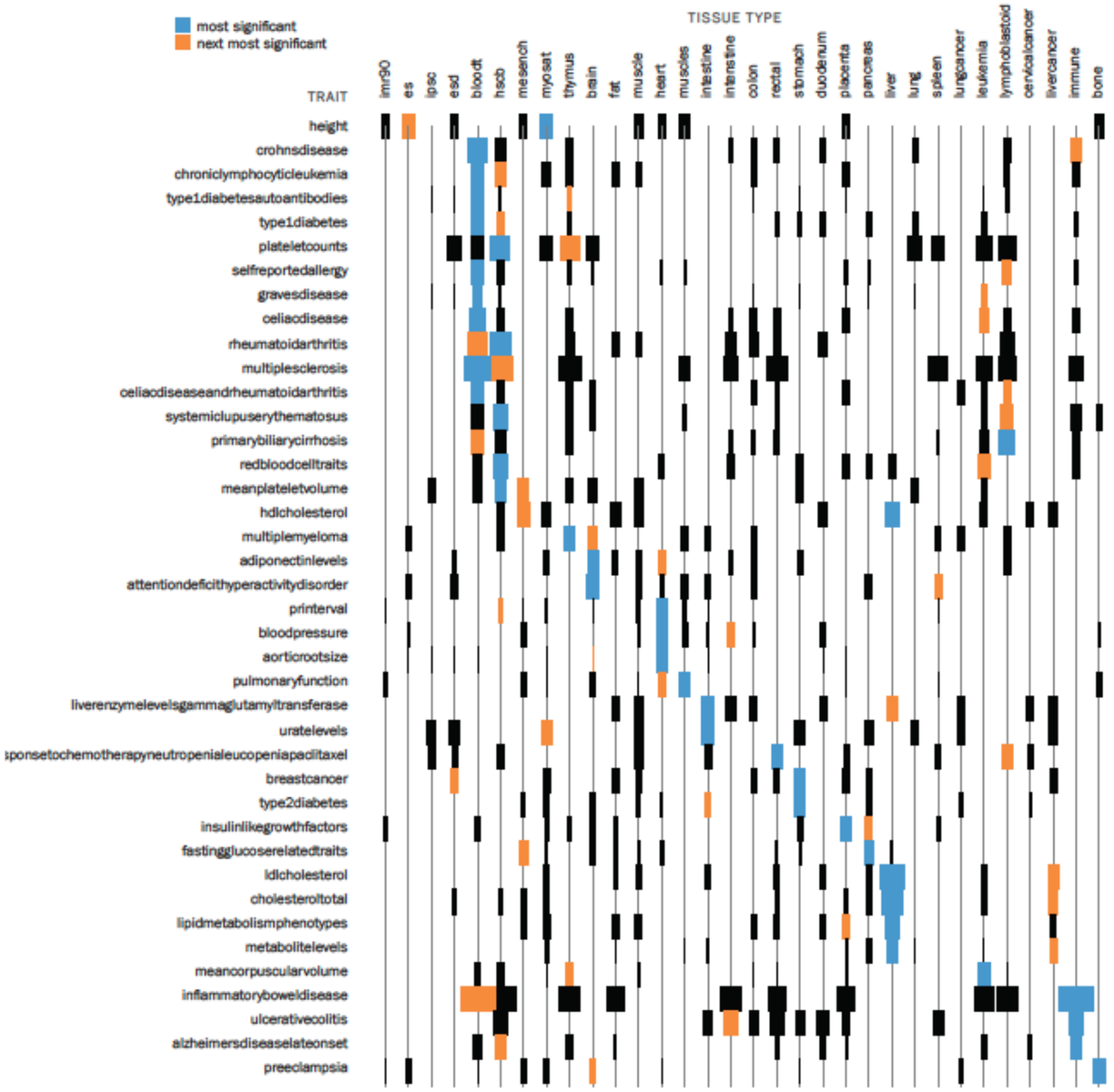
Figure 9 | Epigenomic enrichments of genetic variants associated with diverse traits. Tissue-specific H3K4me1 peak enrichment significance (−log$_{10}$ P value) for genetic variants associated with diverse traits. Circles denote reference epigenome (column) of most significant enrichment for SNPs reported by a given study (row), defined by trait and publication (PubMed identifier, PMID). Tissue (Abbrev) and P value (−log$_{10}$) of most significant enrichment are shown. Only rows and columns containing a value meeting a FDR of 2% are shown (see Extended Data Figs 11 and 12 for full matrix for all studies showing at least 2% FDR).

Nature (2015) 518:317–330.



Nature (2015) 518:317–330.


TISSUE TYPE
TRAIT
imr90
es
ipsc
esd
bloodt
hscb
mesench
myosat
thymus
brain
fat
muscle
heart
muscles
intestine
interstine
colon
rectal
stomach
duodenum
placenta
pancreas
liver
lung
spleen
lungcancer
leukemia
lymphoblastoid
cervicalcancer
livercancer
immune
bone
height
crohnsdisease
chroniclymphocyticleukemia
type1diabetesautoantibodies
type1diabetes
plateletcounts
selfreportedallergy
gravesdisease
celiacdisease
rheumatoidarthritis
multiplesclerosis
celiacdiseaseandrheumatoidarthritis
systemiclupuserythematosus
primarybiliarycirrhosis
redbloodcelltraits
meanplateletvolume
hdlcholesterol
multiplemyeloma
adiponectinlevels
attentiondeficithyperactivitydisorder
printerval
bloodpressure
aortarootsize
pulmonaryfunction
liverenzymelevelsgammaglutamyltransferase
uratelevels
sponsetochemotherapyneutropenialeucopeniapaclitaxel
breastcancer
type2diabetes
insulinlikegrowthfactors
fastingglucoserelatedtraits
ldlcholesterol
cholesteroltotal
lipidmetabolismphenotypes
metabolitelevels
meancorpuscularvolume
inflammatoryboweldisease
ulcerativecolitis
alzheimersdiseaselateonset
preeclampsia


most significant
next most significant
TISSUE TYPE
TRAIT
imr90
es
ipsc
esd
bloodt
hscb
mesench
myosat
thymus
brain
fat
muscle
heart
muscles
intestine
intestine
colon
rectal
stomach
duodenum
placenta
pancreas
liver
lung
spleen
lungcancer
leukemia
lymphoblastoid
cervicalcancer
livercancer
immune
bone
height
crohnsdisease
chroniclymphocyticleukemia
type1diabetesautoantibodies
type1diabetes
plateletcounts
selfreportedallergy
gravesdisease
celiacdisease
rheumatoidarthritis
multiplesclerosis
celiacdiseaseandrheumatoidarthritis
systemiclupuserythematosus
primarybiliarycirrhosis
redbloodcelltraits
meanplateletvolume
hdlcholesterol
multiplemyeloma
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attentiondeficithyperactivitydisorder
printerval
bloodpressure
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pulmonaryfunction
liverenzymelevelsgammaglutamyltransferase
uratelevels
sponsetochemotherapyneutropenialeucopeniapaclitaxel
breastcancer
type2diabetes
insulinlikegrowthfactors
fastingglucoserelatedtraits
ldlcholesterol
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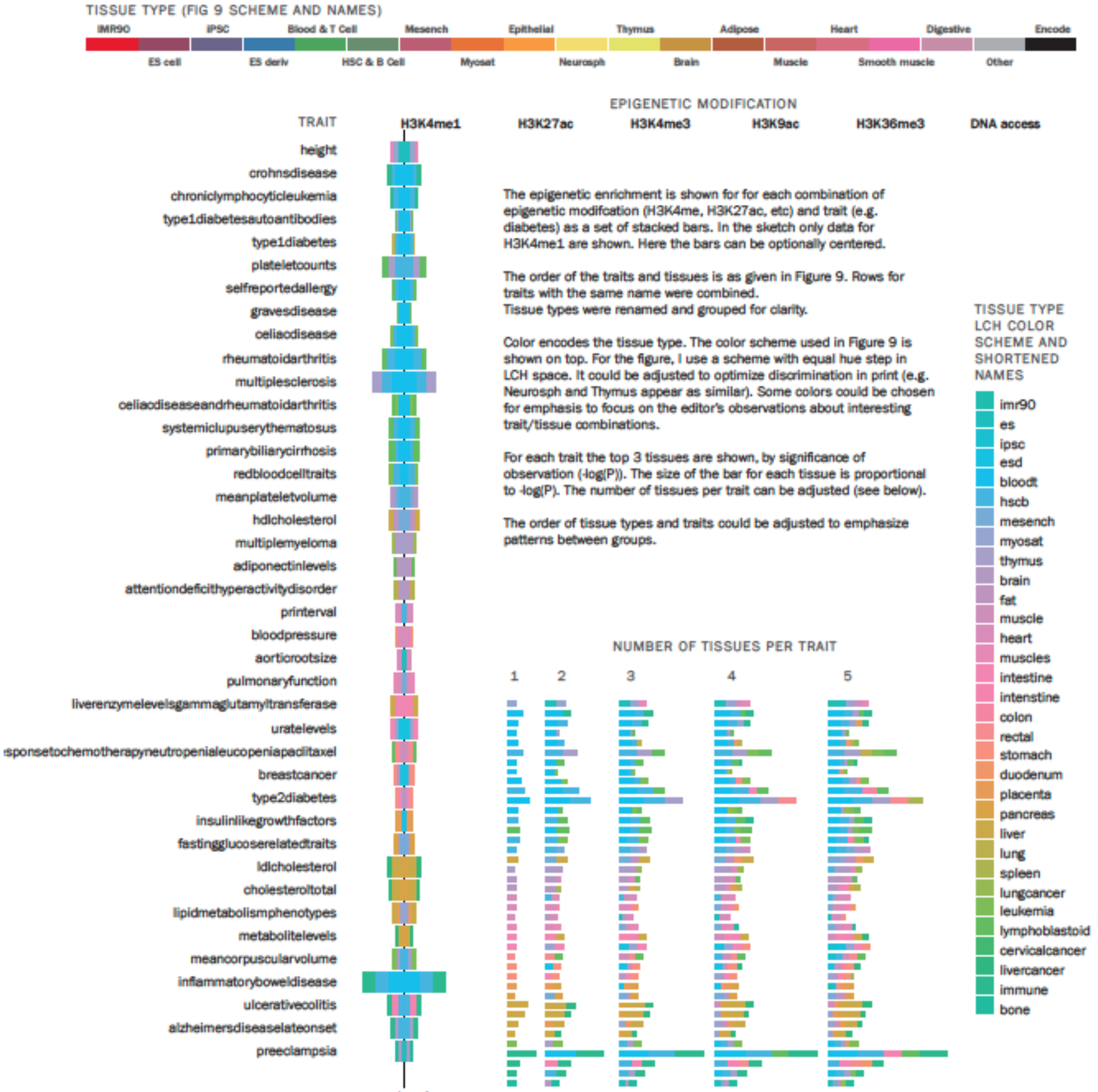
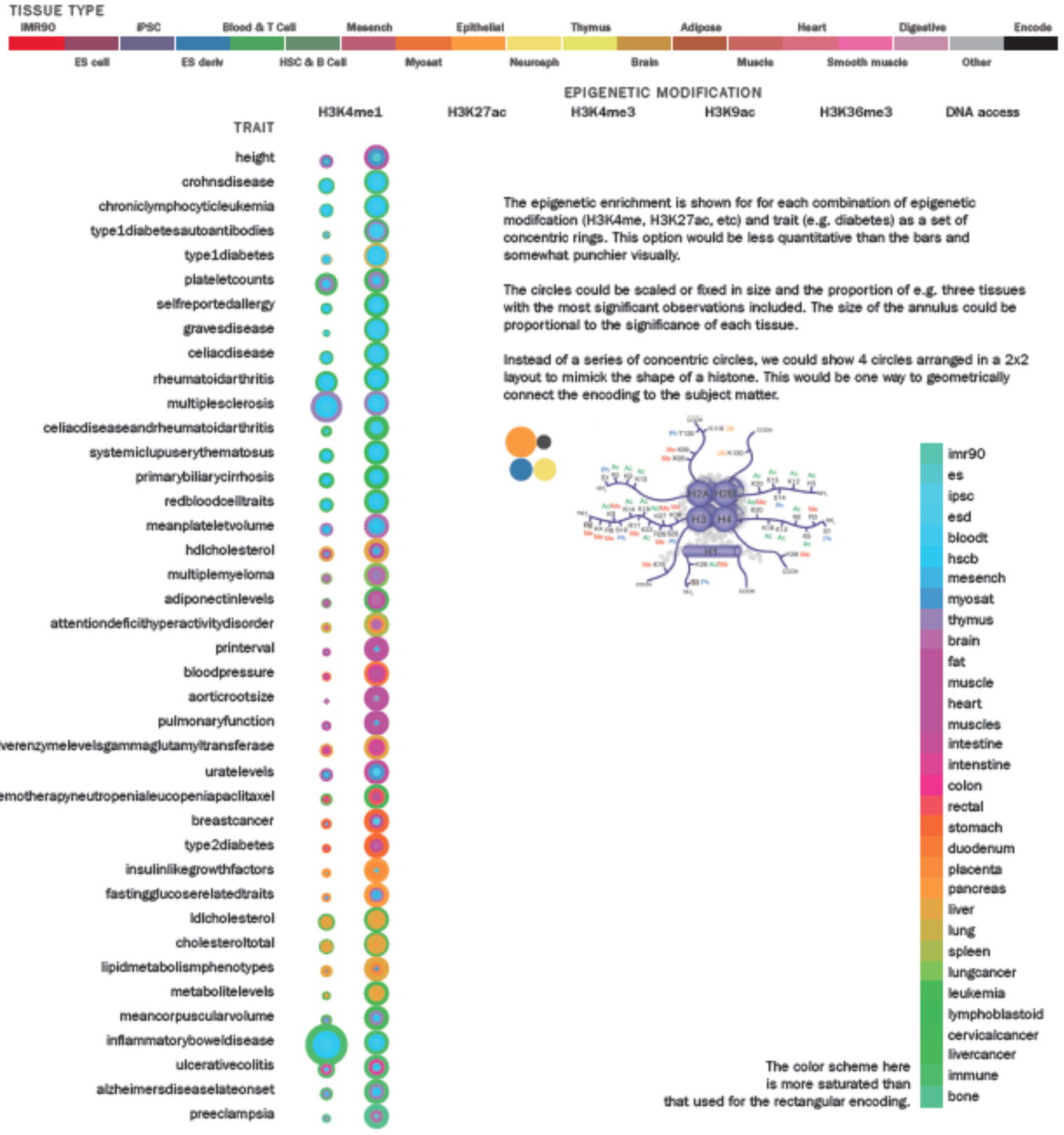
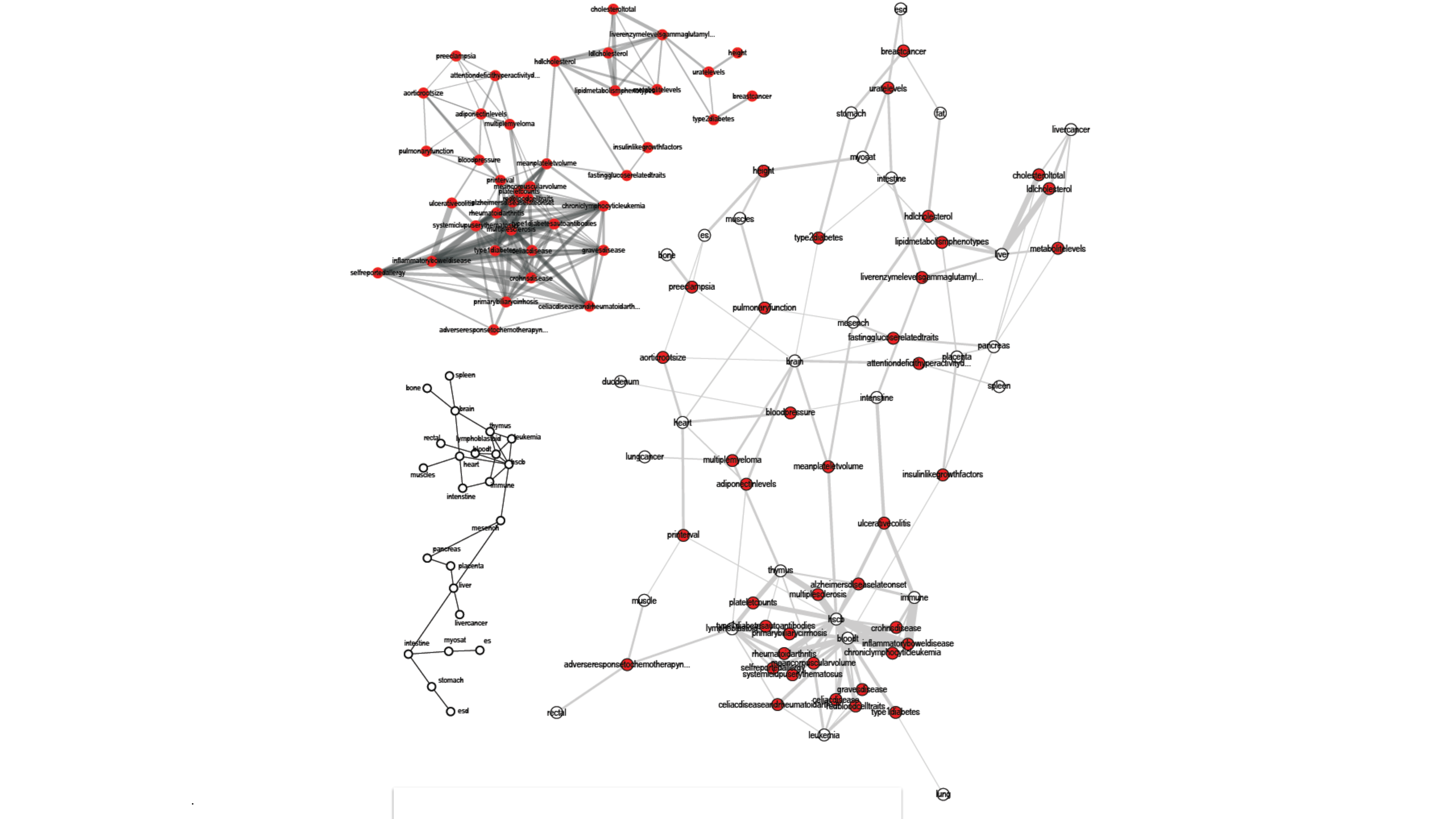
lipidmetabolismphenotypes
metabolitelevels
meancorpuscularvolume
inflammatoryboweldisease
ulcerativecolitis
alzheimersdiseaselateonset
preeclampsia


TISSUE TYPE (FIG 9 SCHEME AND NAMES)
IMR90
IPSC
Blood & T Cell
Mesench
Epithelial
Thymus
Adipose
Heart
Digestive
Encode
ES cell
ES deriv
HSC & B Cell
Myosat
Neurosph
Brain
Muscle
Smooth muscle
Other
EPIGENETIC MODIFICATION
TRAIT
H3K4me1
H3K27ac
H3K4me3
H3K9ac
H3K36me3
DNA access
height
crohnsdisease
chroniclymphocyticleukemia
type1diabetesautoantibodies
type1diabetes
plateletcounts
selfreportedallergy
gravesdisease
celiacdisease
rheumatoidarthritis
multiplesclerosis
celiacdiseaseandrheumatoidarthritis
systemiclupuserythematosus
primarybiliarycirrhosis
redbloodcelltraits
meanplateletvolume
hdlcholesterol
multiplemyeloma
adiponectinlevels
attentiondeficithyperactivitydisorder
printerval
bloodpressure
aorticrootsize
pulmonaryfunction
liverenzymelevelsgammaglutamyltransferase
uratelevels
sponsetochemotherapyneutropenialeucopeniapaclitaxel
breastcancer
type2diabetes
insulinlikegrowthfactors
fastingglucoserelatedtraits
ldlcholesterol
cholesteroltotal
lipidmetabolismphenotypes
metabolitelevels
meancorpuscularvolume
inflammatoryboweldisease
ulcerativecolitis
alzheimersdiseaselateonset
preeclampsia
The epigenetic enrichment is shown for for each combination of epigenetic modifcation (H3K4me, H3K27ac, etc) and trait (e.g. diabetes) as a set of stacked bars. In the sketch only data for H3K4me1 are shown. Here the bars can be optionally centered.
The order of the traits and tissues is as given in Figure 9. Rows for traits with the same name were combined.
Tissue types were renamed and grouped for clarity.
Color encodes the tissue type. The color scheme used in Figure 9 is shown on top. For the figure, I use a scheme with equal hue step in LCH space. It could be adjusted to optimize discrimination in print (e.g. Neurosph and Thymus appear as similar). Some colors could be chosen for emphasis to focus on the editor's observations about interesting trait/tissue combinations.
For each trait the top 3 tissues are shown, by significance of observation (-log(P)). The size of the bar for each tissue is proportional to -log(P). The number of tissues per trait can be adjusted (see below).
The order of tissue types and traits could be adjusted to emphasize patterns between groups.
NUMBER OF TISSUES PER TRAIT
1
2
3
4
5
TISSUE TYPE LCH COLOR SCHEME AND SHORTENED NAMES
imr90
es
ipsc
esd
bloodt
hscb
mesench
myosat
thymus
brain
fat
muscle
heart
muscles
intestine
intenstine
colon
rectal
stomach
duodenum
placenta
pancreas
liver
lung
spleen
lungcancer
leukemia
lymphoblastoid
cervicalcancer
livercancer
immune
bone


TISSUE TYPE
IMR90
iPSC
Blood & T Cell
Mesench
Epithelial
Thymus
Adipose
Heart
Digestive
Encode
ES cell
ES deriv
HSC & B Cell
Myosat
Neurosph
Brain
Muscle
Smooth muscle
Other
EPIGENETIC MODIFICATION
H3K4me1
H3K27ac
H3K4me3
H3K9ac
H3K36me3
DNA access
TRAIT
height
crohnsdisease
chroniclymphocyticleukemia
type1diabetesautoantibodies
type1diabetes
plateletcounts
selfreportedallergy
gravesdisease
celiacdisease
rheumatoidarthritis
multiplesclerosis
celiacdiseaseandrheumatoidarthritis
systemiclupuserythematosus
primarybiliarycirrhosis
redbloodcelltraits
meanplateletvolume
hdlcholesterol
multiplemyeloma
adiponectinlevels
attentiondeficithyperactivitydisorder
printerval
bloodpressure
aorticrootsize
pulmonaryfunction
liverenzymelevelsgammaglutamyltransferase
uratelevels
sponsetochemotherapyneutropenialeucopeniapaclitaxel
breastcancer
type2diabetes
insulinlikegrowthfactors
fastingglucoserelatedtraits
ldlcholesterol
cholesteroltotal
lipidmetabolismphenotypes
metabolitelevels
meancorpuscularvolume
inflammatoryboweldisease
ulcerativecolitis
alzheimersdiseaselateonset
preeclampsia
The epigenetic enrichment is shown for for each combination of epigenetic modifcation (H3K4me, H3K27ac, etc) and trait (e.g. diabetes) as a set of concentric rings. This option would be less quantitative than the bars and somewhat punchier visually.
The circles could be scaled or fixed in size and the proportion of e.g. three tissues with the most significant observations included. The size of the annulus could be proportional to the significance of each tissue.
Instead of a series of concentric circles, we could show 4 circles arranged in a 2x2 layout to mimick the shape of a histone. This would be one way to geometrically connect the encoding to the subject matter.
H2A
H2B
H3
H4
H1
imr90
es
ipsc
esd
bloodt
hscb
mesench
myosat
thymus
brain
fat
muscle
heart
muscles
intestine
intenstine
colon
rectal
stomach
duodenum
placenta
pancreas
liver
lung
spleen
lungcancer
leukemia
lymphoblastoid
cervicalcancer
livercancer
immune
bone
The color scheme here is more saturated than that used for the rectangular encoding.


cholesteroltotal
liverenzymelevelsgammaglutamyl...
preeclampsia
hdlcholesterol
ldlcholesterol
height
attentiondeficithyperactivityd...
uratelevels
aortarootsize
lipidmetabolismphenotypes
breastcancer
type2diabetes
adiponectinlevels
multiplemyeloma
pulmonaryfunction
insulinlikegrowthfactors
bloodpressure
meanplateletvolume
fastingglucoserelatedtraits
printerval
meancorpuscularvolume
plateletcounts
ulcerativecolitis
alzheimersdiseaselateonset
chronicLymphocyticleukemia
rheumatoidarthritis
systemiclupuserythematosus
type1diabetesautoantibodies
multiplesclerosis
type1diabeteselliacdisease
gravesdisease
inflammatoryboweldisease
selfreportedallergy
crohnsdisease
primarybiliarycirrhosis
celiacdiseaseandrheumatoidarth...
adverseresponsetochemotherapyn...
esd
breastcancer
uratelevels
stomach
fat
livercancer
myosat
height
intestine
cholesteroltotal
ldlcholesterol
hdlcholesterol
muscles
es
type2diabetes
lipidmetabolismphenotypes
liver
metabolitelevels
bone
liverenzymelevelsgammaglutamyl...
preeclampsia
pulmonaryfunction
mesench
fastingglucoserelatedtraits
pancreas
aortarootsize
brain
placenta
attentiondeficithyperactivityd...
duodenum
spleen
intenstine
bloodpressure
heart
lungcancer
multiplemyeloma
meanplateletvolume
insulinlikegrowthfactors
adiponectinlevels
ulcerativecolitis
printerval
thymus
alzheimersdiseaselateonset
multiplesclerosis
immune
muscle
plateletcounts
lscb
crohnsdisease
primarybiliarycirrhosis
bloodt
inflammatoryboweldisease
chronicLymphocyticleukemia
rheumatoidarthritis
meancorpuscularvolume
selfreportedallergy
systemiclupuserythematosus
adverseresponsetochemotherapyn...
gravesdisease
celiacdisease
redbloodcelltraits
type1diabetes
celiacdiseaseandrheumatoidarth...
leukemia
rectal
lung
spleen
bone
brain
thymus
rectal
lymphoblastoid
leukemia
bloodt
lscb
heart
muscles
immune
intenstine
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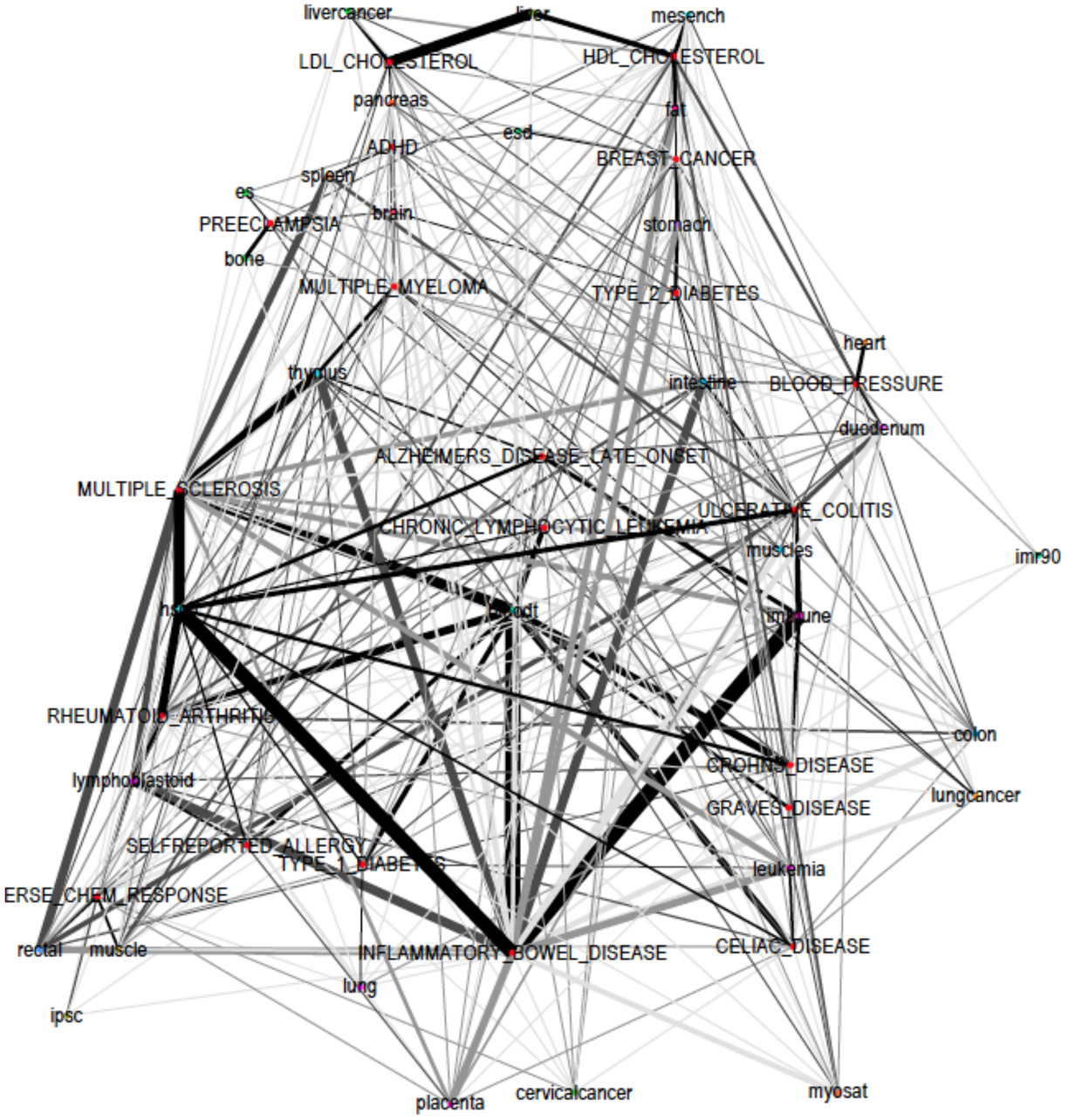
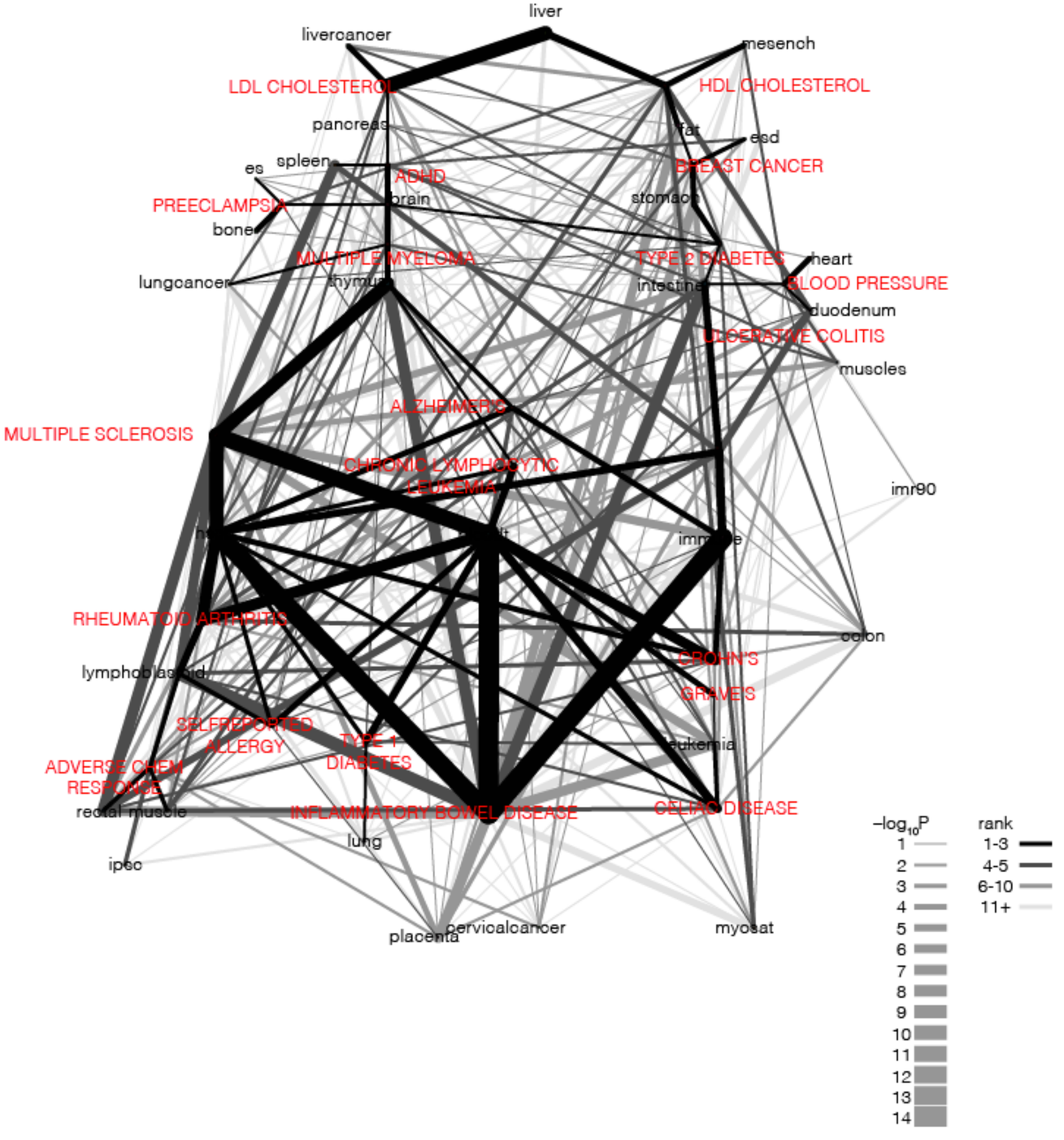
pancreas
placenta
liver
livercancer
intestine
myosat
es
stomach
esd


livercancer
liver
mesench
LDL_CHOLESTEROL
HDL_CHOLESTEROL
pancreas
fat
esd
ADHD
BREAST_CANCER
spleen
es
brain
PREECLAMPSIA
stomach
bone
MULTIPLE_MYELOMA
TYPE_2_DIABETES
heart
thymus
intestine
BLOOD_PRESSURE
duodenum
ALZHEIMERS_DISEASE_LATE_ONSET
MULTIPLE_SCLEROSIS
ULCERATIVE_COLITIS
CHRONIC_LYMPHOCYTIC_LEUKEMIA
muscles
imr90
hsc
adipocyte
immune
RHEUMATOID_ARTHRITIS
colon
CROHNS_DISEASE
lymphoblastoid
lungcancer
GRAVES_DISEASE
SELFREPORTED_ALLERGY
TYPE_1_DIABETES
leukemia
ERSE_CHEM_RESPONSE
rectal
muscle
INFLAMMATORY_BOWEL_DISEASE
CELIAC_DISEASE
lung
ipsc
placenta
cervicalcancer
myosat


liver
livercancer
mesench
LDL CHOLESTEROL
HDL CHOLESTEROL
pancreas
fat
esd
spleen
es
BREAST CANCER
ADHD
PREECLAMPSIA
brain
stomach
bone
MULTIPLE MYELOMA
TYPE 2 DIABETES
heart
lungcancer
thymus
intestine
BLOOD PRESSURE
duodenum
ULCERATIVE COLITIS
muscles
ALZHEIMER'S
MULTIPLE SCLEROSIS
CHRONIC LYMPHOCYTIC LEUKEMIA
imr90
RHEUMATOID ARTHRITIS
colon
CROHN'S
lymphoblastoid
GRAVE'S
SELFREPORTED ALLERGY
TYPE 1 DIABETES
ADVERSE CHEM RESPONSE
rectal muscle
INFLAMMATORY BOWEL DISEASE
CELIAC DISEASE
lung
ipsc
placenta
cervicalcancer
myosat
−log10P
1
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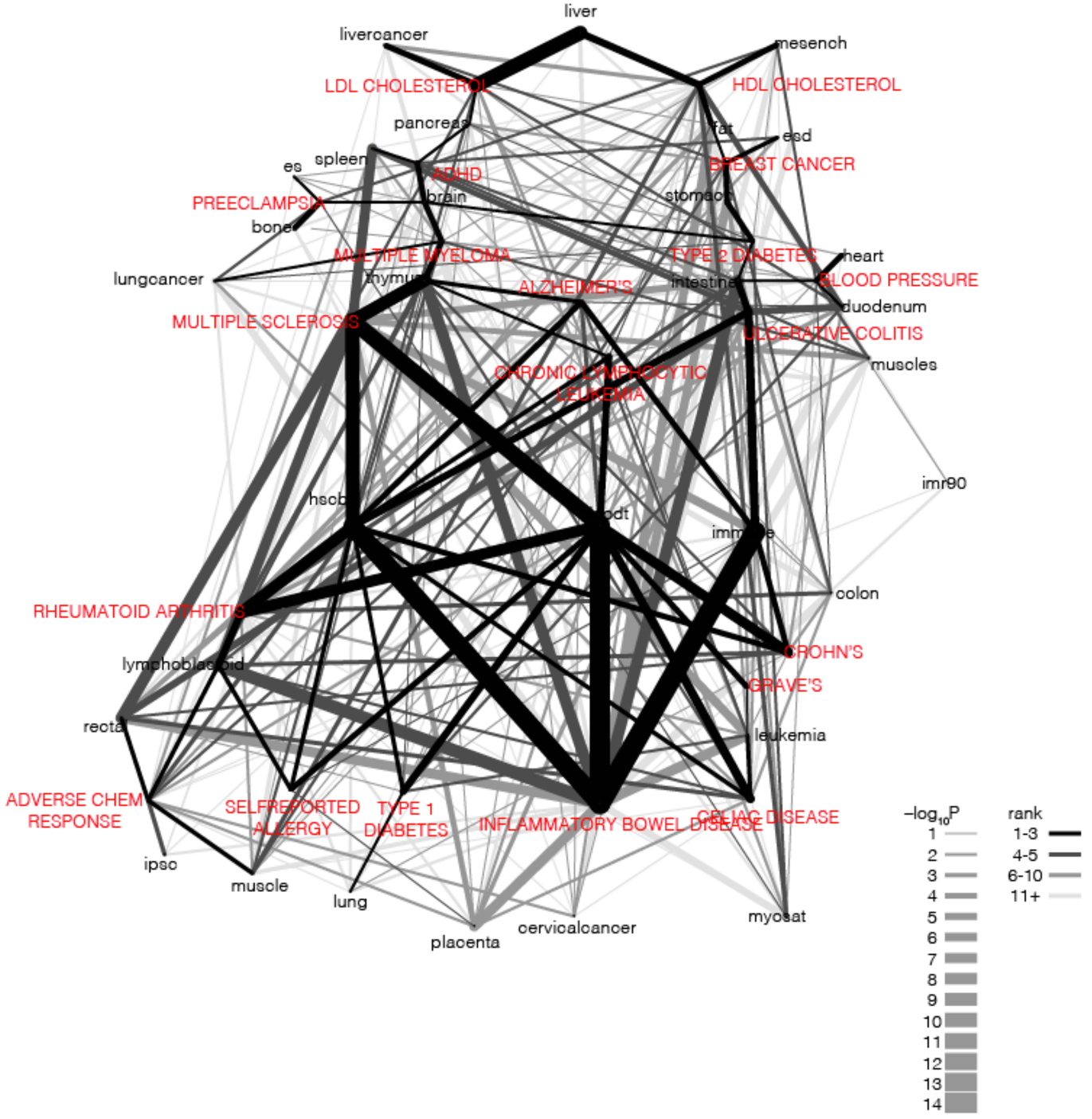
12
13
14
rank
1-3
4-5
6-10
11+


liver
livercancer
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LDL CHOLESTEROL
HDL CHOLESTEROL
pancreas
fat
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spleen
es
ADHD
BREAST CANCER
brain
stomach
PREECLAMPSIA
bone
MULTIPLE MYELOMA
TYPE 2 DIABETES
heart
lungcancer
thymus
ALZHEIMER'S
intestine
BLOOD PRESSURE
duodenum
MULTIPLE SCLEROSIS
ULCERATIVE COLITIS
muscles
CHRONIC LYMPHOCYTIC LEUKEMIA
imr90
hsob
odt
imm e
colon
RHEUMATOID ARTHRITIS
CROHN'S
lymphoblastoid
GRAVE'S
rectal
leukemia
ADVERSE CHEM RESPONSE
SELFREPORTED ALLERGY
TYPE 1 DIABETES
INFLAMMATORY BOWEL DISEASE
CELIAC DISEASE
ipsc
muscle
lung
placenta
cervicalcancer
myosat
−log10P
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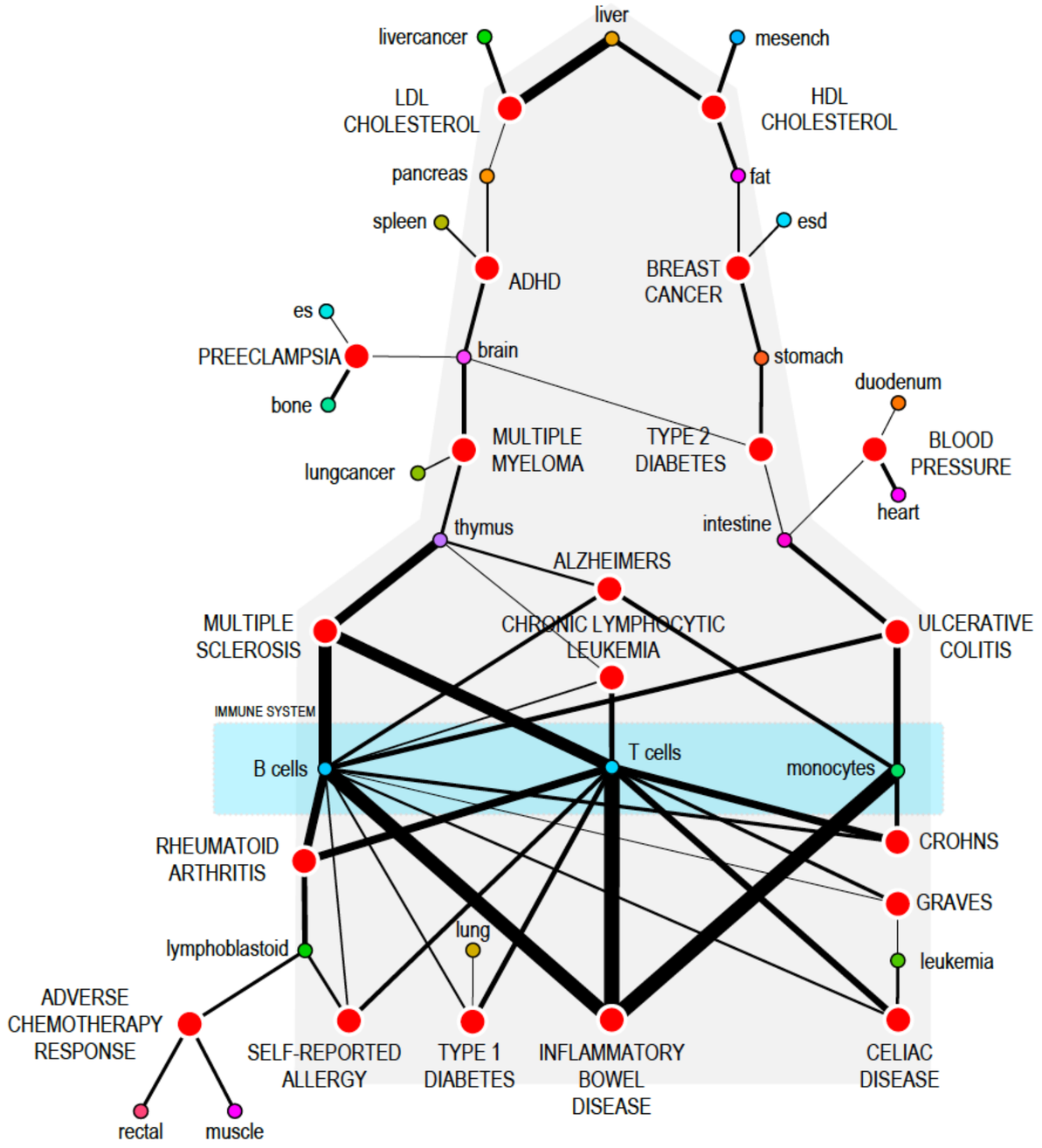
12
13
14
rank
1-3
4-5
6-10
11+


liver
livercancer
mesench
LDL CHOLESTEROL
HDL CHOLESTEROL
pancreas
fat
spleen
esd
ADHD
BREAST CANCER
es
PREECLAMPSIA
brain
stomach
bone
duodenum
MULTIPLE MYELOMA
TYPE 2 DIABETES
BLOOD PRESSURE
lungcancer
heart
thymus
intestine
ALZHEIMERS
MULTIPLE SCLEROSIS
CHRONIC LYMPHOCYTIC LEUKEMIA
ULCERATIVE COLITIS
IMMUNE SYSTEM
B cells
T cells
monocytes
RHEUMATOID ARTHRITIS
CROHNS
GRAVES
lung
lymphoblastoid
leukemia
ADVERSE CHEMOTHERAPY RESPONSE
SELF-REPORTED ALLERGY
TYPE 1 DIABETES
INFLAMMATORY BOWEL DISEASE
CELIAC DISEASE
rectal
muscle

Epigenome Head Tk

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—Dina Maron

Pre-eclampsia is surprisingly

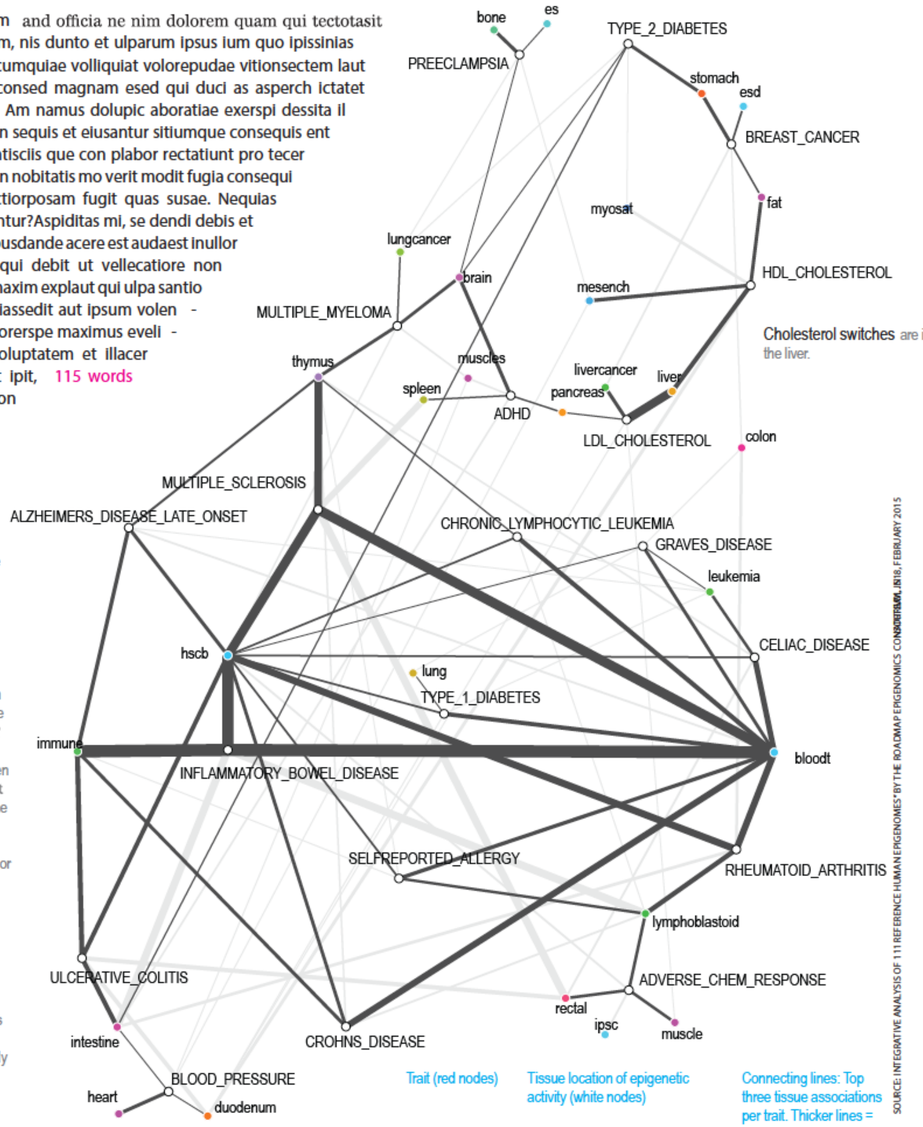
Breast cancer here is linked to regulatory switch of stomach mucosa. Why would that be? It doesn't really make any sense to us today but maybe it's because soft tissue there has to do with tissues inside the breast?

Cholesterol switches are in the liver.

Alzheimer's disease you would think might be associated with a regulatory switch for the brain (the switches in brown across the top) but actually it's mostly strongly related to the immune system. Maybe one day we'll declare that Alzheimer's disease is an immune system disease like MS.

Blood pressure you might think would be associated with the brain governing it or maybe the liver metabolizing caffeine? Or maybe the muscles? The heart? It turns out that it's driven by the heart, specifically the left ventricle. That makes sense the regulatory circuitry seems to matter for blood pressure and blood pressure builds there prior to pumping through the circulatory system

Inflammatory bowel has its regulatory switch in the immune system. We knew it was an immune disorder but here it also seems to be associated with the digestive system. That basically says IBD is not just immune-associated but it's also linked with the digestive system.



Trait (red nodes)

Tissue location of epigenetic activity (white nodes)

Connecting lines: Top three tissue associations per trait. Thicker lines = stronger association

SOURCE: INTEGRATIVE ANALYSIS OF 111 REFERENCE HUMAN EPIGENOMES" BY THE ROADMAP EPIGENOMICS CONSORTIUM, NATURE 518, FEBRUARY 2015

SCIENTIFIC AMERICAN ONLINE For more classification notes, see ScientificAmerican.com/apr2015/graphic-science

Graphic by Martin Krzywinski

Epigenome Head Tk

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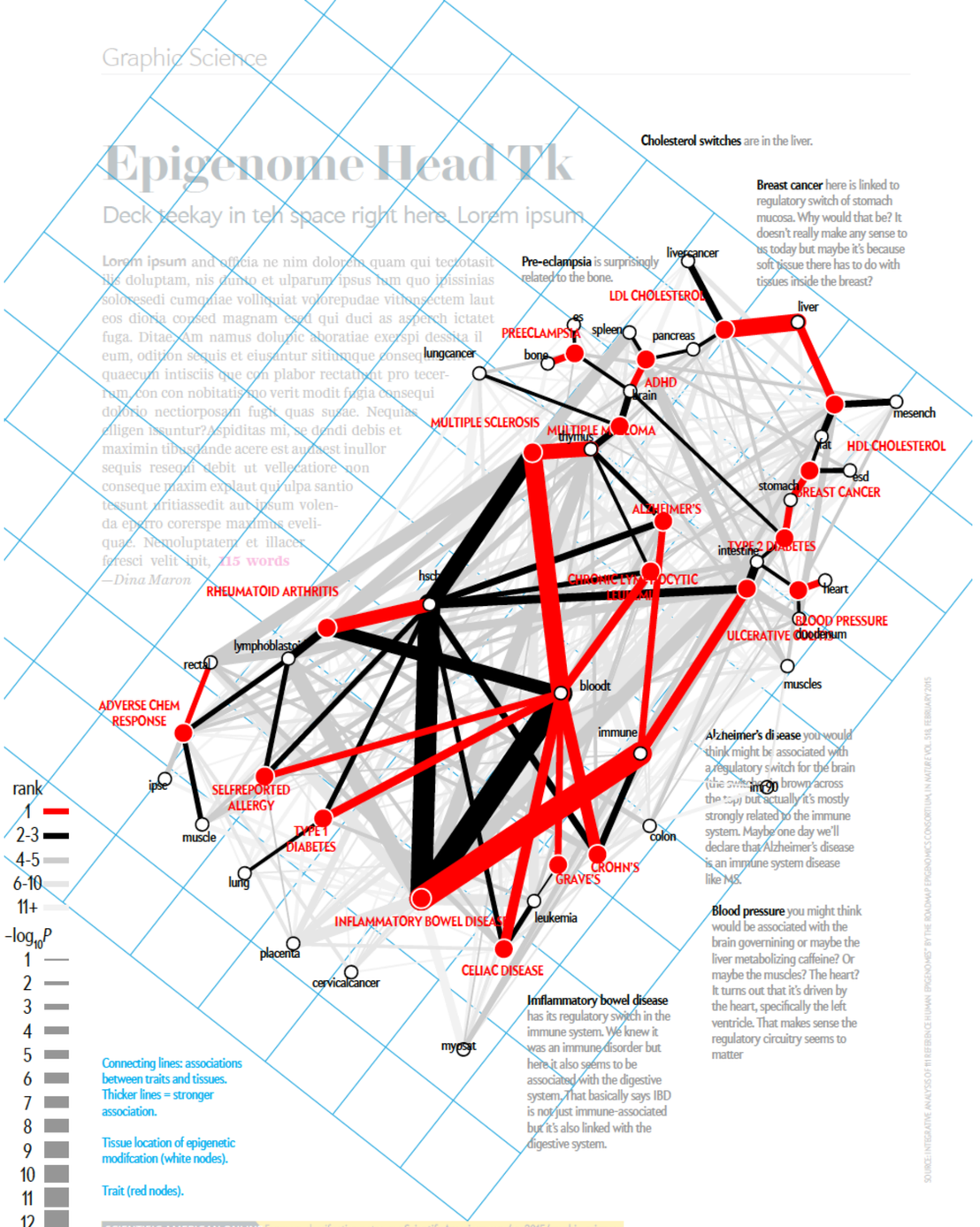
Lorem ipsum and officia ne nim dolorem quam qui tecotasit iis doluptam, nis dunto et ulparum ipsus lum quo ipissinias solorsedi cumquiae volliqniat volorepudae vitiunsectem laut eos dioria consed magnam esed qui duci as aspere ictatet fuga. Ditae. Am namus dolupic aboratiae exerspi dessim il eum, oditiore sequis et eiusantur sitiumque consequatem quaecum intiscilis que con plabor rectatiunt pro tecer-rum, con con nobitatis no verit modit fugia consequi dolorio nectiorposam fugit quas susae. Nequias culigen isuntur? Aspiditas mi, se dendi debis et maximin tiusdande acere est audiest inullor sequis reseqni debit ut vellcatiore non conseque maxim explaut qui ulpa santio tessunt aritiassedit aut ipsum volen-da eperro corerspe maximus eveli-quae. Nemoluptatem et illacer ferferi velit ipit, 115 words

—Dina Maron



SCIENTIFIC AMERICAN ONLINE: For more classification notes, see ScientificAmerican.com/apr2015/graphic-science

Graphic by Martin Krzywinski

SOURCE: INTEGRATIVE ANALYSIS OF 111 REFERENCE HUMAN EPIGENOMES" BY THE ROADMAP EPIGENOMICS CONSORTIUM IN NATURE VOL. 518, FEBRUARY 2015

Epigenome Head Tk

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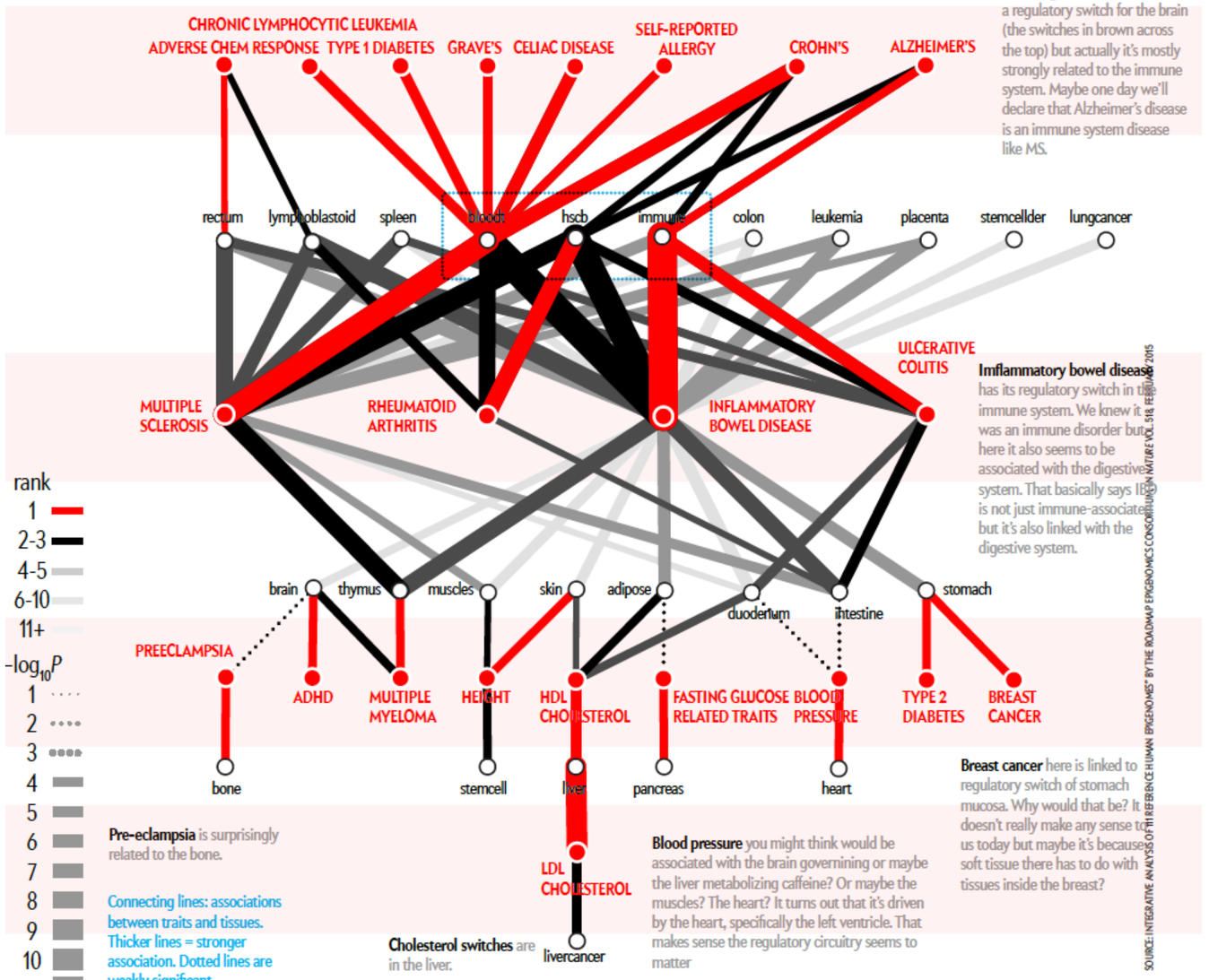

Alzheimer's disease you would think might be associated with a regulatory switch for the brain (the switches in brown across the top) but actually it's mostly strongly related to the immune system. Maybe one day we'll declare that Alzheimer's disease is an immune system disease like MS.

Imflammatory bowel disease has its regulatory switch in the immune system. We knew it was an immune disorder but here it also seems to be associated with the digestive system. That basically says IBD is not just immune-associated but it's also linked with the digestive system.

Breast cancer here is linked to regulatory switch of stomach mucosa. Why would that be? It doesn't really make any sense to us today but maybe it's because soft tissue there has to do with tissues inside the breast?

Pre-eclampsia is surprisingly related to the bone.

Connecting lines: associations between traits and tissues. Thicker lines = stronger association. Dotted lines are

Cholesterol switches are in the liver.

Blood pressure you might think would be associated with the brain governining or maybe the liver metabolizing caffeine? Or maybe the muscles? The heart? It turns out that it's driven by the heart, specifically the left ventricle. That makes sense the regulatory circuitry seems to matter

SOURCE: INTEGRATIVE ANALYSIS OF 111 REFERENCE HUMAN EPIGENOMES" BY THE ROADMAP EPIGENOMICS CONSORTIUM IN *NATURE* VOL. 518, FEBRUARY 2015

Twists of Fate

Genes, traits and disease are linked in complex and surprising ways

Our genes are not the last word on disease risk or other traits. Myriad control switches help to arbitrate how genes get expressed in different cells and tissues, and those switches are often triggered by maternal diet, toxic exposures and many other environmental factors. To begin to understand what drives these complex epigenetic effects, scientists analyzed 150 billion bits of genomic data from more than 100 human tissues and cells—brain, heart, bone, and so forth.

The first step was to locate the switches by analyzing specific chemical modifications on the DNA and the proteins that it wraps around. Then researchers took data comparing individuals who have specific biological traits with those who do not to see which traits are associated with which switches. The result is an epigenomic road map that links diseases and traits (*red dots*) with the locations in the body (*white dots*) of the switches most correlated with those features; thicker lines correspond to more robust links. This blueprint should come in handy in sussing out the molecular basis of human variation and disease and in discovering potential new treatments. —*Dina Fine Maron*

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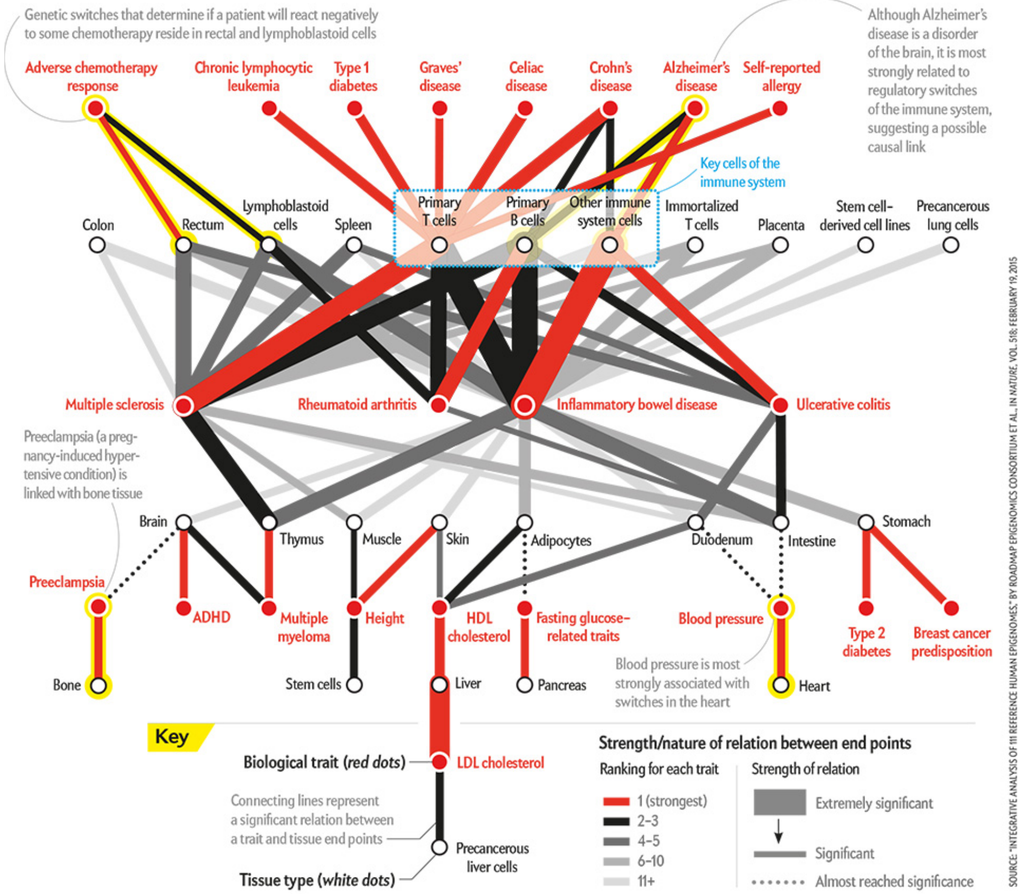
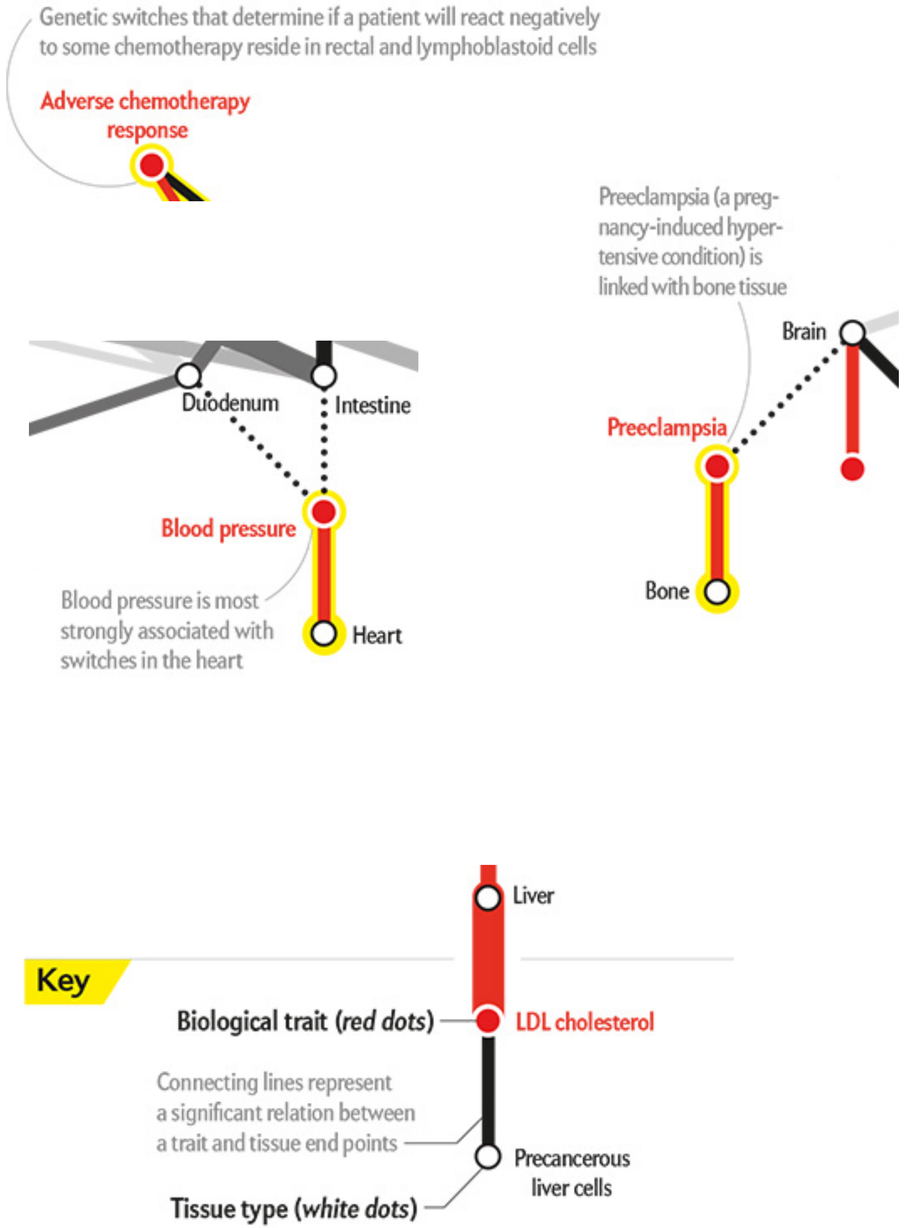
For more graphics about human genetics, see ScientificAmerican.com/jun2015/graphic-science



SOURCE: "INTEGRATIVE ANALYSIS OF 111 REFERENCE HUMAN EPIGENOMES," BY ROADMAP EPIGENOMICS CONSORTIUM ET AL., IN *NATURE*, VOL. 518; FEBRUARY 19, 2015

Graphic by Martin Krzywinski



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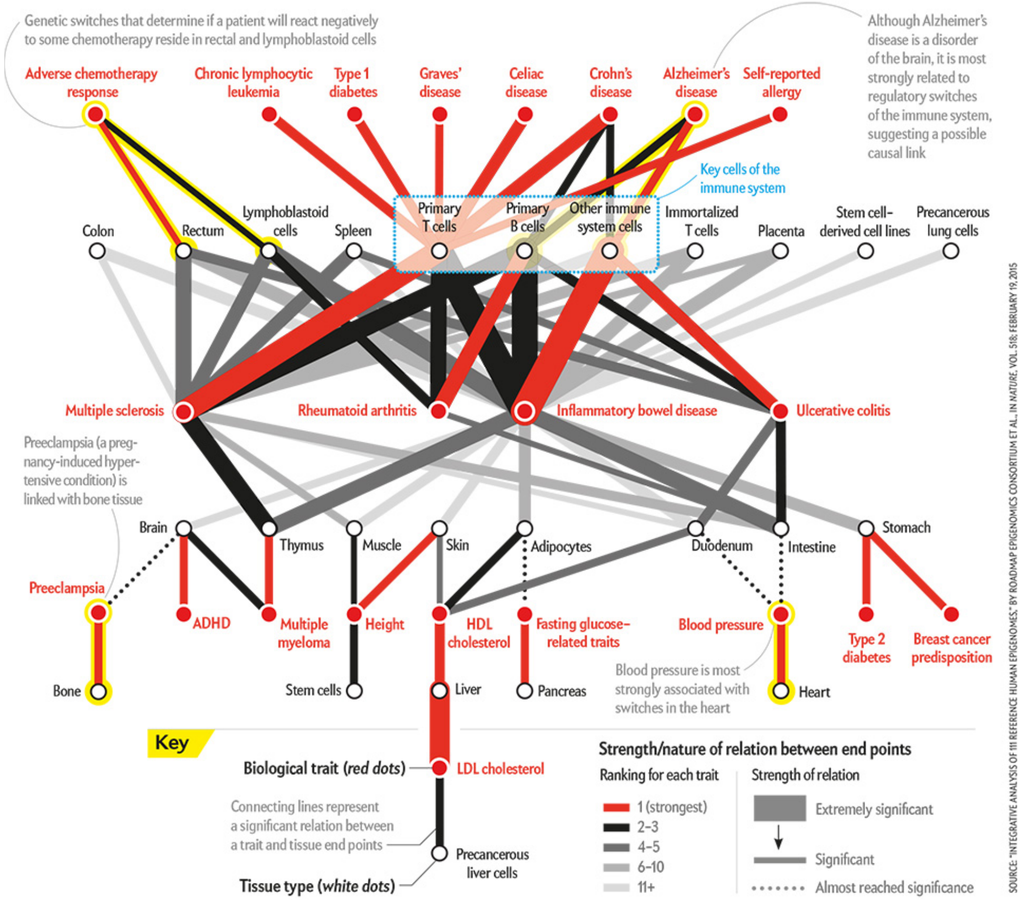

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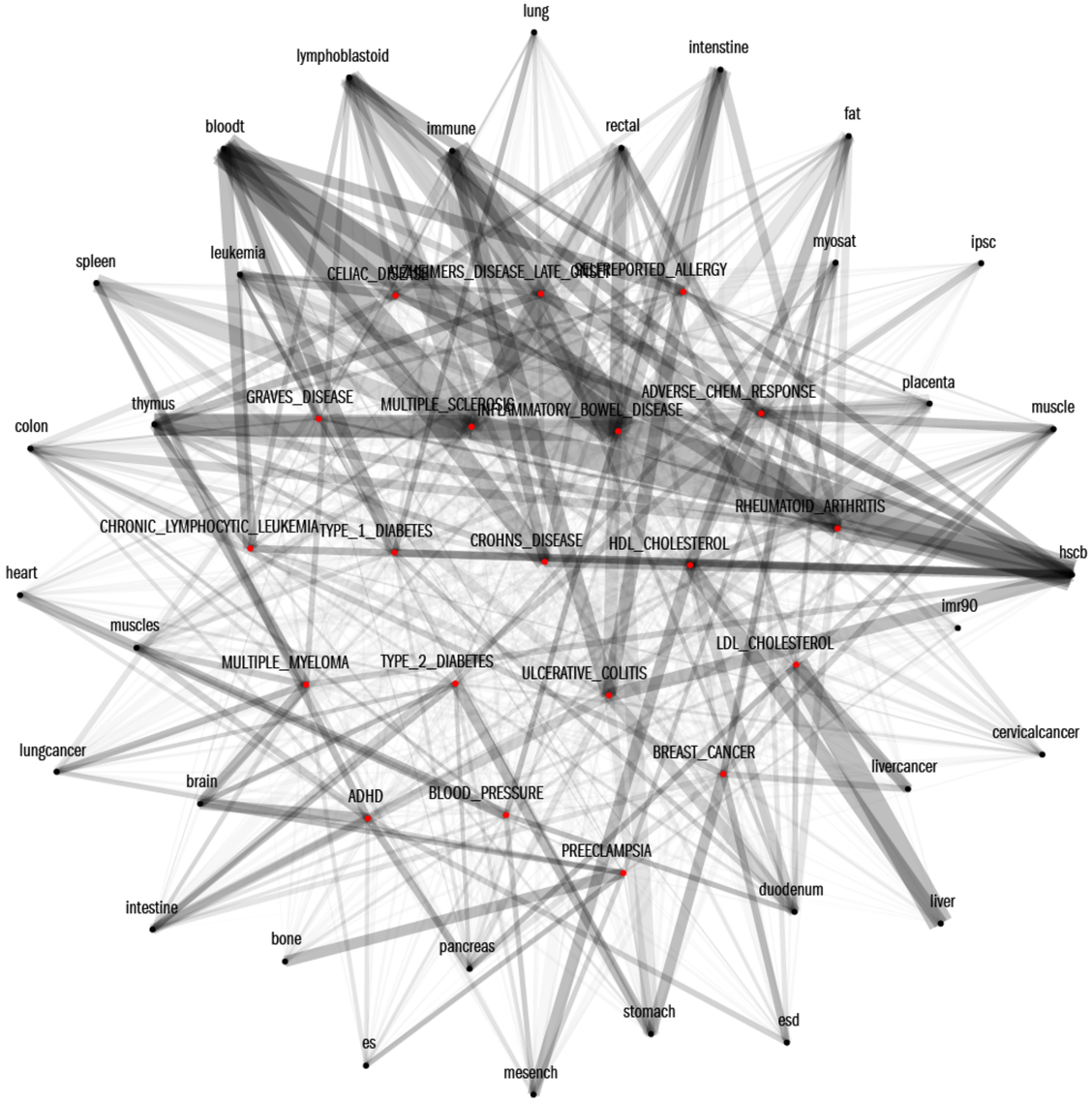

Graphic by Martin Krzywinski

This graphic took about 40 hours of work, give or take, and about 7 iterations.

The final product is constrained by the available space on a page—some room had to be left for the 120-odd word intro. As well as the level of interest and patience of the reader.

There's no real way to automate this kind of display because it's highly contingent on the data. None of the usual layout algorithms gave us anything useable. For a paper, or a magazine, the amount of manual labor is worth it.

I can't achieve this level of polish and inquiry into every visualization that I make—it would simply take too long. But once in a while you have to sit down and really work through something.

Whatever you're interested in, you should always have some projects on the go. Chip away at them. Keep yourself in a state of confusion—it's a kind of endurance training.

I wish you good luck and hope that the topics presented here have been, or will be, helpful in your visualization and artistic endeavours.

created by

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written and designed by

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