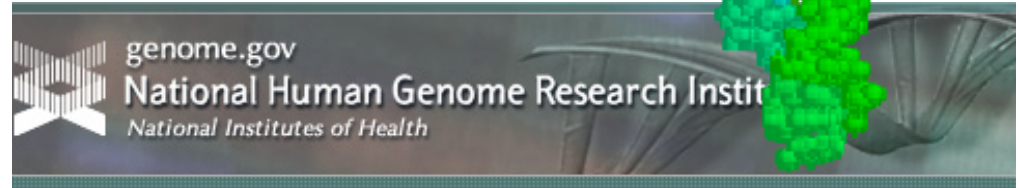
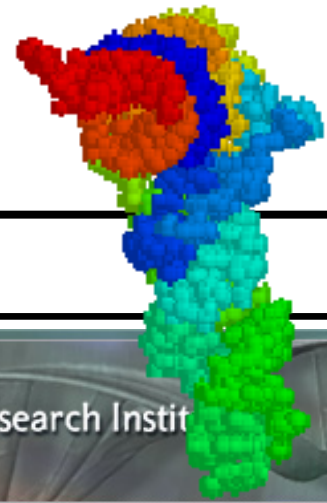


Seeking Radical Breakthroughs in Alternative Energy

10-Sep-08 X-Prize Forum: 4:30 PM



National Heart Lung and Blood Institute



GENOMES to LIFE
BIOLOGICAL SOLUTIONS FOR ENERGY CHALLENGES
U.S. DEPARTMENT OF ENERGY
INNOVATIVE APPROACHES ALONG UNCONVENTIONAL PATHS



molecular systems biology

A new type of online journal from EMBO and Nature Publishing Group



CORIELL INSTITUTE for Medical Research

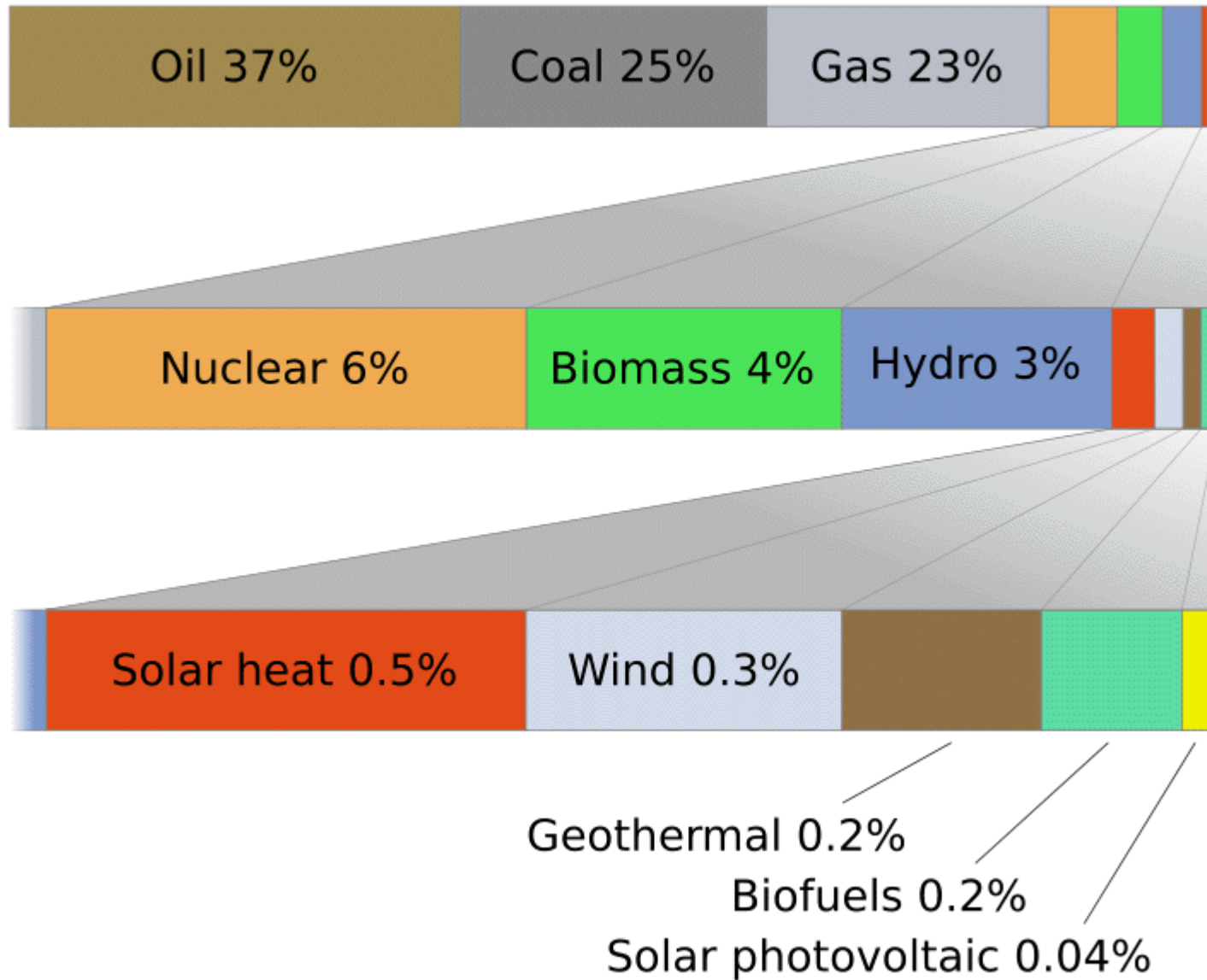


Agilent Technologies

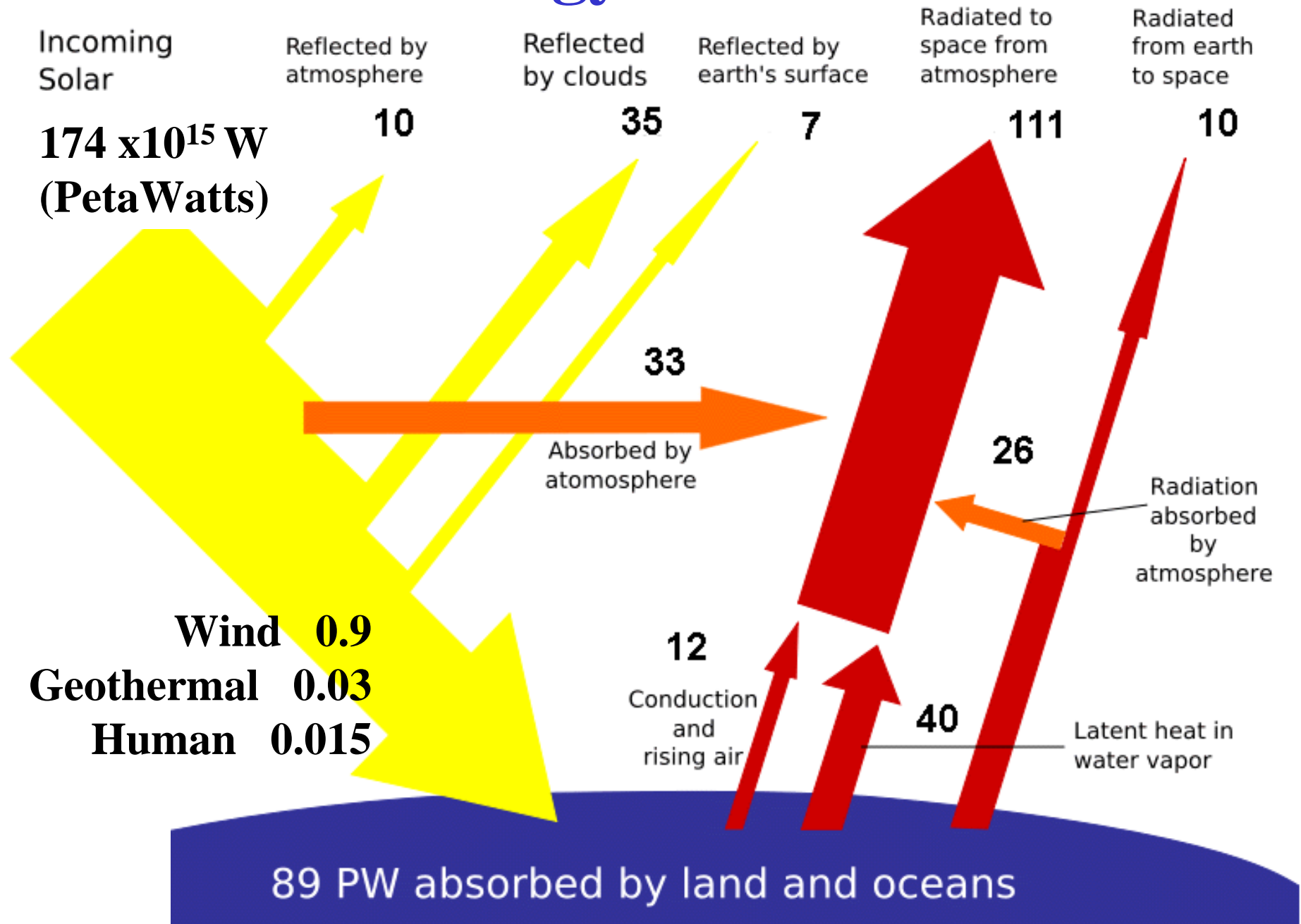


LS9, INC the renewable petroleum company™

Global Human Energy Use: $15 \times 10^{12} \text{ W} = 5 \times 10^{20} \text{ J/yr}$



Global Energy Resources



Photovoltaics vs Photosynthesis



1. **Energy efficiency** can be demonstrated as up to 43% for experimental photovoltaics and 11% for photosynthesis, but the first is peak performance and ignores storage & conversion, while the latter is calculated from grams of biofuel per hectare per year (including night & winter).

Energy Density:

Lithium ion Battery	0.7 kJ/g
(Bio)Diesel fuel	43 kJ/g

Atmospheric CO₂ is addressed by few energy sources

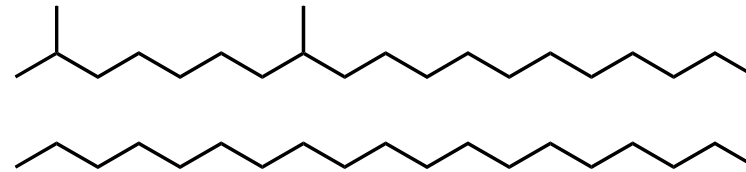
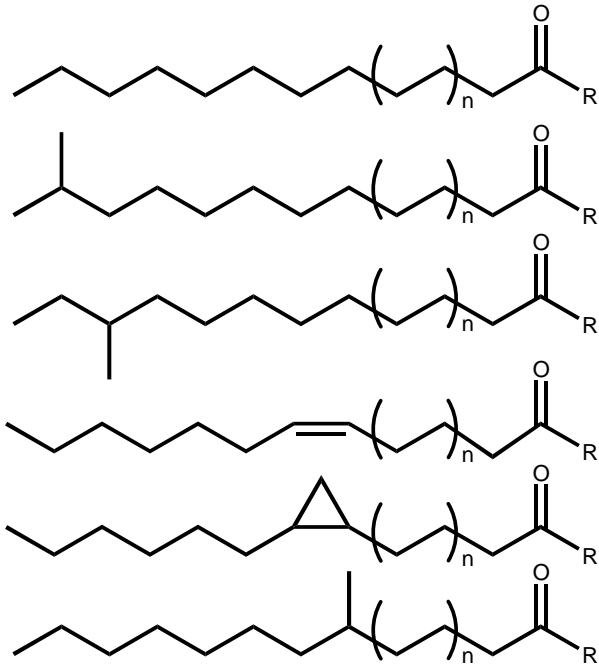
Total : 2E12 tons

1% added by human activities

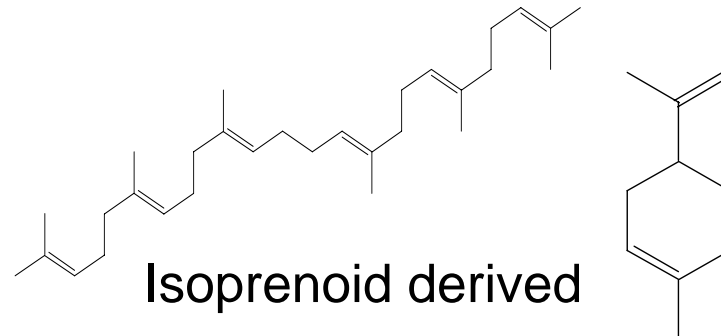
15% removed by photosynthesis yearly

Agricultural biomass: 3% of the total & 15% yearly change

Bio-petroleum from grasses & algae (not competing for crop land)



Fatty acid derived



Isoprenoid derived

Leverage current
infrastructure & engines

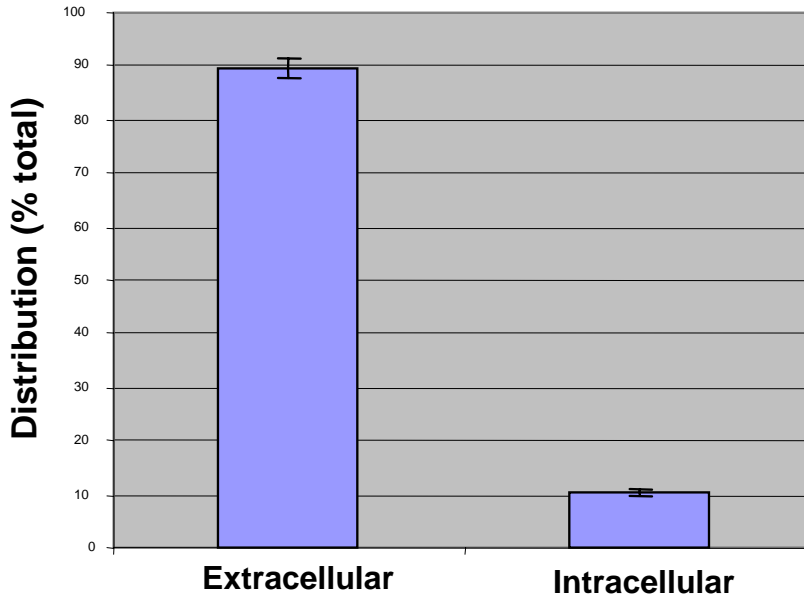
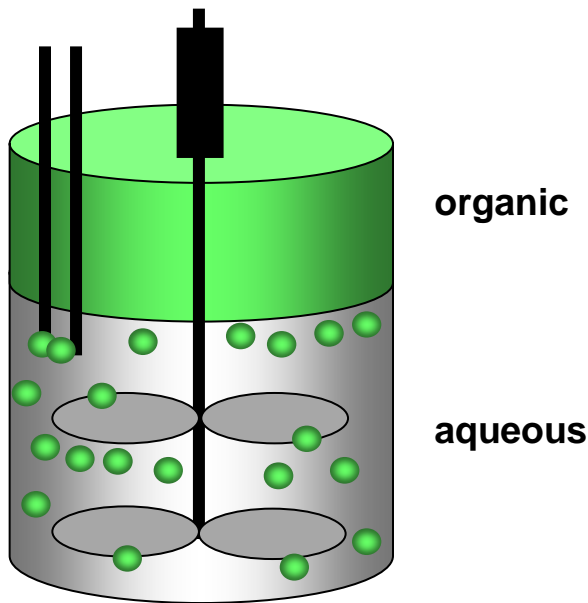


LS9, INC.
the renewable petroleum company™

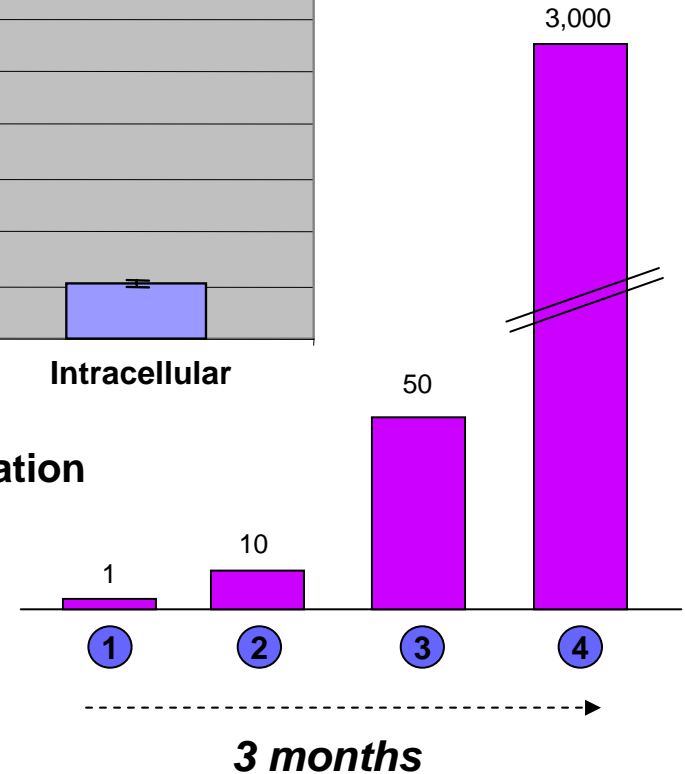


Immiscible Products Facilitate Purification

- Separate from water without distillation
- Decrease toxicity to producer strain
- > 2 Million liters in 2009



Localization



LS9, INC.
the renewable petroleum company™

Design + Evolution

Lenski

Citrate utilization

Palsson

Glycerol utilization

Edwards

Radiation resistance

Ingram

Lactate production

Marliere

Thermotolerance

J&J

Diarylquinoline resistance (TB)

DuPont

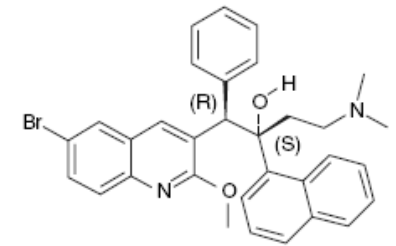
1,3-propanediol production

Tolonen

Alcohol resistance (4 to 8%)

Lin&Reppas

Trp/Tyr (pharma precursors)



Genome engineering examples

•Dupont/Genencor: 1,3 Propanediol: **27 changes** to 4.6 Mbp *E.coli*
135 g/l at 3.5 g/l/h, 2.4 Mliter scale 51% yield (90% of theoretical)
from glucose

ackA aldA aldB arcA crr edd gldA glpK mgsA pta ptsH ptsI yqhC

Saccharomyces: DAR1 GPP2 *Klebsiella*: dhaB1,B2,B3,X; orfX,Y

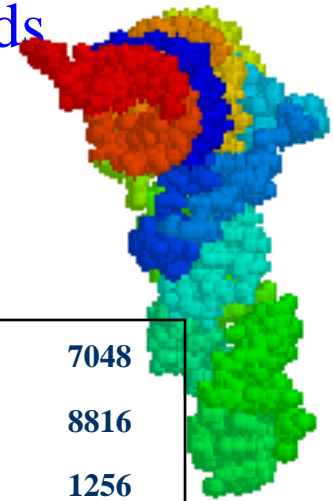
P1.5.gapA P1.6.ppc P1.6.btuR P1.6.yqhD Ptrc.galP Ptrc.glk

(13 ko, 8 ins, 6 regul) <http://www.patentstorm.us/patents/6432686-description.html>

**Plants tolerant to the herbicide glyphosate, producing the Bacillus
Bt toxin insecticide, or biosynthesize a precursor of vitamin A**

New genetic code: viral-resistance, novel amino acids no functional GMO DNA exchange

Safety & Productivity : synergy not tradeoff.



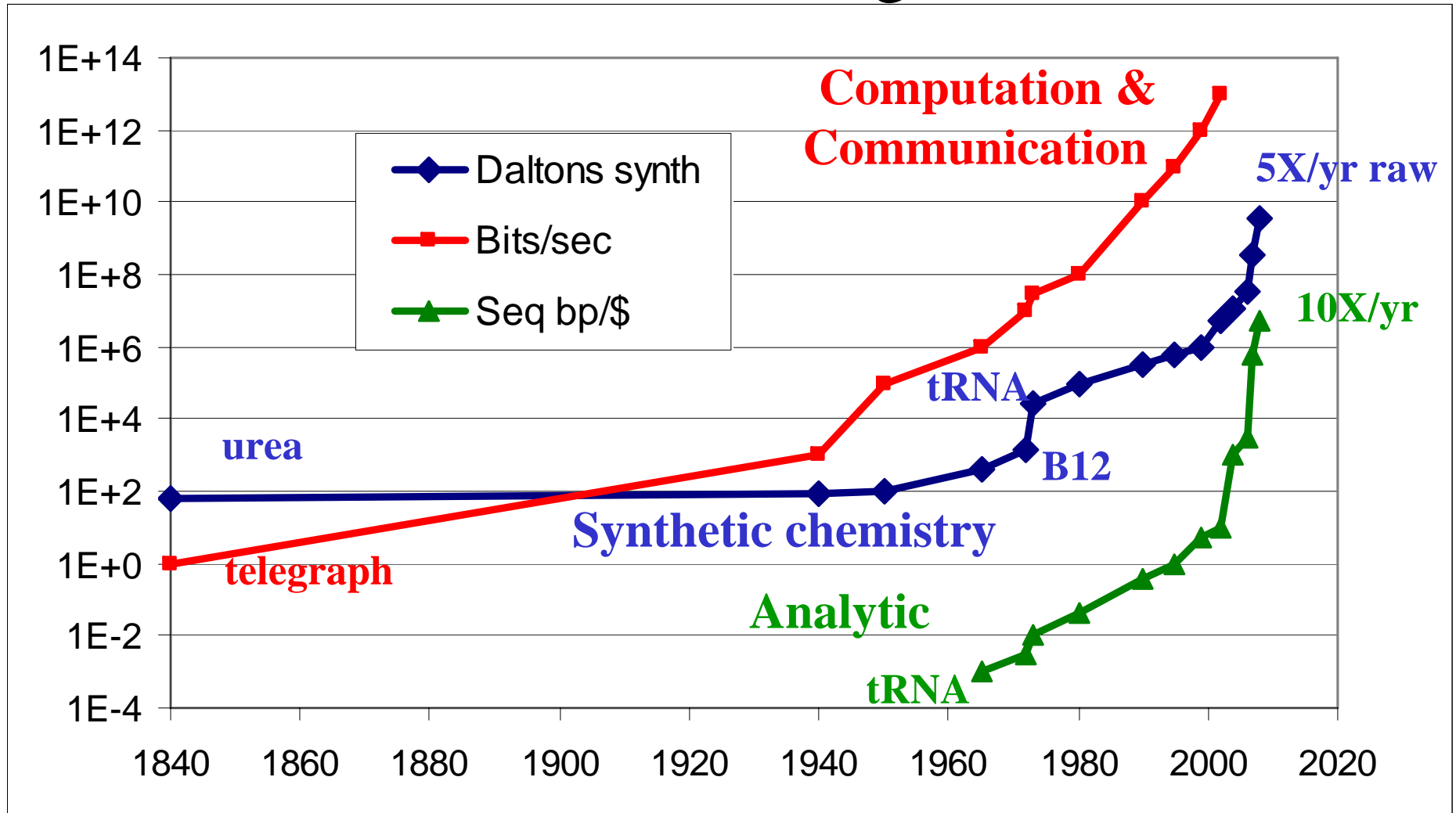
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TTC	F	22516	TCC		11720	TAC	Y	16601	TGC	C	8816
TTA		18932	TCA	S	9783	TAA	STOP	2703	TGA	STOP	1256
TTG	L	18602	TCG		12166	TAG	STOP	1 314	TGG	W	20683
CTT		15002	CCT		9559	CAT		17613	CGT		28382
CTC		15077	CCC		7485	CAC	H	13227	CGC		29898
CTA		5314	CCA	P	11471	CAA		20888	CGA	R	4859
CTG	L	71553	CCG		31515	CAG	Q	39188	CGG		7399
ATT		41309	ACT		12198	AAT		24159	AGT		11970
ATC	I	34178	ACC		31796	AAC	N	29385	AGC	S	21862
ATA		5967	ACA	T	9670	AAA		45687	AGA		2896
ATG	M	37915	ACG		19624	AAG	K	14029	AGG	R	1692
GTT		24858	GCT		20762	GAT		43719	GGT		33622
GTC		20753	GCC		34695	GAC	D	25918	GGC		40285
GTA	V	14822	GCA	A	27418	GAA		53641	GGA	G	10893
GTG		35918	GCG		45741	GAG	E	24254	GGG		15090

Charalel
Church
Isaacs
Sun
Wang

Carr
Jacobson
Kong
Sterling

3 Exponential technologies

“law of accelerating returns”



Shendure et al. 2004 Nature Reviews of Genetics.
 Kurzweil 2002; Moore 1965 (2X/2yr til 2020)