In-class Lecture 4 - Scaling, Part 2 Tuesday, January 25, 2022 12:43 PM Thinking o-bout competition Lese broz prob. of binding is defermined by the competition between binding and entropy Moss-specific metabolic rates 10^{3} 10° metabolic rate, *B* (W) 10₋₉ 10₋₉ 10-12 slope for $B = M^{3/4}$; $B/M = M^{-1/4}$ 10^{-15} $10^{-12} \quad 10^{-9} \quad 10^{-6}$ 10^{-3} 10^{3} mass, M (kg) mass-specific metabolic rates ■ heterotrophs
■ photoautotrophs ectothermic endothermic aquatic species o w prokaryotes insects invertebrates vertebrates vertebrates n = 40290 60 150 240 numberof 10 0 100 60 40 160 30 50 0 0.1 1 10 100 0.1 1 10 100 0.1 1 10 100 0.1 1 10 100 microalgae green leaves numberof species 18 240 45 15 160 12 60 30 10 5 15 0.1 1 10 100 0.1 1 10 100 0.1 1 10 100 0.1 1 10 100 0.1 1 10 100 0.1 1 10 100 mass-specific metabolic rate (W/kg) Estimate E. coli metabolic roste Note to class: I decided to consider only the energy to assemble proteins energy ossociated w/ putting together the proteins energy consumed by E. colito make another cell cell eycle time cell cycle time We know that I pay 4Atfs/0-0-0-ssembled: AMINO ACID LOADING PEPTIDE ELONGATION CYCLE amino acid tRNA GDP codon ATP **AMP** \bigcirc translocation peptide bond formation GDP GTP Table 3. ATP requirement for the formation of microbial cells from preformed monomers (glucose, amino acids and nucleic acid bases). Formation of lipids from acetate or glucose are separately considered. ATP required Macromolecule Amount of ATP required per moles \times 10⁻⁴/g cells monomer monomer moles × moles/mole 10^{-4} /g cells Lipids formed from Acetate Glucose Acetate Glucose Polysaccharide 10.26 20.52 20.52 4 191.40 Protein 47.85 191.40 Lipid 1.40 33 1 46.20 1.40 RNA1 5 5 23.00 23.00 4.60 DNA 0.96 5.76 5.76 13.90 Turnover RNA 13.90 300.78 255.98 Total ATP required for transport of Amino acids 47.85 47.85 Acetate 22.40 1.92 Potassium ions 1.92 Phosphate 7.74 7.74 Total ATP requirement 380.69 313.49 Total ATP requirement 31,9 26.4 ¹ For the calculation of the RNA content the UMP content (Table 1) has been taken as basis. workers · 300 ao . 4 ATP = 9.10 · 4 ATP = 4.109 ATP Volume-specific energy required $M_{V} = \frac{4 \cdot 10^{9} \text{ ATP}}{1 \text{ Mm}^{3}}$ 10⁶ 10⁵ molecules ATP/cell 10⁶ molecules ATP/cell 10⁷ 10¹ 10⁻¹ 10^{5} growth 10^{1} maintenance/hr 10^{1} 10² 10^{3} 10^{0} cell volume (µm³) o bacteria unicellular eukaryotes cells from multicellular species in culture We see that there's a good agreement between our estimated metabolic rate for growth and that from Lynch + Marinov. To colculate a rote, divide by the cell cycle Metaboliz = 4.109 ATP/ rate // 10005 = 4.10⁶ ATP How do you morke all this ATP? DATP synthase: spins of 100 revolutions -100 HZ = 6000 revol 7 comparable to jet = 6000 RPM engine! makes 3 ATP/revolution How many ATP synthoses do I need to support this maintenance metabolic rate? 4.106 ATP /100 ATP = 4.104 synthoses total 179 rote per For MMm3 600/ Mass spec data: 10^{4} 0 cell size dependence estimated value 10^{3} Li et al. 2014 Peebo et al. 2015 Schmidt et al. 2016 Valgepea et al. 2013 10^{2} 0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 growth rate [hr⁻¹] Lo Q: What's their spacing on the membroone density = $\frac{5.10^3 \text{ synthase s] from mass spec}}{6 \text{ Mm}^2}$ Jell area. symbose = 1 = 10 -3 Mm = 10 -3 Mm spacing ~ Jordan per 1 Joo 40 An = 10.3 Mm > 30nm spo-cing is comparable to size! They re closely packed We posit that there's or competition between cell rolume and area in energy production and consumption ATP needed = 4.106 ATP Mm3.5. Vcell ATPProduced = calculate maximum production rate Boynth = surface density = Asynthose

of synthoses

Asynthoses assume membrane closely packed with ATP synthose molecules ATPproduced = 6 synth. 100 ATP. Acell = 1 25 nm . 100 ATP Acel = 1 1 25.10 Mm

ATPAcell $= 10^6 \frac{\text{ATP}}{3 \text{Mm}^2}$ ATP_needed = 4.406 ATP Mm3.5 . 4 TT. R3 ATP Produced = 106 ATP. 4TTR2 Let's Find the R for which consumption and production become equal 4.10 HTP ST TIPS = 10 MATP CATTRE R ~1 Mm cells much larger than 111 m count produce their ATP exclusively on their membroine 4) Make this plot