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References

1. Adachi S, Fukushima T, Hiraga S (2008) Dynamic events of sister chromosomes in the cell cycle of Escherichia coli. Genes Cells 13: 181-197.

2. Atlung T, Lobner-Olesen A, Hansen FG (1987) Overproduction of DnaA protein stimulates initiation of chromosome and minichromosome replication in Escherichia coli. Mol Gen Genet 206: 51-59.

3. Avery SV (2006) Microbial cell individuality and the underlying sources of heterogeneity. Nat Rev Microbiol 4: 577-587.

4. Bach T, Krekling MA, Skarstad K (2003) Excess SeqA prolongs sequestration of oriC and delays nucleoid segregation and cell division. Embo J 22: 315-323.

5. Bach T, Krekling MA, Skarstad K (2003) Excess SeqA prolongs sequestration of oriC and delays nucleoid segregation and cell division. Embo J 22: 315-323.

6. Barcena M, Ruiz T, Donate LE, Brown SE, Dixon NE, et al. (2001) The DnaB.DnaC complex: a structure based on dimers assembled around an occluded channel. Embo J 20: 1462-1468.

7. Bates D, Kleckner N (2005) Chromosome and replisome dynamics in E. coli: loss of sister cohesion triggers global chromosome movement and mediates chromosome segregation. Cell 121: 899-911.

8. Bayne-Jones S, Adoplh EF (1932) Growth in size of micro-organisms measured from motion pictures. Journal of Cellular and Comparative Physiology 1: 387-407.

9. Benzer S (1953) Induced synthesis of enzymes in bacteria analyzed at the cellular level. Biochim Biophys Acta 11: 383-395.

10. Blomfield I (2001) The Regulation of Pap and Type 1 Fimbriation in Escherichia coli: Academic Press. 1-49 p.

11. Blomfield IC, McClain MS, Princ JA, Calie PJ, Eisenstein BI (1991) Type 1 fimbriation and fimE mutants of Escherichia coli K-12. J Bacteriol 173: 5298-5307.

12. Blomfield IC, Vaughn V, Rest RF, Eisenstein BI (1991) Allelic exchange in Escherichia coli using the Bacillus subtilis sacB gene and a temperature-sensitive pSC101 replicon. Mol Microbiol 5: 1447-1457.

13. Boye E, Stokke T, Kleckner N, Skarstad K (1996) Coordinating DNA replication initiation with cell growth: differential roles for DnaA and SeqA proteins. Proc Natl Acad Sci U S A 93: 12206-12211.

14. Boye E, Nordstrom K (2003) Coupling the cell cycle to cell growth. EMBO Rep 4: 757-760.

15. Brehm-Stecher BF, Johnson EA (2004) Single-cell microbiology: tools, technologies, and applications. Microbiol Mol Biol Rev 68: 538-559.

16. Bremer H, Churchward G (1977) Deoxyribonucleic acid synthesis after inhibition of initiation of rounds of replication in Escherichia coli B/r. J Bacteriol 130: 692-697.

17. Bremer H, Churchward G (1978) Age fractionation in bacteria by membrane elution: relation between age distribution and elution profile. J Theor Biol 74: 69-81.

18. Bremer H, Chuang L (1981) The cell cycle in Escherichia coli B/r. J Theor Biol 88: 47-81.

19. Brendler T, Sawitzke J, Sergueev K, Austin S (2000) A case for sliding SeqA tracts at anchored replication forks during Escherichia coli chromosome replication and segregation. Embo J 19: 6249-6258.

20. Bullitt E, Makowski L (1995) Structural polymorphism of bacterial adhesion pili. Nature 373: 164-167.

21. Burns LS, Smith SG, Dorman CJ (2000) Interaction of the FimB integrase with the fimS invertible DNA element in Escherichia coli in vivo and in vitro. J Bacteriol 182: 2953-2959.

22. Cairns J (1963) The bacterial chromosome and its manner of replication as seen by autoradiography. J Mol Biol 6: 208-213.

23. Campbell JL, Kleckner N (1990) E. coli oriC and the dnaA gene promoter are sequestered from dam methyltransferase following the passage of the chromosomal replication fork. Cell 62: 967-979.

24. Chandler M, Bird RE, Caro L (1975) The replication time of the Escherichia coli K12 chromosome as a function of cell doubling time. J Mol Biol 94: 127-132.

25. Chu D, Blomfield IC (2007) Orientational control is an efficient control mechanism for phase switching in the E. coli fim system. J Theor Biol 244: 541-551.

26. Churchward G, Estiva E, Bremer H (1981) Growth rate-dependent control of chromosome replication initiation in Escherichia coli. J Bacteriol 145: 1232-1238.

27. Cooper S, Helmstetter CE (1968) Chromosome replication and the division cycle of Escherichia coli B/r. J Mol Biol 31: 519-540.

28. Cooper S (1991) Bacterial Growth and Division. San Diego: Academic Press, Inc.

29. Cooper S (2006) Regulation of DNA synthesis in bacteria: Analysis of the Bates/Kleckner licensing/initiation-mass model for cell cycle control. Mol Microbiol 62: 303-307.

30. Cormack BP, Valdivia RH, Falkow S (1996) FACS-optimized mutants of the green fluorescent protein (GFP). Gene 173: 33-38.

31. Davidsen T, Tonjum T (2006) Meningococcal genome dynamics. Nat Rev Microbiol 4: 11-22.

32. den Blaauwen T, Aarsman ME, Wheeler LJ, Nanninga N (2006) Pre-replication assembly of E. coli replisome components. Mol Microbiol 62: 695-708.

33. Donachie WD (1968) Relationship between cell size and time of initiation of DNA replication. Nature 219: 1077-1079.

34. Donachie WD (1969) Control of cell division in Escherichia coli: experiments with thymine starvation. J Bacteriol 100: 260-268.

35. Dove SL, Dorman CJ (1994) The site-specific recombination system regulating expression of the type 1 fimbrial subunit gene of Escherichia coli is sensitive to changes in DNA supercoiling. Mol Microbiol 14: 975-988.

36. Dybvig K (1993) DNA rearrangements and phenotypic switching in prokaryotes. Mol Microbiol 10: 465-471.

37. Eisenstein BI (1981) Phase variation of type 1 fimbriae in Escherichia coli is under transcriptional control. Science 214: 337-339.

38. El-Labany S, Sohanpal BK, Lahooti M, Akerman R, Blomfield IC (2003) Distant cis-active sequences and sialic acid control the expression of fimB in Escherichia coli K-12. Mol Microbiol 49: 1109-1118.

39. Elowitz MB, Levine AJ, Siggia ED, Swain PS (2002) Stochastic gene expression in a single cell. Science 297: 1183-1186.

40. Fujikawa N, Kurumizaka H, Nureki O, Tanaka Y, Yamazoe M, et al. (2004) Structural and biochemical analyses of hemimethylated DNA binding by the SeqA protein. Nucleic Acids Res 32: 82-92.

41. Gally DL, Bogan JA, Eisenstein BI, Blomfield IC (1993) Environmental regulation of the fim switch controlling type 1 fimbrial phase variation in Escherichia coli K-12: effects of temperature and media. J Bacteriol 175: 6186-6193.

42. Gally DL, Leathart J, Blomfield IC (1996) Interaction of FimB and FimE with the fim switch that controls the phase variation of type 1 fimbriae in Escherichia coli K-12. Mol Microbiol 21: 725-738.

43. Grindley ND, Whiteson KL, Rice PA (2006) Mechanisms of site-specific recombination. Annu Rev Biochem 75: 567-605.

44. Guarne A, Brendler T, Zhao Q, Ghirlando R, Austin S, et al. (2005) Crystal structure of a SeqA-N filament: implications for DNA replication and chromosome organization. Embo J 24: 1502-1511.

45. Hahn E, Wild P, Hermanns U, Sebbel P, Glockshuber R, et al. (2002) Exploring the 3D molecular architecture of Escherichia coli type 1 pili. J Mol Biol 323: 845-857.

46. Hanks MC, Masters M (1987) Transductional analysis of chromosome replication time. Mol Gen Genet 210: 288-293.

47. Helmstetter CE, Pierucci O (1976) DNA synthesis during the division cycle of three substrains of Escherichia coli B/r. J Mol Biol 102: 477-486.

48. Henderson IR, Owen P, Nataro JP (1999) Molecular switches--the ON and OFF of bacterial phase variation. Mol Microbiol 33: 919-932.

49. Herrick J, Kohiyama M, Atlung T, Hansen FG (1996) The initiation mess? Mol Microbiol 19: 659-666.

50. Hinde P, Deighan P, Dorman CJ (2005) Characterization of the detachable Rho-dependent transcription terminator of the fimE gene in Escherichia coli K-12. J Bacteriol 187: 8256-8266.

51. Hiraga S, Ichinose C, Niki H, Yamazoe M (1998) Cell cycle-dependent duplication and bidirectional migration of SeqA-associated DNA-protein complexes in E. coli. Mol Cell 1: 381-387.

52. Hiraga S, Ichinose C, Onogi T, Niki H, Yamazoe M (2000) Bidirectional migration of SeqA-bound hemimethylated DNA clusters and pairing of oriC copies in Escherichia coli. Genes Cells 5: 327-341.

53. Holden N, Blomfield IC, Uhlin BE, Totsika M, Kulasekara DH, et al. (2007) Comparative analysis of FimB and FimE recombinase activity. Microbiology 153: 4138-4149.

54. Jacob-Dubuisson F, Heuser J, Dodson K, Normark S, Hultgren S (1993) Initiation of assembly and association of the structural elements of a bacterial pilus depend on two specialized tip proteins. Embo J 12: 837-847.

55. Jones CH, Pinkner JS, Roth R, Heuser J, Nicholes AV, et al. (1995) FimH adhesin of type 1 pili is assembled into a fibrillar tip structure in the Enterobacteriaceae. Proc Natl Acad Sci U S A 92: 2081-2085.

56. Joyce SA, Dorman CJ (2002) A Rho-dependent phase-variable transcription terminator controls expression of the FimE recombinase in Escherichia coli. Mol Microbiol 45: 1107-1117.

57. Kaguni JM (2006) DnaA: controlling the initiation of bacterial DNA replication and more. Annu Rev Microbiol 60: 351-375.

58. Kang S, Lee H, Han JS, Hwang DS (1999) Interaction of SeqA and Dam methylase on the hemimethylated origin of Escherichia coli chromosomal DNA replication. J Biol Chem 274: 11463-11468.

59. Kang S, Han JS, Kim KP, Yang HY, Lee KY, et al. (2005) Dimeric configuration of SeqA protein bound to a pair of hemi-methylated GATC sequences. Nucleic Acids Res 33: 1524-1531.

60. Kawakami H, Su'etsugu M, Katayama T (2006) An isolated Hda-clamp complex is functional in the regulatory inactivation of DnaA and DNA replication. J Struct Biol 156: 220-229.

61. Kelly A, Conway C, T OC, Smith SG, Dorman CJ (2006) DNA supercoiling and the Lrp protein determine the directionality of fim switch DNA inversion in Escherichia coli K-12. J Bacteriol 188: 5356-5363.

62. Keyamura K, Fujikawa N, Ishida T, Ozaki S, Su'etsugu M, et al. (2007) The interaction of DiaA and DnaA regulates the replication cycle in E. coli by directly promoting ATP DnaA-specific initiation complexes. Genes Dev 21: 2083-2099.

63. Koppes LH, Woldringh CL, Nanninga N (1978) Size variations and correlation of different cell cycle events in slow-growing Escherichia coli. J Bacteriol 134: 423-433.

64. Koppes LJ, Meyer M, Oonk HB, de Jong MA, Nanninga N (1980) Correlation between size and age at different events in the cell division cycle of Escherichia coli. J Bacteriol 143: 1241-1252.

65. Kornberg A, Baker J (1992) DNA Replication. New York: W.H Freeman & Co.

66. Kubitschek HE, Freedman ML (1971) Chromosome replication and the division cycle of Escherichia coli B-r. J Bacteriol 107: 95-99.

67. Kubitschek HE (1974) Estimation of the D period from residual division after exposure of exponential phase bacteria to chloramphenicol. Mol Gen Genet 135: 123-130.

68. Kubitschek HE, Newman CN (1978) Chromosome replication during the division cycle in slowly growing, steady-state cultures of three Escherichia coli B/r strains. J Bacteriol 136: 179-190.

69. Kubitschek HE, Woldringh CL (1983) Cell elongation and division probability during the Escherichia coli growth cycle. J Bacteriol 153: 1379-1387.

70. Kussell E, Leibler S (2005) Phenotypic diversity, population growth, and information in fluctuating environments. Science 309: 2075-2078.

71. Lane HE, Denhardt DT (1975) The rep mutation. IV. Slower movement of replication forks in Escherichia coli rep strains. J Mol Biol 97: 99-112.

72. Leathart JB, Gally DL (1998) Regulation of type 1 fimbrial expression in uropathogenic Escherichia coli: heterogeneity of expression through sequence changes in the fim switch region. Mol Microbiol 28: 371-381.

73. Longo D, Hasty J (2006) Dynamics of single-cell gene expression. Mol Syst Biol 2: 64.

74. Louarn J, Funderburgh M, Bird RE (1974) More precise mapping of the replication origin in Escherichia coli K-12. J Bacteriol 120: 1-5.

75. Low DA, Weyand NJ, Mahan MJ (2001) Roles of DNA adenine methylation in regulating bacterial gene expression and virulence. Infect Immun 69: 7197-7204.

76. Lu M, Campbell JL, Boye E, Kleckner N (1994) SeqA: a negative modulator of replication initiation in E. coli. Cell 77: 413-426.

77. Luria SE, Delbruck M (1943) Mutations of Bacteria from Virus Sensitivity to Virus Resistance. Genetics 28: 491-511.

78. Maaloe O, Hanawalt PC (1961) Thymine deficiency and the normal DNA replication cycle. I. J Mol Biol 3: 144-155.

79. Maamar H, Raj A, Dubnau D (2007) Noise in gene expression determines cell fate in Bacillus subtilis. Science 317: 526-529.

80. Manor H, Deutscher MP, Littauer UZ (1971) Rates of DNA chain growth in Escherichia coli. J Mol Biol 61: 503-524.

81. Marunouchi T, Messer W (1973) Replication of a specific terminal chromosome segment in Escherichia coli which is required for cell division. J Mol Biol 78: 211-228.

82. Meury J, Bahloul A, Kohiyama M (1995) Importance of the replication origin sequestration in cell division of Escherichia coli. Biochimie 77: 875-879.

83. Michelsen O, Teixeira de Mattos MJ, Jensen PR, Hansen FG (2003) Precise determinations of C and D periods by flow cytometry in Escherichia coli K-12 and B/r. Microbiology 149: 1001-1010.

84. Miller J (1972) Experiments in Molecular Genetics. New York: Cold Spring Harbor Laboratory Press.

85. Molina F, Skarstad K (2004) Replication fork and SeqA focus distributions in Escherichia coli suggest a replication hyperstructure dependent on nucleotide metabolism. Mol Microbiol 52: 1597-1612.

86. Mott ML, Berger JM (2007) DNA replication initiation: mechanisms and regulation in bacteria. Nat Rev Microbiol 5: 343-354.

87. Mumm JP, Landy A, Gelles J (2006) Viewing single lambda site-specific recombination events from start to finish. Embo J 25: 4586-4595.

88. Newman CN, Kubitschek HE (1978) Variation in periodic replication of the chromosome in Escherichia coli B/rTT. J Mol Biol 121: 461-471.

89. Nielsen O, Lobner-Olesen A (2008) Once in a lifetime: strategies for preventing re-replication in prokaryotic and eukaryotic cells. EMBO Rep 9: 151-156.

90. Norris TL, Baumler AJ (1999) Phase variation of the lpf operon is a mechanism to evade cross-immunity between Salmonella serotypes. Proc Natl Acad Sci U S A 96: 13393-13398.

91. Onogi T, Niki H, Yamazoe M, Hiraga S (1999) The assembly and migration of SeqA-Gfp fusion in living cells of Escherichia coli. Mol Microbiol 31: 1775-1782.

92. Ozbudak EM, Thattai M, Kurtser I, Grossman AD, van Oudenaarden A (2002) Regulation of noise in the expression of a single gene. Nat Genet 31: 69-73.

93. Painter PR (1974) The relative numbers of different genes in exponential microbial cultures. Genetics 76: 401-410.

94. Pardee AB (1974) A restriction point for control of normal animal cell proliferation. Proc Natl Acad Sci U S A 71: 1286-1290.

95. Powell EO, Errington FP (1963) Generation times of individual bacteria: some corroborative measurements. J Gen Microbiol 31: 315-327.

96. Pritchard RH, Barth PT, Collins J (1969) Control of DNA synthesis in bacteria. SympSocGenMicrobiol 19 263-297.

97. Pritchard RH, Zaritsky A (1970) Effect of thymine concentration on the replication velocity of DNA in a thymineless mutant of Escherichia coli. Nature 226: 126-131.

98. Ramsey S, Ozinsky A, Clark A, Smith KD, de Atauri P, et al. (2006) Transcriptional noise and cellular heterogeneity in mammalian macrophages. Philos Trans R Soc Lond B Biol Sci 361: 495-506.

99. Remaut H, Tang C, Henderson NS, Pinkner JS, Wang T, et al. (2008) Fiber formation across the bacterial outer membrane by the chaperone/usher pathway. Cell 133: 640-652.

100. Rosenfeld N, Young JW, Alon U, Swain PS, Elowitz MB (2005) Gene regulation at the single-cell level. Science 307: 1962-1965.

101. Ryan VT, Grimwade JE, Nievera CJ, Leonard AC (2002) IHF and HU stimulate assembly of pre-replication complexes at Escherichia coli oriC by two different mechanisms. Mol Microbiol 46: 113-124.

102. Sakakibara Y, Yuasa S (1982) Continuous synthesis of the dnaA gene product of Escherichia coli in the cell cycle. Mol Gen Genet 186: 87-94.

103. Sambrook J, Russell DW (2001) Molecular Cloning A Laboratory Manual USA: Cold Spring Harbor Laboratory Press.

104. Schaechter M, Maaloe O, Kjeldgaard NO (1958) Dependency on medium and temperature of cell size and chemical composition during balanced grown of Salmonella typhimurium. J Gen Microbiol 19: 592-606.

105. Schaechter M, Williamson JP, Hood JR, Jr., Kochal (1962) Growth, cell and nuclear divisions in some bacteria. J Gen Microbiol 29: 421-434.

106. Schilling JD, Mulvey MA, Hultgren SJ (2001) Structure and function of Escherichia coli type 1 pili: new insight into the pathogenesis of urinary tract infections. J Infect Dis 183 Suppl 1: S36-40.

107. Sekimizu K, Bramhill D, Kornberg A (1988) Sequential early stages in the in vitro initiation of replication at the origin of the Escherichia coli chromosome. J Biol Chem 263: 7124-7130.

108. Skarstad K, Steen HB, Boye E (1985) Escherichia coli DNA distributions measured by flow cytometry and compared with theoretical computer simulations. J Bacteriol 163: 661-668.

109. Slater S, Wold S, Lu M, Boye E, Skarstad K, et al. (1995) E. coli SeqA protein binds oriC in two different methyl-modulated reactions appropriate to its roles in DNA replication initiation and origin sequestration. Cell 82: 927-936.

110. Sohanpal BK, Kulasekara HD, Bonnen A, Blomfield IC (2001) Orientational control of fimE expression in Escherichia coli. Mol Microbiol 42: 483-494.

111. Sohanpal BK, El-Labany S, Lahooti M, Plumbridge JA, Blomfield IC (2004) Integrated regulatory responses of fimB to N-acetylneuraminic (sialic) acid and GlcNAc in Escherichia coli K-12. Proc Natl Acad Sci U S A 101: 16322-16327.

112. Sohanpal BK, Friar S, Roobol J, Plumbridge JA, Blomfield IC (2007) Multiple co-regulatory elements and IHF are necessary for the control of fimB expression in response to sialic acid and N-acetylglucosamine in Escherichia coli K-12. Mol Microbiol 63: 1223-1236.

113. Stewart EJ, Madden R, Paul G, Taddei F (2005) Aging and death in an organism that reproduces by morphologically symmetric division. PLoS Biol 3: e45.

114. Stocker B (1949) Measurements of rate of mutation of flagellar antigenic phase in Salmonella typhi-murium. J Hyg 47: 398-413.

115. Thattai M, van Oudenaarden A (2004) Stochastic gene expression in fluctuating environments. Genetics 167: 523-530.

116. van der Woude MW, Baumler AJ (2004) Phase and antigenic variation in bacteria. Clin Microbiol Rev 17: 581-611.

117. Veening JW, Smits WK, Kuipers OP (2008) Bistability, epigenetics, and bet-hedging in bacteria. Annu Rev Microbiol 62: 193-210.

118. Veening JW, Stewart EJ, Berngruber TW, Taddei F, Kuipers OP, et al. (2008) Bet-hedging and epigenetic inheritance in bacterial cell development. Proc Natl Acad Sci U S A 105: 4393-4398.

119. Visco P, Allen RJ, Evans MR (2008) Exact Solution of a Model DNA-Inversion Genetic Switch with Orientational Control. Physical Review Letters 101: 11810041-11810044.

120. Wold S, Skarstad K, Steen HB, Stokke T, Boye E (1994) The initiation mass for DNA replication in Escherichia coli K-12 is dependent on growth rate. Embo J 13: 2097-2102.

121. Wolf DM, Arkin AP (2002) Fifteen minutes of fim: control of type 1 pili expression in E. coli. Omics 6: 91-114.

122. Wolf DM, Vazirani VV, Arkin AP (2005) Diversity in times of adversity: probabilistic strategies in microbial survival games. J Theor Biol 234: 227-253.

123. Wolf DM, Vazirani VV, Arkin AP (2005) A microbial modified prisoner's dilemma game: how frequency-dependent selection can lead to random phase variation. J Theor Biol 234: 255-262.

124. Xia Y, Gally D, Forsman-Semb K, Uhlin BE (2000) Regulatory cross-talk between adhesin operons in Escherichia coli: inhibition of type 1 fimbriae expression by the PapB protein. Embo J 19: 1450-1457.

125. Yamazoe M, Adachi S, Kanaya S, Ohsumi K, Hiraga S (2005) Sequential binding of SeqA protein to nascent DNA segments at replication forks in synchronized cultures of Escherichia coli. Mol Microbiol 55: 289-298.

126. Yoshikawa H, O'Sullivan A, Sueoka N (1964) Sequential Replication of the Bacillus Subtilis Chromosome. 3. Regulation of Initiation. Proc Natl Acad Sci U S A 52: 973-980.

127. Yu J, Xiao J, Ren X, Lao K, Xie XS (2006) Probing gene expression in live cells, one protein molecule at a time. Science 311: 1600-1603.

128. Zaritsky A (1975) Rate stimulation of deoxyribonucleic acid synthesis after inhibition. J Bacteriol 122: 841-846.