The diagram illustrates the cell cycle with the following stages:

- **G1**: Cell growth phase.
- **S**: DNA replication phase.
- **G2**: Premitotic growth phase.
- **M**: Mitosis phase.

The cycle progresses from the G1 phase, moves to S for replication, and then to G2 before entering the M phase, which includes mitosis.
Classical genetic analysis of the cell cycle in fission yeast
Identification of the CDK cdc2
Edinburgh, Zoology 1973-1980

Murdoch Mitchison

Urs Leupold
Genetic Control of the Cell Division Cycle
In the Fission Yeast *Schizosaccharomyces pombe*
Paul Nurse, Pierre Thuriaux and Kim Nasmyth
Department of Zoology, West Mains Road, Edinburgh EH9 3JT, UK.
Institut für Allgemeine Mikrobiologie, Universität Bern, Altenbergrain 21, CH 3013 Bern, Switzerland
Cell mass

'wee' cell cycle

'wee' advanced through cell cycle

'cdc' cell cycle block

'cdc' delayed through cell cycle

Time
Genetic control of cell size at cell division in yeast

Paul Nurse
Department of Zoology, West Mains Road, Edinburgh EH9 3JT, UK

Peter Fantes
Regulatory genes controlling mitosis in the Fission Yeast *Schizosaccharomyces pombe*

Paul Nurse and Pierre Thuriaux

| Strain                               | Cell length at septation | %  
|--------------------------------------|--------------------------|-----
| wee1+ sup3-5 ade6-704                | 14.7                     | 100 |
| wee1-112 sup3+ ade6-704              | 7.5                      | 51  |
| wee1-112 sup3-5 ade6-704             | 13.1                     | 89  |
| wee1+ sup+ ade6-704                  | 15.0                     | 102 |
Genetics 96: 627-637, November, 1980

### Table 1: Cell length at septation in haploid strain grown at 25\(^\circ\)C and heterozygous cdc2\(^+\)/cdc2\(^{-}\) diploid strain grown at 35\(^\circ\)C

<table>
<thead>
<tr>
<th>cdc2(^{-}) allele tested</th>
<th>Cell length at septation in haploid strain grown at 25(^\circ)C</th>
<th>Cell length at septation in heterozygous cdc2(^+)/cdc2(^{-}) diploid strain grown at 35(^\circ)C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\mu m)</td>
<td>%</td>
</tr>
<tr>
<td>cdc2-L7</td>
<td>14.6</td>
<td>112</td>
</tr>
<tr>
<td>cdc2-M26</td>
<td>13.8</td>
<td>106</td>
</tr>
<tr>
<td><strong>cdc2-33</strong></td>
<td>14.2</td>
<td>109</td>
</tr>
<tr>
<td>cdc2-M35</td>
<td>22.4</td>
<td>172</td>
</tr>
<tr>
<td>cdc2-M55</td>
<td>13.6</td>
<td>105</td>
</tr>
<tr>
<td>cdc2-56</td>
<td>10.2</td>
<td>79</td>
</tr>
<tr>
<td>cdc2-M63</td>
<td>16.7</td>
<td>128</td>
</tr>
<tr>
<td>cdc2-M72</td>
<td>13.4</td>
<td>103</td>
</tr>
<tr>
<td>cdc2-M76</td>
<td>13.6</td>
<td>105</td>
</tr>
<tr>
<td>cdc2-130</td>
<td>10.0</td>
<td>77</td>
</tr>
</tbody>
</table>

### Dominance relations of cdc2 alleles when the mutant allele is active

<table>
<thead>
<tr>
<th>Strain</th>
<th>Temperature of growth</th>
<th>Cell length at septation</th>
<th>Mean protein content per cell</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\mu m)</td>
<td>%</td>
<td>pg/cell</td>
</tr>
<tr>
<td>cdc2(^+)/cdc2(^+)</td>
<td>35(^\circ)</td>
<td>23.9</td>
<td>100</td>
</tr>
<tr>
<td>cdc2(^+)/cdc2-1w</td>
<td>35(^\circ)</td>
<td>15.6</td>
<td>65</td>
</tr>
<tr>
<td><strong>cdc2-1w/cdc2-1w</strong></td>
<td>35(^\circ)</td>
<td>13.4</td>
<td>56</td>
</tr>
<tr>
<td>cdc2(^+)/cdc2(^+)</td>
<td>25(^\circ)</td>
<td>20.3</td>
<td>100</td>
</tr>
<tr>
<td>cdc2(^+)/cdc2-56</td>
<td>25(^\circ)</td>
<td>16.6</td>
<td>82</td>
</tr>
<tr>
<td>cdc2(^+)/cdc2-130</td>
<td>25(^\circ)</td>
<td>16.9</td>
<td>83</td>
</tr>
<tr>
<td>cdc2-56/cdc2-56</td>
<td>25(^\circ)</td>
<td>15.2</td>
<td>75</td>
</tr>
<tr>
<td>cdc2-130/cdc2-130</td>
<td>25(^\circ)</td>
<td>15.8</td>
<td>78</td>
</tr>
</tbody>
</table>
Gene required in $G_1$ for commitment to cell cycle and in $G_2$ for control of mitosis in fission yeast

Paul Nurse & Yvonne Bissett

---

**Table 1**  % Conjugation for each temperature regime

<table>
<thead>
<tr>
<th>cdc Mutant</th>
<th>36/33°C</th>
<th>25/25°C</th>
<th>25/33°C</th>
<th>Viability</th>
<th>Can Cells Conjugate at this Block?</th>
</tr>
</thead>
<tbody>
<tr>
<td>cdc 1.7</td>
<td>0.046</td>
<td>76.2</td>
<td>10.4</td>
<td>47.6</td>
<td>No</td>
</tr>
<tr>
<td>cdc 2.33</td>
<td>30.9</td>
<td>106</td>
<td>105</td>
<td>97.1</td>
<td>Yes</td>
</tr>
<tr>
<td>cdc 2.M63</td>
<td>19.0</td>
<td>112</td>
<td>129</td>
<td>32.7</td>
<td>No</td>
</tr>
<tr>
<td>cdc 6.23</td>
<td>3.09</td>
<td>52.6</td>
<td>37.4</td>
<td>20.8</td>
<td>No</td>
</tr>
<tr>
<td>cdc 10.129</td>
<td>138</td>
<td>94.6</td>
<td>88.2</td>
<td>78.1</td>
<td>Yes</td>
</tr>
<tr>
<td>cdc 10.K28</td>
<td>108</td>
<td>101</td>
<td>117</td>
<td>56.4</td>
<td>No</td>
</tr>
<tr>
<td>cdc 13.117</td>
<td>0.205</td>
<td>60.3</td>
<td>33.5</td>
<td>59.4</td>
<td>No</td>
</tr>
<tr>
<td>cdc 17.K42</td>
<td>0.295</td>
<td>29.0</td>
<td>31.9</td>
<td>58.7</td>
<td>No</td>
</tr>
<tr>
<td>cdc 22.M45</td>
<td>4.44</td>
<td>51.2</td>
<td>42.8</td>
<td>87.3</td>
<td>No</td>
</tr>
<tr>
<td>cdc 23.M36</td>
<td>2.93</td>
<td>72.0</td>
<td>51.0</td>
<td>65.8</td>
<td>No</td>
</tr>
<tr>
<td>cdc 24.M38</td>
<td>2.83</td>
<td>80.3</td>
<td>119</td>
<td>19.2</td>
<td>No</td>
</tr>
<tr>
<td>cdc 25.22</td>
<td>0.086</td>
<td>36.7</td>
<td>14.0</td>
<td>57.6</td>
<td>No</td>
</tr>
<tr>
<td>cdc 27.K8</td>
<td>4.98</td>
<td>93.9</td>
<td>78.6</td>
<td>56.9</td>
<td>No</td>
</tr>
</tbody>
</table>
Molecular characterisation of the CDK cdc2 protein kinase

Sussex, Biology 1980-1984
ICRF, LIF London 1984-1988

David Beach
Barbara Durkacz
Kathy Gould
Jacky Hayles

Sergio Moreno
Paul Russell
Viesturs Simanis
High-frequency transformation of the fission yeast *Schizosaccharomyces pombe*

David Beach & Paul Nurse

Functionally homologous cell cycle Control genes in budding and fission yeast

David Beach, Barbara Durkacz & Paul Nurse
The Cell Cycle Control Gene cdc2\(^+\) of Fission Yeast Encodes a Protein Kinase Potentially Regulated by Phosphorylation

Viesturs Simanis and Paul Nurse
Cell Cycle Control Laboratory
Imperial Cancer Research Fund, P. O. Box 123
Lincoln's Inn Fields
London WC2A 3PX England

Regulation of p34\(^{cdc2}\) Protein Kinase during Mitosis

Sergio Moreno, Jacqueline Hayles, and Paul Nurse
ICRF Cell Cycle Control Group
Microbiology Unit, Department of Biochemistry
University of Oxford
Oxford OX1 3QU
England

Sergio Moreno
**cdc25** Functions as an Inducer in the Mitotic Control of Fission Yeast

Paul Russell and Paul Nurse  
Cell Cycle Control Laboratory  
Imperial Cancer Research Fund  
Lincoln's Inn Fields  
London, WC2A 3PX, England

**Negative Regulation of Mitosis by wee1**, a Gene Encoding a Protein Kinase Homolog

Paul Russell and Paul Nurse  
Cell Cycle Control Laboratory  
Imperial Cancer Research Fund  
Lincoln’s Inn Fields  
London WC2A 3PX, England
Tyrosine phosphorylation of the fission yeast \textit{cdc2}^{+} protein kinase regulates entry into mitosis

Kathleen L. Gould & Paul Nurse

ICRF Cell Cycle Group, Microbiology Unit, Department of Biochemistry, University of Oxford, South Parks Road, Oxford OX1 3QU, UK

Kathy Gould
Cloning and sequencing of the cyclin-related $c_{dc13}^+$ gene and a cytological study of its role in fission yeast mitosis

IAIN HAGAN, JACQUELINE HAYLES* and PAUL NURSE

ICRF Cell Cycle Control Laboratory, Microbiology Unit, Department of Biochemistry, University of Oxford, South Parks Road, Oxford, OX1 3QU

*Author for correspondence
G2

\[ \text{p80cdc25} \rightarrow \text{ppa2} \rightarrow \text{G2} \rightarrow \text{M} \]

\[ \text{cdc1} \rightarrow \text{cdc27} \]

\[ \text{p34cdc2} \rightarrow \text{p56cdc3} \rightarrow \text{wist} \rightarrow \text{p107weel} \rightarrow \text{mkl} \rightarrow \text{nml1 (cdr1)} \rightarrow \text{pyp1/2} \rightarrow \text{pyp3} \]
Cdc2 conserved in humans, starfish and frogs

ICRF, LIF London 1984-1988

Marcel Doree
Iain Hagan
Jacky Hayles

Melanie Lee
Jim Maller
Chris Norbury
Complementation used to clone a human homologue of the fission yeast cell cycle control gene *cdc2*

Melanie G. Lee & Paul Nurse
Cell Cycle Control Laboratory, Imperial Cancer Research Fund, Lincoln’s Inn Fields, London, WC2A 3PX, UK

---

**Melanie Lee**
Rare plasmid containing the cdc gene

Transformation

Plasmid with correct cdc gene complements defective cdc gene

cdc gene is defective

cdc cells die

cells divide and form colonies on plate
Purified Maturation-Promoting Factor Contains the Product of a Xenopus Homolog of the Fission Yeast Cell Cycle Control Gene cdc2$^+$

Jean Gautier,* Chris Norbury,†
Manfred Lohka,* ‡ Paul Nurse,†
and James Maller*

*Department of Pharmacology
University of Colorado School of Medicine
Denver, Colorado 80262
†ICRF Cell Cycle Control Laboratory
Microbiology Unit
Department of Biochemistry
University of Oxford
Oxford OX13QU, England
Yoshio Masui
Purified Maturation-Promoting Factor Contains the Product of a Xenopus Homolog of the Fission Yeast Cell Cycle Control Gene cdc2¹

Jean Gautier,‡ Chris Norbury,‡
Manfred Lohka,‡ Paul Nurse,‡
and James Maller*‡
*Department of Pharmacology
University of Colorado School of Medicine
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†ICRF Cell Cycle Control Laboratory
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Department of Biochemistry
University of Oxford
Oxford OX13QU, England

Jim Maller

Western

IP
Purification of MPF from Starfish: Identification as the H1 Histone Kinase $p34^{cdc2}$ and a Possible Mechanism for Its Periodic Activation

J. C. Labbe,* A. Picard,† G. Peaucellier,‡ J. C. Cavadore,* R. Nurse,§ and M. Doree*
* CNRS and INSERM
BP 5051
34033 Montpellier Cedex
France
† Laboratoire Arago
66650 Banyuls-sur-Mer
France
‡ Station Biologique
29211 Roscoff
France
§ ICRF Cell Cycle Control Laboratory
Microbiology Unit
Department of Biochemistry
South Parks Road
Oxford OX1 3QU
England


Activation at M-phase of a protein kinase encoded by a starfish homologue of the cell cycle control gene $cdc2^*$

J. C. Labbe*, M. G. Lee†, P. Nurse†, A. Picard* & M. Doree*
* CNRS and INSERM, BP 5051, 34033 Montpellier, Cedex, France
† ICRF Cell Cycle Control Laboratory, Microbiology Unit,
Department of Biochemistry, University of Oxford,
South Parks Road, Oxford OX1 3QU, UK

Marcel Doree
Universal control mechanism regulating onset of M-phase

Paul Nurse

The onset of M-phase is regulated by a mechanism common to all eukaryotic cells. Entry into M-phase is determined by activation of the p34\(^{\text{cdc2}}\) protein kinase which requires p34\(^{\text{cdc2}}\) dephosphorylation and association with cyclin.
the essential cell cycle

- G1
- M
- G2
- S

- CDK2/E
- CDK2/A
- Cdc2/B
- Cdc2/A
We have seen that all organisms are composed of essentially like parts, namely, of cells; that these cells are formed and grow in accordance with essentially the same laws; hence, that these processes must everywhere result from the operation of the same forces.

Schwann 1839
Further roles for cdc2

ICRF, LIF London 1993-2001

Tamar Enoch
Daniel Brock

Jacky Hayles
Sergio Morenó
Mutation of Fission Yeast Cell Cycle Control Genes Abolishes Dependence of Mitosis on DNA Replication

Tamar Enoch and Paul Nurse
ICRF Cell Cycle Group
Microbiology Unit
Department of Biochemistry
Oxford University
Oxford OX1 3QU
England

Tamar Enoch
A single fission yeast mitotic cyclin B p34cdc2 kinase promotes both S- phase and mitosis in the absence of G1 cyclins

D.L.Fisher and P.Nurse
Cell Cycle Laboratory, Imperial Cancer Research Fund, London, UK.
Temporal Order of S Phase and Mitosis in Fission Yeast Is Determined by the State of the p34^{cd}c2-Mitotic B Cyclin Complex

Jacqueline Hayles, Daniel Fisher, Alison Woollard, and Paul Nurse
Cell Cycle Laboratory
Imperial Cancer Research Fund
Lincoln's Inn Fields
London WC2A 3PX
England
A Long Twentieth Century of the Cell Cycle and Beyond

Paul Nurse
Cell Cycle Laboratory
Imperial Cancer Research Fund
44 Lincoln’s Inn Fields
London WC2A 3PX
United Kingdom

1. CDKs and cell cycle events
2. Checkpoints
3. Meiotic cell cycles
4. Cell cycle and development
5. Cell cycle molecular machines
6. Spatial and temporal organisation