Corynebacterium glutamicum

From Systems Biology to Biotechnological Applications

Edited by

Andreas Burkovski

Department of Biology University of Erlangen-Nuremberg Erlangen Germany

Copyright © 2015

Caister Academic Press Norfolk, UK

www.caister.com

British Library Cataloguing-in-Publication Data A catalogue record for this book is available from the British Library

ISBN: 978-1-910190-05-0 (hardback) ISBN: 978-1-910190-06-7 (ebook)

Description or mention of instrumentation, software, or other products in this book does not imply endorsement by the author or publisher. The author and publisher do not assume responsibility for the validity of any products or procedures mentioned or described in this book or for the consequences of their use.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publisher. No claim to original U.S. Government works.

Cover design adapted from Figure 4.1

Contents

	V
	ix
	erium glutamicum Research and Application 1
	ebacterium glutamicum 11 ar Poetsch
	tion of Intracellular Metabolism of tamicum by Using Flux Analysis Technology 25 oshi Shimizu
	on Capabilities of <i>Corynebacterium</i> ating a Genome-scale Metabolic Network Model 39 a Nöh and Wolfgang Wiechert
	g of <i>Corynebacterium glutamicum</i> for burce Utilization 57 d Zahoor, Steffen N. Lindner and Volker F. Wendisch
i	gen Metabolism and Alternative Nitrogen acterium glutamicum 71 ger and Andreas Burkovski
	on and Assimilation of Aromatic Compounds n Corynebacterium glutamicum 83 g Xu, Ning-Yi Zhou and Shuang-Jiang Liu
1	acterium glutamicum for the Production of cohols 111 and Michael Bott
1	the Production of Polyesters: A New Platform <i>alutamicum</i> ani Nduko, Ken'ichiro Matsumoto and Seiichi Taguchi
	on Capabilities of Corynebacterium ating a Genome-scale Metabolic Network Model a Nöh and Wolfgang Wiechert g of Corynebacterium glutamicum for ource Utilization d Zahoor, Steffen N. Lindner and Volker F. Wendisch gen Metabolism and Alternative Nitrogen acterium glutamicum ger and Andreas Burkovski on and Assimilation of Aromatic Compounds on Corynebacterium glutamicum g Xu, Ning-Yi Zhou and Shuang-Jiang Liu acterium glutamicum for the Production of cohols ond Michael Bott the Production of Polyesters: A New Platform

iv | Contents

caister.com/cory2

10	Biotechnological Application of <i>Corynebacterium glutamicum</i> Under Oxygen Deprivation Toru Jojima, Masayuki Inui and Hideaki Yukawa	151
11	Corynebacterium glutamicum as a Platform Organism for the Secretory Production of Heterologous Proteins Roland Freudl	161
12	Genetically Encoded Biosensors for Strain Development and Single-cell Analysis of Corynebacterium glutamicum Nurije Mustafi, Michael Bott and Julia Frunzke	179
	Index	197
	Colour Plate	A1

Preface

Corynebacterium glutamicum is most widely known for its role in the industrial production of L-glutamate and L-lysine and as a platform organism for the production of a variety of fine chemicals, biofuels and polymers. The organism's accessibility to genetic manipulation has resulted in a wealth of data on its metabolism and regulatory networks; this in turn makes *C. glutamicum* the model organism of choice in white biotechnology.

The book provides a comprehensive overview of current knowledge and research on *C. glutamicum* systems biology and biotechnological applications. It summarizes the recent advances of analysis approaches as well as the progress

made in respect of new products and applications as well as the utilization of a broader spectrum of nutrient sources by *C. glutamicum*. Topics covered include proteomics, flux analysis of metabolism, metabolic engineering for alternative carbon source utilization, manipulation of nitrogen metabolism, transport, degradation and assimilation of aromatic compounds, engineering for production of organic acids and alcohols, microbial factory for the production of polyesters, biotechnological application oxygen deprivation, the secretory production of heterologous proteins and the development of genetically encoded biosensors.

Index

Carbon sources 58 13C-MFa 28, 33-34, 173 15N labelling 16-18 2D-DIGE 12 2D gels 11, 20 see also 2-D PAGE 2-D PAGE 2-Net object at 124, 125 2-Ketoisocaproate 124, 126 2-Ketoisocaproate 124, 125 2-Coogularate dehydrogenase 74-75 3-Hydroxyheracate degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate degradation 95 Acetylation 18 Adenylylation 72 Adenylylation 72 Adenylylation 72 Alectolotic catabolism 112 Alectolot catabolism 112 Alectoloty and an analysis 43 Alectory and an analysis 43 Alemantic carbon sources 59 Alternative carbon sources 76 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic compounds 58 B Benzoate transporter 94 Aromatic compounds 58 B Benzoate transporter 18, 92 β-Ketodipate pathway 94-95 Bio-based polymers 139 Biomass composition 48 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179-181 Carbon sources 58 Catchol branch 96 Cellobiose 62 Cellulose 62 Chitin 65, 77 CoBRA 43 Constraint-based reconstruction and analysis 43 Constraint-based reconstruction analysis 43 Constraint-based reconstruction analysis		
19C-metabolic flux analysis 49, 51 19C-MEA 28, 33-34, 173 19C-MEA 28 19D-MEA 28, 33-34, 173 19C-MEA 28, 33-34 19C-MEA 28 19C	¹³ C labelling 29	С
Jac. MA 28, 33–34, 173 ISN labelling 16–18 2D-DIGE 12 Digels 11, 20 See also 2-D PAGE 2D-PAGE 2, 12, 14 2-Ketoglutarate 124, 126 2-Ketoisocaproate 124, 126 2-Ketoisocaproate 124, 125 2-Oxoglutarate dehydrogenase 74–75 3-Hydroxyyelarate 134 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 A Cetylation 18 Adenylytanis 72 Adenylytransferase 72 Aerobic catabolism 112 AlEC 14, 15 Alcohol production 127 a-Amylase 145 a-Ketoglutarate 74 see also 2-Ketoisouraproate 124, 126 CoryneBrick vectors 3 Co-utilization of carbon sources 58 Crude glycerol 65 Degradation of aromatic compounds 90–91 Diauxic growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 F FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Fax 3-Mydase 145 a-Ketoglutarate 74 see also 2-Ketoisouraproachy see AIEC Annonnium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arbinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate degradation 97 Benzoate degradation 96 Benzoate degradation 97 Glutamate production 1, 26, 27 Glutamate synthase 74 Glutamate techydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate techydrogenase 71, 73 Glutamate techydrogenase 71, 73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 133, 156–157 H Heterologous proteins 166–167		-
ISN labelling 16–18 2D-DIGE 12 2D gels 11, 20 see also 2-D PAGE 2D PAGE 2, 12, 14 2-Ketolyatrate 124 See also a-Ketoglutarate 2-Ketoisocaproate 124, 126 2-Ketoisovalerate 124, 126 2-Ketoisovalerate 124, 125 2-Kosol degradation 95 3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 96 4-Retodipta exident 94 4-Rapelotic pathway 25, 28 4-Retodipta exident 94 4-Rapelotic pathway 25, 28 4-Romonieum assimilation 71 4-Ramonium transport 75 4-Raneorbic catabolism 113 4-Raneorbic production 4 4-Rapelotic pathway 25, 28 4-Romonieum assimilation 71 4-Ramonium transport 75 4-Raneorbic catabolism 113 4-Romonium assimilation 71 4-Raneorbic production 4 4-Rapelotic pathway 25, 28 4-Romonieum assimilation 71 4-Raneorbic production 4 4-Rapelotic pathway 25, 28 4-Romonieum assimilation 71 4-Romonium transport 94 4-Romonium assimilation 71 4-Romonium transport 94 4-Romonium assimilation 71 4-Romonium transport 94 4-Romonium assimilation 71 4-Romonium transport 75 4-Retodipate pathway 94–95 6-Retodipate pathway		
2D-DIGE 12 Degls 11, 20 see also 2-D PAGE 2D pAGE 2, 12, 14 See also a-Ketoglutarate 124 see also a-Ketoglutarate 124, 125 2-Oxoglutarate dehydrogenase 74-75 3-Hydroxyvalerate 124, 125 2-Oxoglutarate dehydrogenase 74-75 3-Hydroxybenzoate degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 Acetylation 18 Adenylylatron 72 Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 a-Amylase 145 a-Ketoglutarate 74 see also 2-Ketoglutarate Alternative airtogen sources 59 Alternative nitrogen sources 59 Alternative nitrogen sources 76 Ammonium transport 75 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Analerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic compounds 58 Benzoate degradation 96 Benzoate degradation 96 Benzoate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 F-Ketodipate pathway 94-95 Bio-based polymers 139 Bioenass composition 48 Bio-based polymers 139 Biosensors 179-181 Cellulose 62 Chtint 65, 77 COBRA 43 Constraint-based reconstruction and analysis 43 Copplmer 143 Copplmer 143 Constraint-based reconstruction and analysis 43 Copplmer 143 Copplemer 148 Coutilitation of carbon sources 58 Crude glycerol 65 Cutilitation of carbon sources 58 Crude glycerol 65 Cutilitation of carbon sources 58 Crude glycerol 65 Cutilitation of carbon sources 58 Crude glycerol 65 Coutilitat	ART CONTRACTOR CONTRAC	
2D gels 11, 20 sec also 2-D PAGE 2-D PAGE 2-D PAGE 2, 12, 14 2-Ketolgutarate 124 see also a-Ketoglutarate 2-Ketoisocaproate 124, 126 2-Ketoisocaproate 124, 126 2-Ketoisocaproate 124, 126 2-Ketoisovalerate 124, 125 3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 Acetylation 18 Acetylation 18 Acetylation 18 Achenylylation 72 Adenylyltransferase 72 Arerobic catabolism 112 AREC 14, 15 Alcohol production 127 a-Amylase 145 a-Ketoglutarate 74 see also 2-Ketoglutarate 74 see also 2-K	·	
See also 2-D PAGE 2-D PAGE 2-D PAGE 2-D PAGE 2-D PAGE 2-Retoglutarate 124 See also a-Ketoglutarate 2-Ketoisovalerate 124, 125 2-Ketoisovalerate 124, 125 2-Rosoglutarate dehydrogenase 74–75 3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate transporter 94 Acetylation 18 Adenylyltansferase 72 Aerobic catabolism 112 AIEC 14, 15 AIEC 14, 15 AICohol production 127 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative introgen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate transporter 18, 92 F-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biosensors 179–181 Constraint-based reconstruction and analysis 43 Constraint-based reconstruction 3 Coutilization of carbon sources 58 Crude glycerol 65 D Degradation of aromatic compounds 90–91 Diauxic growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 F F FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 G G Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome scale reconstruction 40, 42 Genome breeding 1, 2 Genome scale reconstruction 40, 42 Genome breeding 1, 2 Genome		
2-D PAGE 2, 12, 14 2-Ketoglutarate 124 see also a-Ketoglutarate 2-Ketoisocaproate 124, 126 2-Ketoisocaproate 124, 125 2-Oxoglutarate dehydrogenase 74–75 3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 A cetylation 18 A deenylylation 72 Adenylyltransferase 72 Adenylyltransferase 72 Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Glutamate synthase 74 Glutamate synthase 74 Glutamate synthase 72 Glycerol 63 Conutilization of carbon sources 58 Crude glycerol 65 D Degradation of aromatic compounds 90–91 Diauxic growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 Goneme annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate synthase 74 Glutamate synthase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167		
2-Ketoglutarate 124 2-Ketoisovalerate 124, 126 2-Ketoisovalerate 124, 125 2-Oxoglutarate dehydrogenase 74–75 3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 A Cetylation 18 A denylylation 72 Adenylylatron 72 Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative ratrosporter 75 Anaerobic catabolism 113 Anaerobic pathway 25, 28 Anion exchange chromatography see AIEC Anabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B enzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fules 4 Bio-based polymers 139 Biosensors 179–181 Copolpmer 143 CoryneBrick vectors 3 Co-utilization of carbon sources 58 Crude glycerol 65 D Degradation of aromatic compounds 90–91 Diauxic growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 E Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate synthase 74 Glutamate transporter 93 Global regulation 104 Glucosamine 63 Glutamate production 1, 26, 27 Glutamate synthase 74 Glutamate transport 75 Glutamite synthease 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth 39 Degradation of aromatic compounds 90–91 Diauxic growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 Galactose 61–62 Genome annotation 40 Genome scale reconstruction 40, 42 Gentisate pathway 97 Gentisate pathway 94 Global regulation 104 Growth are also proved in the province of the proved in the province of the province of the province of the province of th		
see also a-Ketoglutarate 2-Ketoisocaproate 124, 126 2-Ketoisocaproate 124, 125 2-Oxoglutarate dehydrogenase 74–75 3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 Acetylation 18 Acetylation 18 Adenylylation 72 Adenylyltransferase 72 Adenylyltransferase 72 Adenylyltransferase 72 Adenylyltransferase 72 Adenylyltransferase 72 Alerobic catabolism 112 AIEC 14, 15 Alcohol production 127 a-Amylase 145 a-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 59 Alternative nitrogen sources 59 Alternative nitrogen sources 76 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic catabolism 113 Anaerobic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biosensors 179–181 CorvneBrick vectors 3 Co-utilization of arbons ources 58 Crude glycerol 65 Corude glycerol 65 Corude glycerol 65 Corude glycerol 65 Courtle glycerol 65 Crude glycerol 65 Crude glycerol 65 Courtle glycerol 65 Cutue glycerol 65 Cute glycerol 65		
2-Ketoisocaproate 124, 126 2-Ketoisocaproate 124, 126 2-Ketoisovalerate 124, 125 2-Oxoglutarate dehydrogenase 74–75 3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 Acetylation 18 Adenylylation 72 Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 A-Ketoglutarate 74	· · · · · · · · · · · · · · · · · · ·	
2-Ketoisovalerate 124, 125 2-Oxoglutarate dehydrogenase 74–75 3-Hydroxyyclarate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate teransporter 94 Acetylation 18 Adenylylation 72 Adenylyltransferase 72 Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative introgen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biosensors 179–181 Crude glycerol 65 D Degradation of aromatic compounds 90–91 Diauxic growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 F F F F F F F F F F F F F F F F F F		
2-Oxoglutarate dehydrogenase 74–75 3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 Acetylation 18 Acetylation 18 Adenylylation 72 Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biomass composition 48 Bio-based polymers 139 Biosensors 179–181 Degradation of aromatic compounds 90–91 Diauxic growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 FACS 189 FRA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 G Galactose 61–62 Genome annotation 40 Genome hereding 1, 2 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Gentisate transporter 93 Gliobal regulation 104 Gliucosamine 63 Glutamate dehydrogenase 71, 73 Glutamate dehydrogenase 71, 73 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167	2	
3-Hydroxyvalerate 143 4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 Acetylation 18 Acetylation 72 Adenylylation 72 Adenylylation 72 Adenylylation 72 Alerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative nitrogen sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biosensors 179–181 Degradation of aromatic compounds 90–91 Diauxic growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 FR Galactose 61–62 Genome sealereorstruction 40, 42 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Genome-scale reconstruction 40, 42 Genome scale reconstruction 40, 42 Genome scale reconstruction 40, 42 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate groduction 1, 26, 27 Glutamate synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167		Crude glycerol 65
4-Cresol degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 A A A A A A A A A A A A A		n
4-Hydroxybenzoate degradation 95 4-Hydroxybenzoate transporter 94 A Cetylation 18 A Catylation 72 Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biosensors 179–181 B Ethanol 127–128 Ethanol 127–128 FR Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Gentisate pathway 97 Glutamate dehydrogenase 71, 73 Glutamate ehydrogenase 71, 73 Glutamate synthase 74 Glutamate synthase 74 Glutamate synthase 74 Glutamate synthetase 72 Glycerol 63–64, 65, 117 Green technology 4 Growth 59 Dicarboxylic acids 11, 63 E Ethanol 127–128 FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 Galactose 61–62 Genome-annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Glutamate dehydrogenase 71, 73 Glutamate dehydrogenase 71, 73 Glutamate synthase 74 Glutamate synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167		U
A Acetylation 18 Acetylation 72 Adenylylation 72 Adenylylation 72 Adenylylation 72 Alenylylation 74 Alerolic catabolism 112 Alenylylation 75 Alenarity and alenylation 74 Alenylase 145 Alenylase 146 Alenylase 147 Alenylase 147 Alenylase 147 Alenylase 148 Alenylase 148 Alenylase 147 Alenylase 148 Alenylase 149 Alenylase 148 Alenylase 149 Alenylase 1		Degradation of aromatic compounds 90–91
A Acetylation 18 Adenylylation 72 Adenylyltransferase 72 Adenylytransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biosensors 179–181 Biosensors 179–181 Ethanol 127–128 FACS 189	· · · · · ·	Diauxic growth 59
Acetylation 18 Adenylylation 72 Adenylyltransferase 72 Adenylyltransferase 72 Aerobic catabolism 112 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biosensors 179–181 Ethanol 127–128 F Ethanol 127–128 Ethanol 127–128 F Ethanol 127–128 Ethanol 127–128 F Extos 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 G G Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Genome-scale reconstruction 40, 42 Genome-scale reconstruction 40, 42 Genome scale reconstruction 40, 42 Genome-scale reconstruction 40, 42 Genome scale reconstruction 40 Galactose 61–62 Genome scale reconstruction 40 Galactose 61–62 Genome scale reconstruction 40 Genome sca	4-Hydroxybenzoate transporter 94	Dicarboxylic acids 11, 63
Acetylation 18 Adenylylation 72 Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Be Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biosensors 179–181 Ethanol 127–128 F F F F F FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 G G G Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Genome scale reconstruction 40, 42 Genome	A	E
Adenylylation 72 Adenylyltransferase 72 Aerobic catabolism 112 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium sasimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Be Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Bio-based polymers 139 Biosensors 179–181 Heterologous proteins 166–167 ARCS 189 FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 Genome breeding 1, 2 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Genitsate transporter 93 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate transport 75 Glutamate synthase 74 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167	Acetylation 18	
Adenylyltransferase 72 Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative nitrogen sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 FACS 189 FBA 43–44, 47 Flow cytometry Flow cytometry FBA 43–44, 47 Flow cytometry Flow cytometry FBA 43–44, 47 Flow cytometry Flow cytometry FBA 43–44, 47 Flow cytometry Flux balance analysis 43, 48 Galactose 61–62 Genome-scale reconstruction 40 Genome-scale rec	Adenylylation 72	Ethanol 12/-128
Aerobic catabolism 112 AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 FACS 189 FBA 43-44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 Galactose 61–62 Genome annotation 40 Genome annotation		F
AIEC 14, 15 Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 FACS 189 FBA 43–44, 47 Flow cytometry 191–192 Flux balance analysis 43, 48 Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate synthase 74 Glutamate production 1, 26, 27 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167		-
Alcohol production 127 α-Amylase 145 α-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative introgen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Analerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Flow cytometry 191–192 Flux balance analysis 43, 48 Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glutamate dehydrogenase 71, 73 Glutamate ethydrogenase 71, 73 Glutamate synthase 74 Glutamate synthase 74 Glutamate synthase 74 Glutamate synthase 74 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167		
a-Amylase 145 a-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Flow Cytomierly 191–192 Flux balance analysis 43, 48 Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Genome-scale reconstruction 40, 42 Genome-scale reconstruction 40, 42 Genome annotation 40 Genome annotation 40 Genome annotation 40 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Genome annotation 40 Genome annotation 40 Genome breeding 1, 2 Genome annotation 40 Genome breeding 1, 2 Genome annotation 40 Genome breeding 1, 2 Genome breeding 1, 2 Genome annotation 40 Genome breeding 1, 2 Genome annotation 40 Genome breeding 1, 2 Genome breeding 1, 2 Genome annotation 40 Genome breeding 1, 2 Genome br		
a-Ketoglutarate 74 see also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Be Benzoate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate dehydrogenase 71, 73 Glutamate transport 75 Glutamate transport 75 Glutamine synthetase 74 Glutamate transport 75 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167		
See also 2-Ketoglutarate Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Galactose 61–62 Galactose 61–62 Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Gentisate pathway 97 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate dehydrogenase 71, 73 Glutamate transport 75 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167	` .	Flux balance analysis 43, 48
Alternative carbon sources 59 Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Galactose 61–62 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Gentisate pathway 97 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucoses 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate synthase 74 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167		G
Alternative nitrogen sources 76 Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate pathway 97 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate synthase 74 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167		
Ammonium assimilation 71 Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Genome annotation 40 Genome breeding 1, 2 Genome-scale reconstruction 40, 42 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate synthase 74 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167	and the second s	Galactose 61–62
Ammonium transport 75 Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Genome breeding 1, 2 Genotiate pathway 97 Gentiate pathway 97 Glubal regulation 104 Glucosamine 63		Genome annotation 40
Anaerobic catabolism 113 Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Bespeciate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Genoms-scale reconstruction 40, 42 Gentisate transporter 93 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate transport 75 Glutamate transport 75 Glutamate synthase 74 Glutamate synthase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167		Genome breeding 1, 2
Anaerobic production 4 Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate transport 75 Glutamite synthase 74 Glutamite synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167		Genome-scale reconstruction 40, 42
Anaplerotic pathway 25, 28 Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Bespeciate degradation 96 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Global regulation 104 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate transport 75 Glutamine synthase 74 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167		Gentisate pathway 97
Anion exchange chromatography see AIEC Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 B Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate synthase 74 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167		Gentisate transporter 93
Arabinose 61, 64, 117 Aromatic amino acid transporter 94 Aromatic compounds 58 Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-plastics 5 Biosensors 179–181 Glucosamine 63 Glucose 59, 114, 117, 123, 125, 126, 128 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157		Global regulation 104
Aromatic amino acid transporter 94 Aromatic compounds 58 Glutamate dehydrogenase 71, 73 Glutamate production 1, 26, 27 Glutamate synthase 74 Glutamate synthase 74 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167		Glucosamine 63
Aromatic compounds 58 Glutamate dehydrogenase 71,73 Glutamate production 1, 26, 27 Glutamate production 1, 26, 27 Glutamate synthase 74 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Glutamate transport 75 Heterologous proteins 166–167		Glucose 59, 114, 117, 123, 125, 126, 128
Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Glutamate synthase 74 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167	•	Glutamate dehydrogenase 71, 73
Benzoate degradation 96 Benzoate transporter 18, 92 Benzoate transporter 18, 92 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Glutamate transport 75 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157	Thomatic compounds 50	Glutamate production 1, 26, 27
Benzoate degradation 96 Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Bionass composition 48 Bio-plastics 5 Biosensors 179–181 Glutamine synthetase 72–73 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157	В	Glutamate synthase 74
Benzoate transporter 18, 92 β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Gluctarimic synthesise 72–75 Glycerol 63–64, 65, 117 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167		Glutamate transport 75
β-Ketodipate pathway 94–95 Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Green technology 4 Growth arrest 153, 156–157 Heterologous proteins 166–167	_	Glutamine synthetase 72–73
Bio-based fuels 4 Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Green technology 4 Growth arrest 153, 156–157 H Heterologous proteins 166–167		Glycerol 63-64, 65, 117
Bio-based polymers 139 Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Growth arrest 153, 150–15/ H Heterologous proteins 166–167		Green technology 4
Biomass composition 48 Bio-plastics 5 Biosensors 179–181 Heterologous proteins 166–167		Growth arrest 153, 156-157
Bio-plastics 5 Biosensors 179–181 Heterologous proteins 166–167	* '	
Biosensors 179–181 Heterologous proteins 166–16/		Н
High-throughput screening 189	•	Heterologous proteins 166–167
	DIOSCIISO15 1/7-101	High-throughput screening 189

caister.com/cory2

I ICAT 19 IEF 13 IMAC 20	Poly(lactic acid) 144–145 Polyester 139 Polyhydroxyalkanoate 141 Posttranslational modification 18–20
Inhibitory compounds 157 Integral membrane proteins 13 Isobutanol 128–131 Isoelectric focusing 13 Isotope coded affinity tag 19	Promoter fusion 182 ProRata 17 Protein export 162 Protein quantification 15–18 Protocatechuate 17
Isotopomer 31–33 ITRAQ 19	Protocatechuate branch 94–95 Protocatechuate transporter 94 PTM 18 Pyruvate 122–123
Lactate 120–122	
Lactic acid 59	Q
Lactose 61–62	QuPE 17
LC-MS 11 Lignocellulose 58, 128, 156–157	R
Lignocellulosic hydrolysates 58	Rational design 1
Lignocellulosics 64	Reactive oxygen species 19
Live cell imaging 192	Redox balance 154–155
Lysine production 1, 26	Regulation of aromatic metabolism 98–104 Regulatory circuits 181–182
M	Reporter protein 182–184
MALDI-MS 11	Resorcinol degradation 97–98
Mechanosensitive channel 75	ROS 19
Membrane proteomics 13	S
Metabolic control analysis 27 Metabolic engineering 1,127	Sampling-based flux balance analysis 47
Metabolic flux analysis 3, 25, 26–27, 48	SDS-PAGE 12, 13
Metabolic labelling 16	Sec pathway 162–163, 167–171
Metabolic network 40	SigB 173
Metabolic network modelling 39	Signal integration 182 SILAC 17
MFA 26–27, 49 see also Metabolic flux analysis	Silage 65
Model validation 44	SIMPLE 15, 18
Molasses 58, 59	Single cell analysis 188–189, 191
MudPIT 15	Single reaction monitoring 18 SRM 18
N	Starch 58, 62, 145
N-acetylglucosamine 63, 77	Stoichiometric modelling 41
Network curation 40, 41	Stress response 188
Network reconstruction 40–41	Succinate 114 Succinate export 120
Nitrate 76	Succinate export 120 Sugars 59, 156
Nitrate reductase 76 Nitrite 76	Surface display 4, 145
NMR 28, 30, 31	Synthetic biology 3
•	Systems biology 2–3
0	Т
Organic acids 58 Oxidative modifications 19	Tat pathway 164–166, 171
Oxidative phosphorylation 44–45	Thiol oxidation 19
Oxidative stress 19	Twin-arginine translocation export pathway 164–166
Oxygen deprivation 152–153	U
Oxygen limitation 114–116, 123, 128, 152	Uncertain stoichiometric coefficients 47
P	
Pentoses 116-117	V
Phenol degradation 96–97	Vanillate degradation 95
Phenylpropopal degradation 98	Vanillate transporter 94
Phenylpropenoid degradation 95–96 Phospho-proteins 20	W
Phospho-proteome 20	Whey 77
Phosphorylation 19-20	v
Phosphotransferase system 58	X
Poly(3-hydroxybutyrate) 141, 145	Xylose 60, 64