Supporting Information

Expanding extender substrate selection for unnatural polyketide biosynthesis by acyltransferase domain exchange within a modular polyketide synthase

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1. Supplementary figures

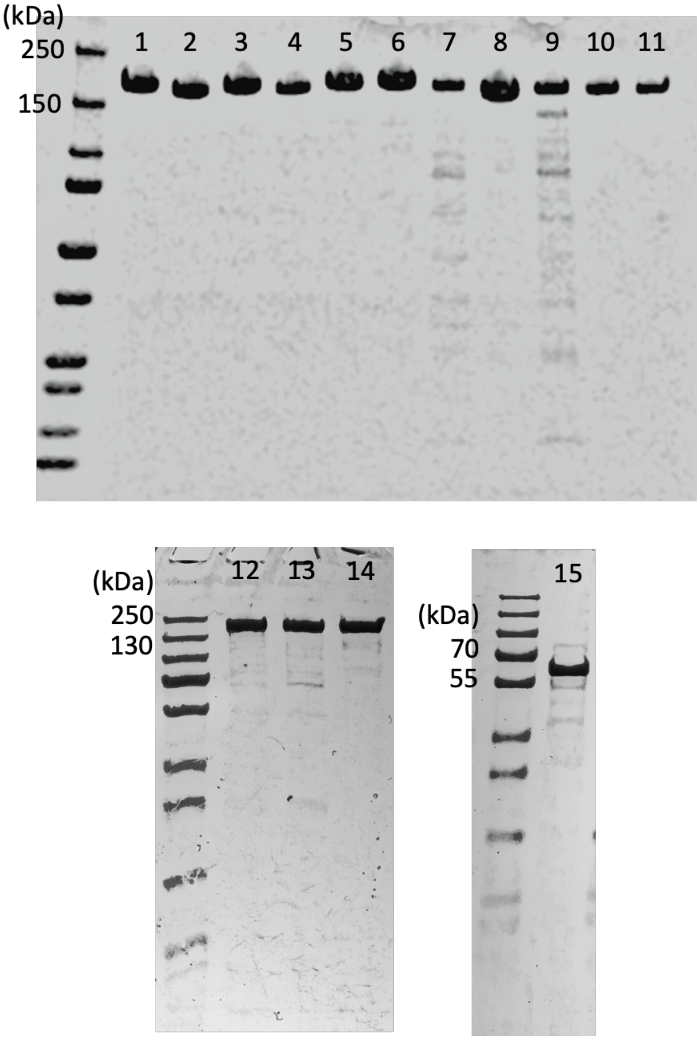
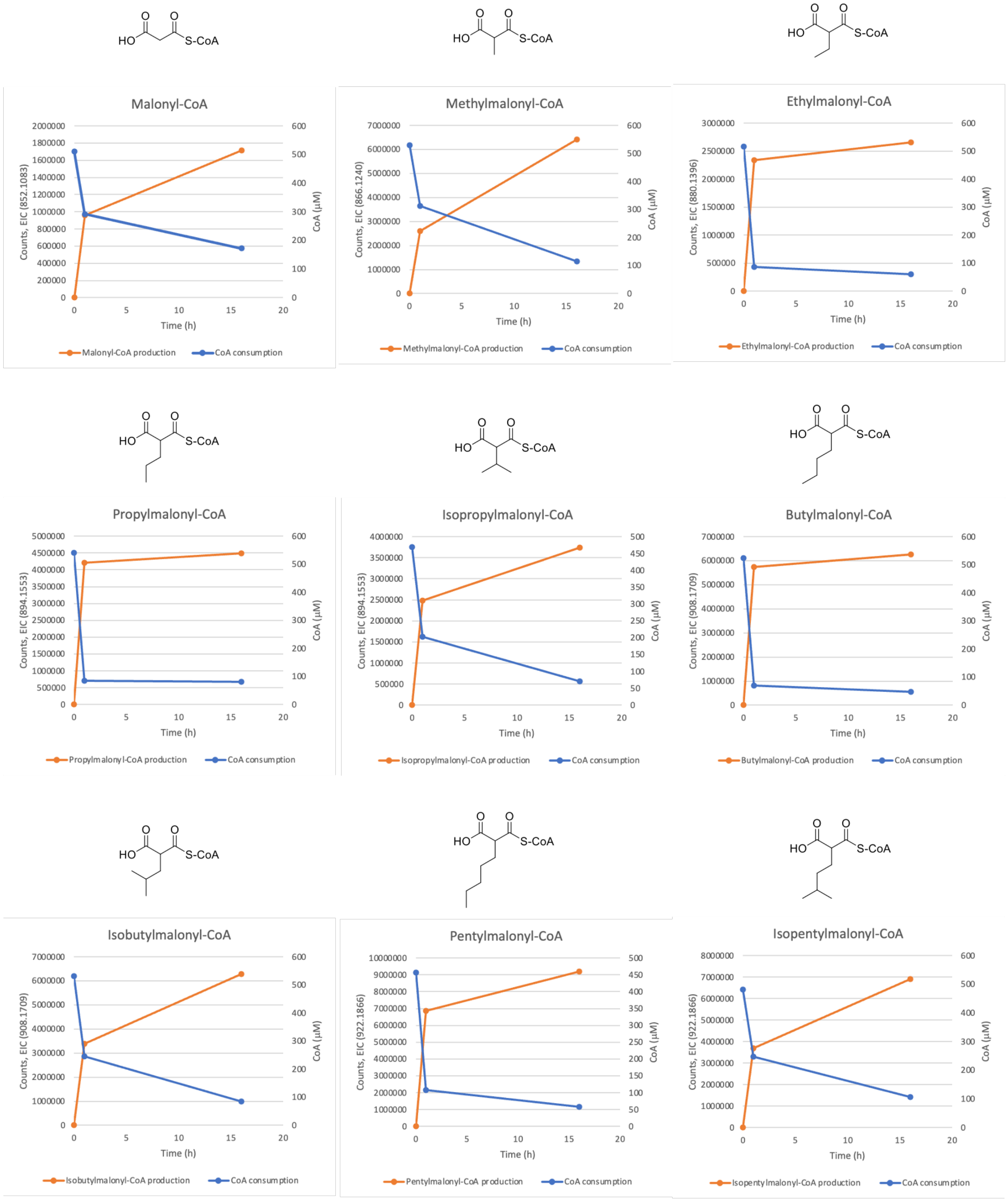
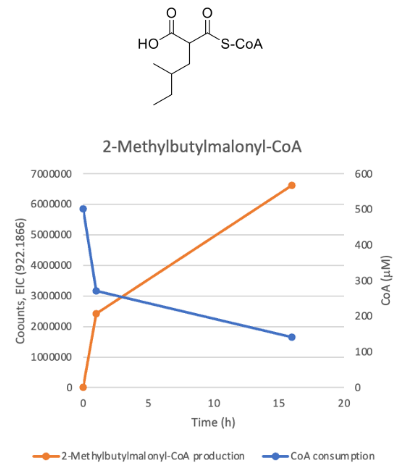


Figure S1. SDS-PAGE analysis of purified AT-exchanged mutants and MatB T207G/M306I. Nid-5 (lane 1); Ans-8 (lane 2); San-13 (lane 3); Leu-2 (lane 4); Div-6 (lane 5); Div-4 (lane 6); Sal-1 (lane 7); Mon-5 (lane 8); Sta-12 (lane 9); Rev-4 (lane 10); Spl-3 (lane 11); WT A162W (lane 12); Epo-4 A162W (lane 13); Rev-4 A162W (lane 14); MatB T207G/M306I (lane 15).

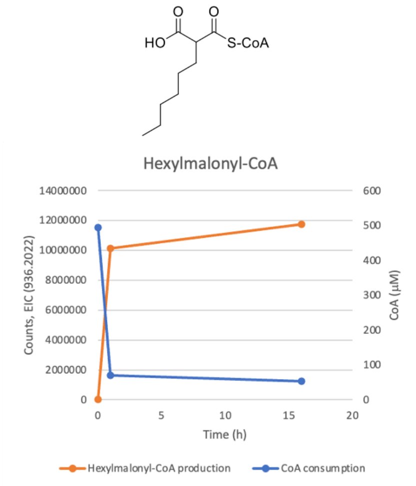
(a)



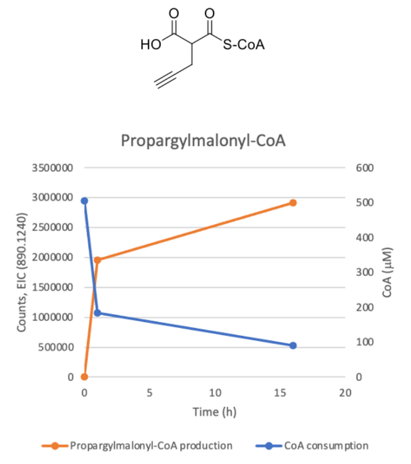
HO
O
O
S-CoA
Malonyl-CoA
Counts, EIC (852.1083)
CoA (µM)
Time (h)
Malonyl-CoA production
CoA consumption
Methylmalonyl-CoA
Counts, EIC (866.1240)
Methylmalonyl-CoA production
Ethylmalonyl-CoA
Counts, EIC (880.1396)
Ethylmalonyl-CoA production
Propylmalonyl-CoA
Counts, EIC (894.1553)
Propylmalonyl-CoA production
Isopropylmalonyl-CoA
Counts, EIC (894.1553)
Isopropylmalonyl-CoA production
Butylmalonyl-CoA
Counts, EIC (908.1709)
Butylmalonyl-CoA production
Isobutylmalonyl-CoA
Counts, EIC (908.1709)
Isobutylmalonyl-CoA production
Pentylmalonyl-CoA
Counts, EIC (922.1866)
Pentylmalonyl-CoA production
Isopentylmalonyl-CoA
Counts, EIC (922.1866)
Isopentylmalonyl-CoA production
0
5
10
15
20
0
100
200
300
400
500
600



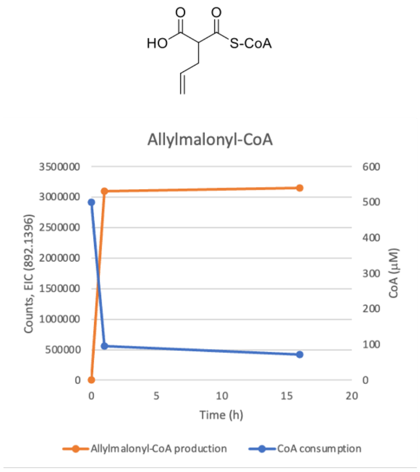
2-Methylbutylmalonyl-CoA



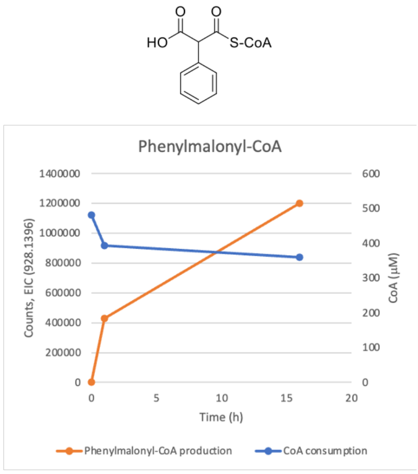
Hexylmalonyl-CoA



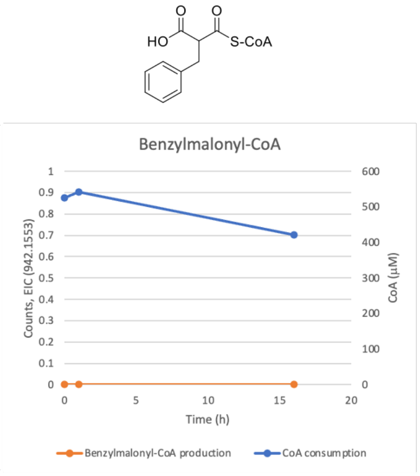
Propargylmalonyl-CoA



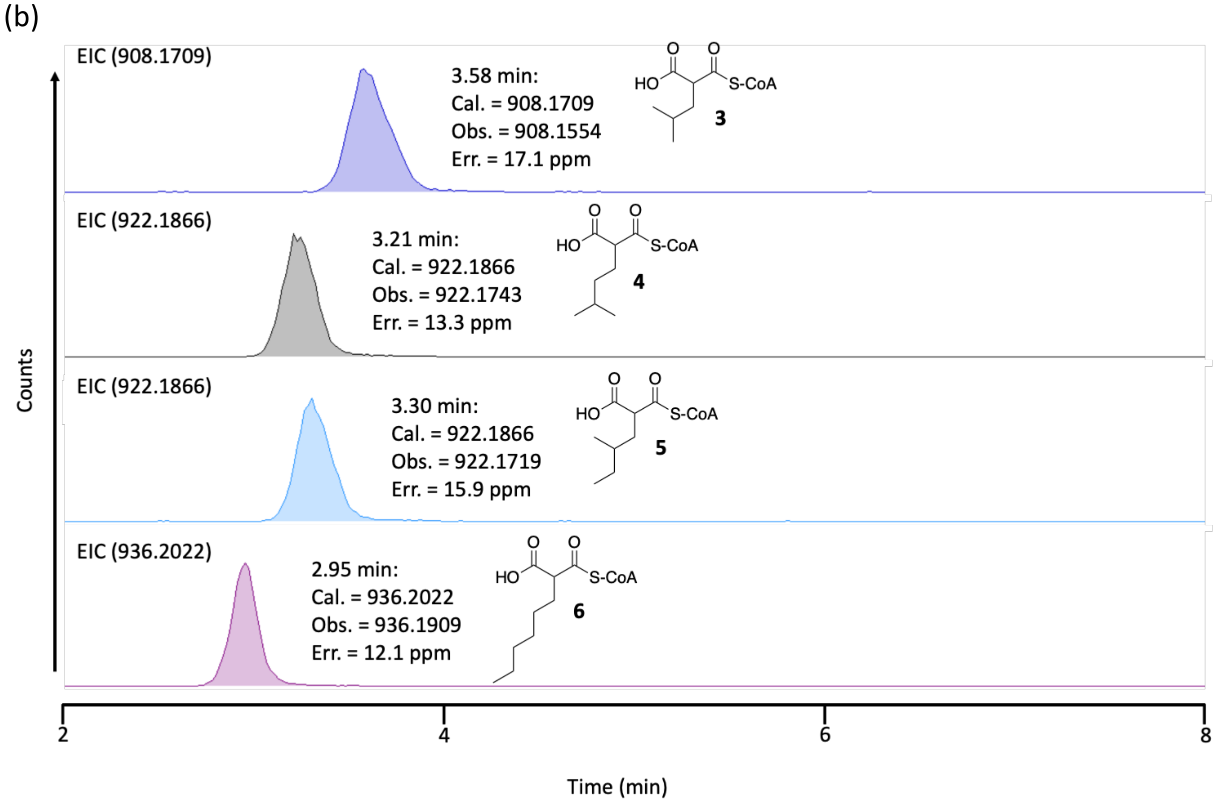
Allylmalonyl-CoA



Phenylmalonyl-CoA



Benzylmalonyl-CoA


(b)
EIC (908.1709)
3.58 min:
Cal. = 908.1709
Obs. = 908.1554
Err. = 17.1 ppm
HO
O
O
S-CoA
3
EIC (922.1866)
3.21 min:
Cal. = 922.1866
Obs. = 922.1743
Err. = 13.3 ppm
HO
O
O
S-CoA
4
EIC (922.1866)
3.30 min:
Cal. = 922.1866
Obs. = 922.1719
Err. = 15.9 ppm
HO
O
O
S-CoA
5
EIC (936.2022)
2.95 min:
Cal. = 936.2022
Obs. = 936.1909
Err. = 12.1 ppm
HO
O
O
S-CoA
6
Counts
2
4
6
8
Time (min)

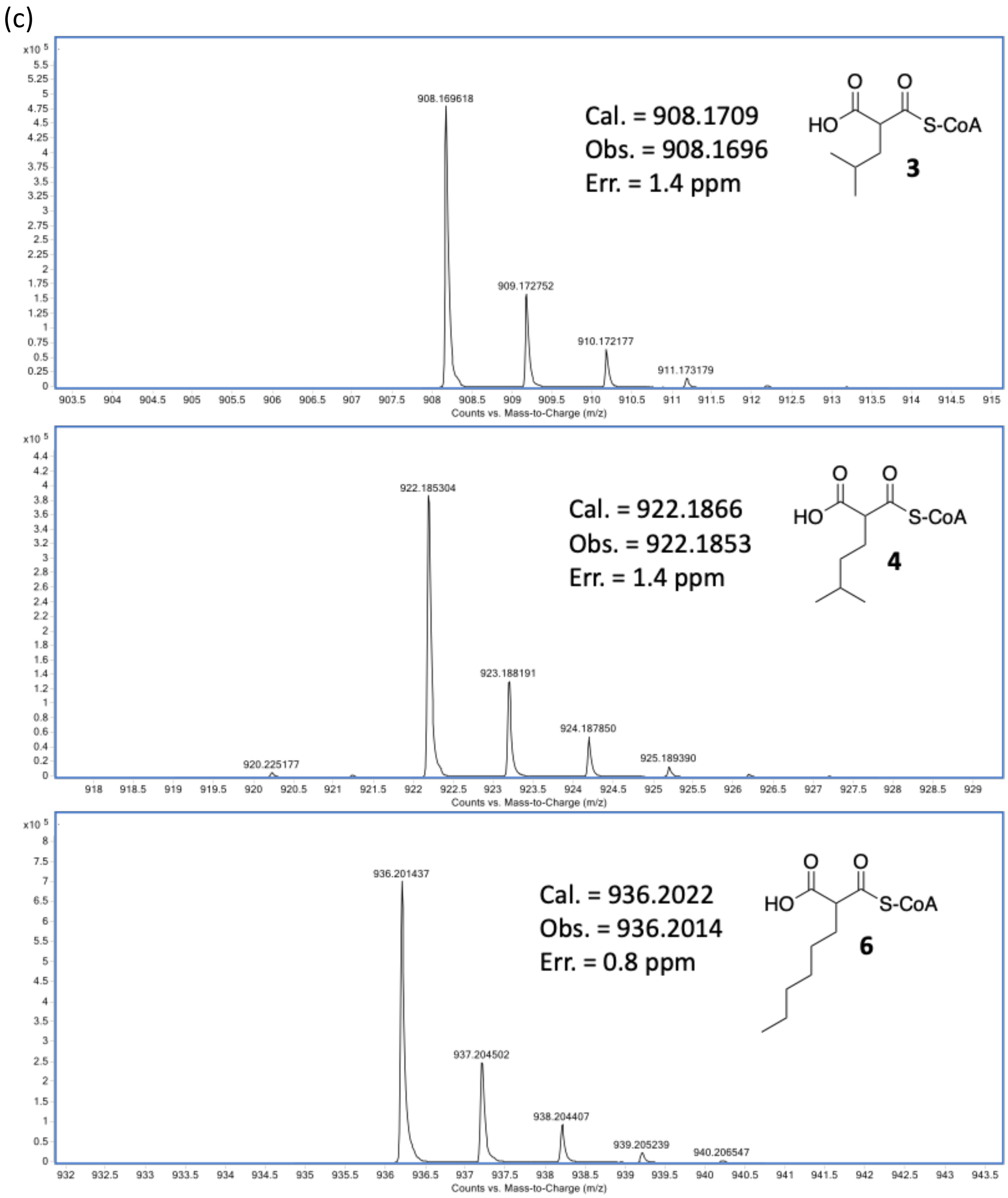


Figure S2. *In vitro* production of extender substrates by MatB T207G/M306I from the corresponding diacids. (a) Substrate production and CoA consumption were monitored by LC-TOF-MS. (b) Extracted ion chromatograms (EIC) of α-carboxyacyl-CoAs **3**-**6** produced *in vitro*. (c) LC-TOF-MS analysis of α-carboxyacyl-CoAs **3**, **4** and **6** was performed using a different method we described previsouly[1]. For α-carboxyacyl-CoA **5**, we could not evaluate the mass accuracy due to unavailability of dimethyl(2-methylbutyl)malonate.

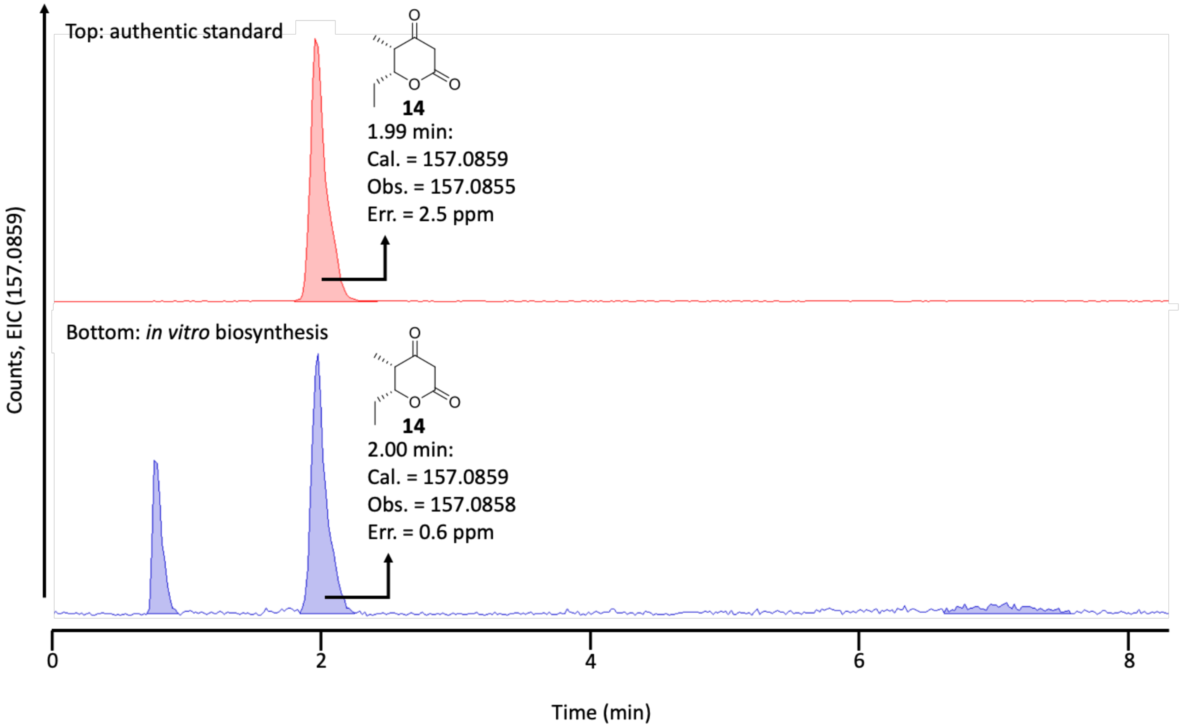


Figure S3. *In vitro* production of polyketide **14** by Epo-4. Extracted ion chromatograms (EIC) of an authentic standard of **14** (top) and an extract from the *in vitro* reaction (bottom). The observed mass errors were within 5 ppm.

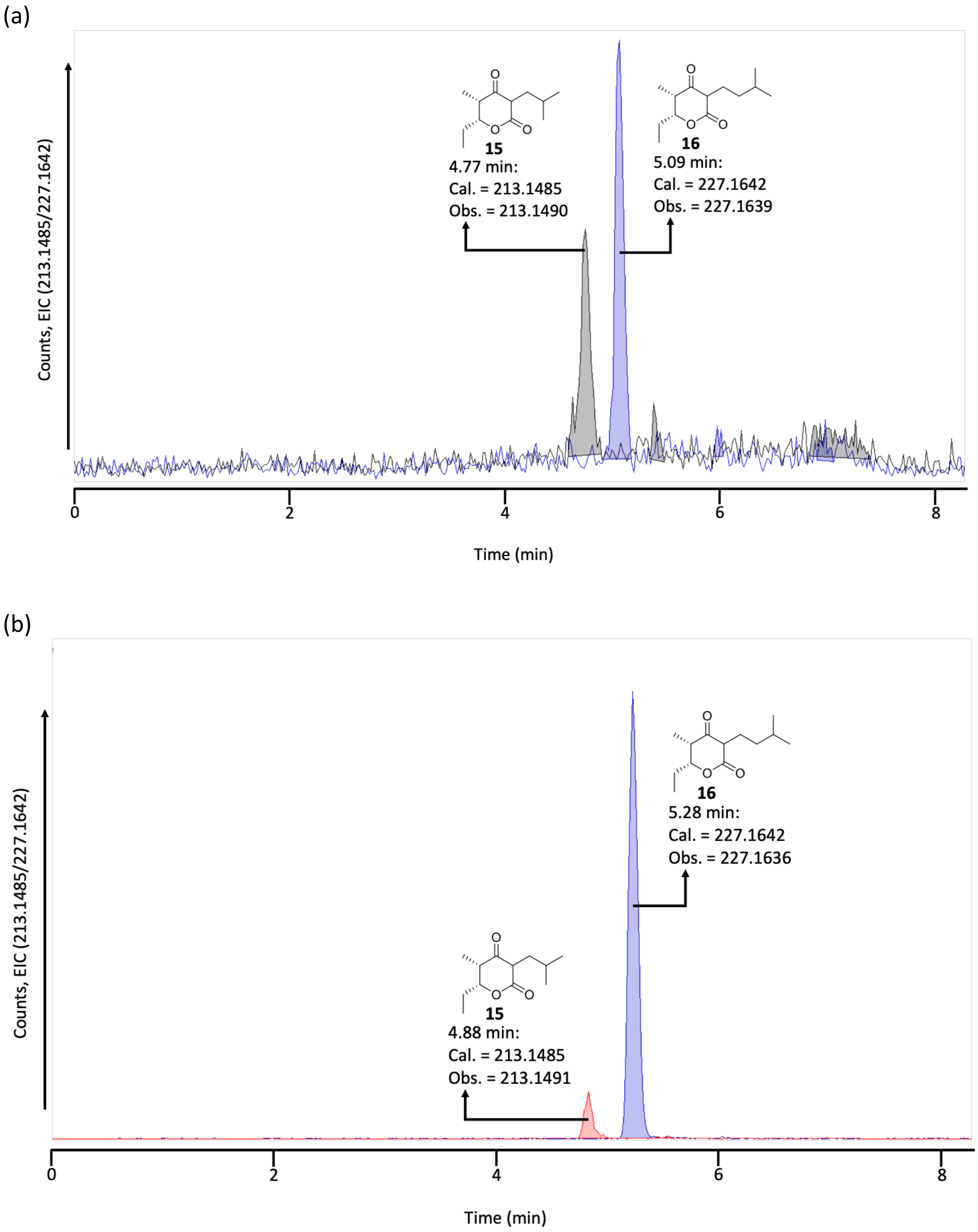


Figure S4. *In vitro* production of polyketides **15** and **16.** (a) Production of polyketides **15** and **16** by Epo-4. Extracted ion chromatograms (EIC) of extracts from the corresponding *in vitro* reactions were overlayed. Observed mass errors for producing **15** and **16** are 2.4 ppm and 1.3 ppm, respectively. (b) Production of polyketides **15** and **16** by Leu-2. Extracted ion chromatograms (EIC) of extracts from the corresponding *in vitro* reactions were overlayed. Observed mass errors for producing **15** and **16** are 2.8 ppm and 2.6 ppm, respectively.

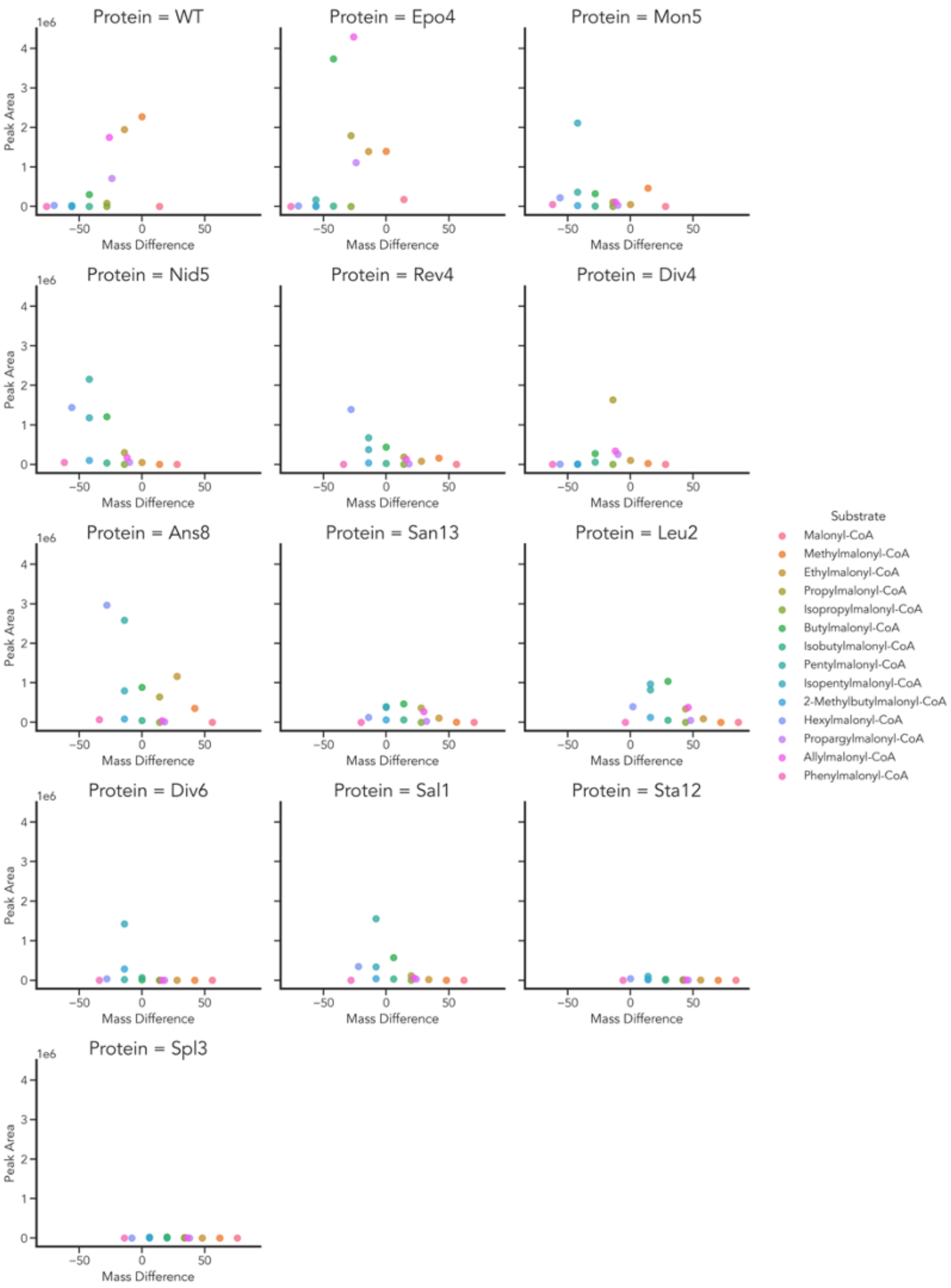


Figure S5. Substrate structure preference of ATs used in this study. A positive mass difference means that the substrate tested was smaller than the native substrate. A negative mass difference means that the substrate tested was larger than the native substrate. For Rev-4 and Sta-12, we employed butylmalonyl-CoA and hexylmalonyl-CoA as native substrates, respectively.

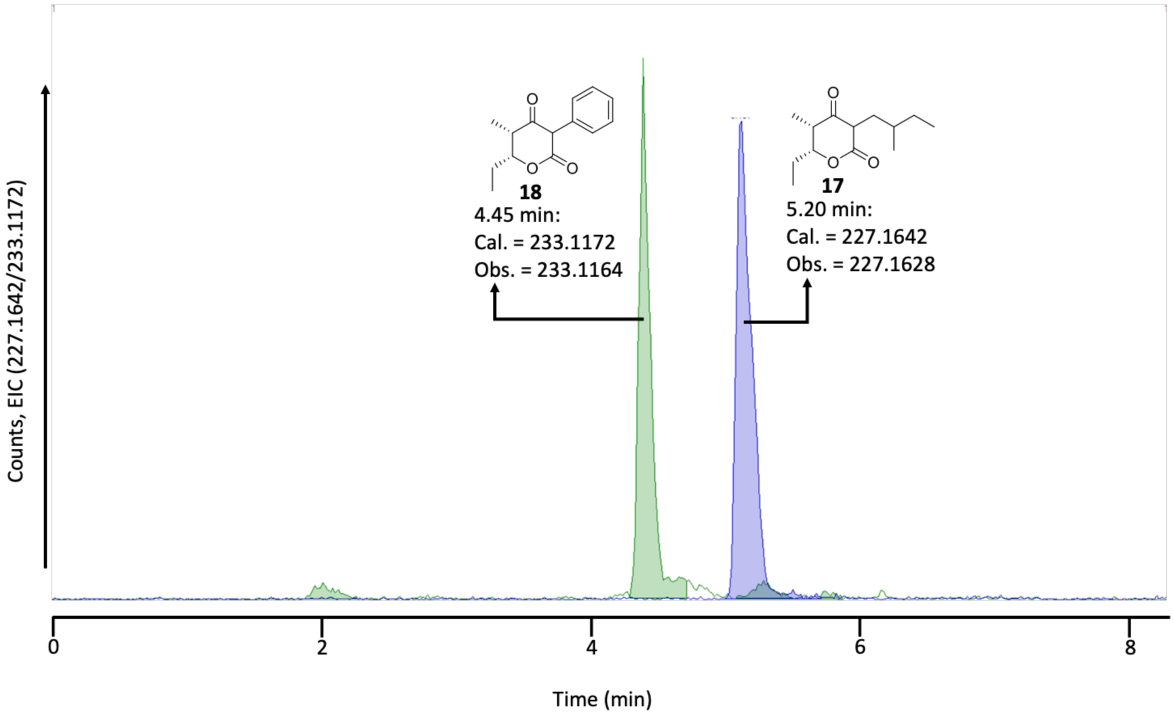
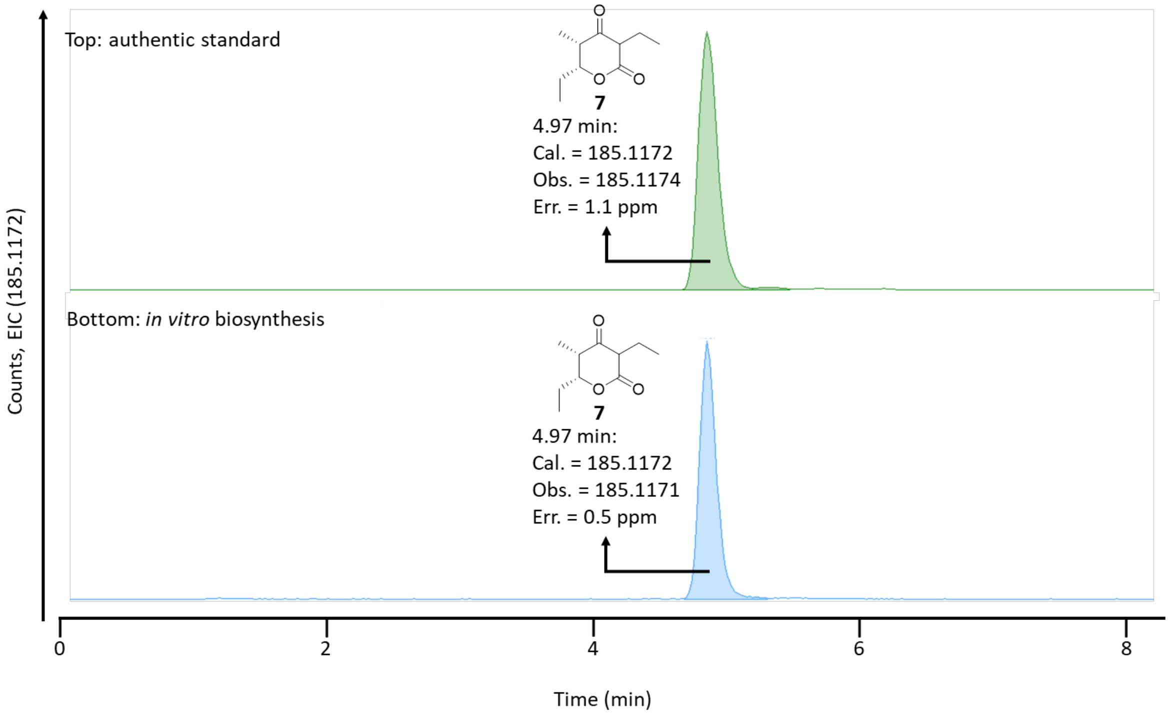
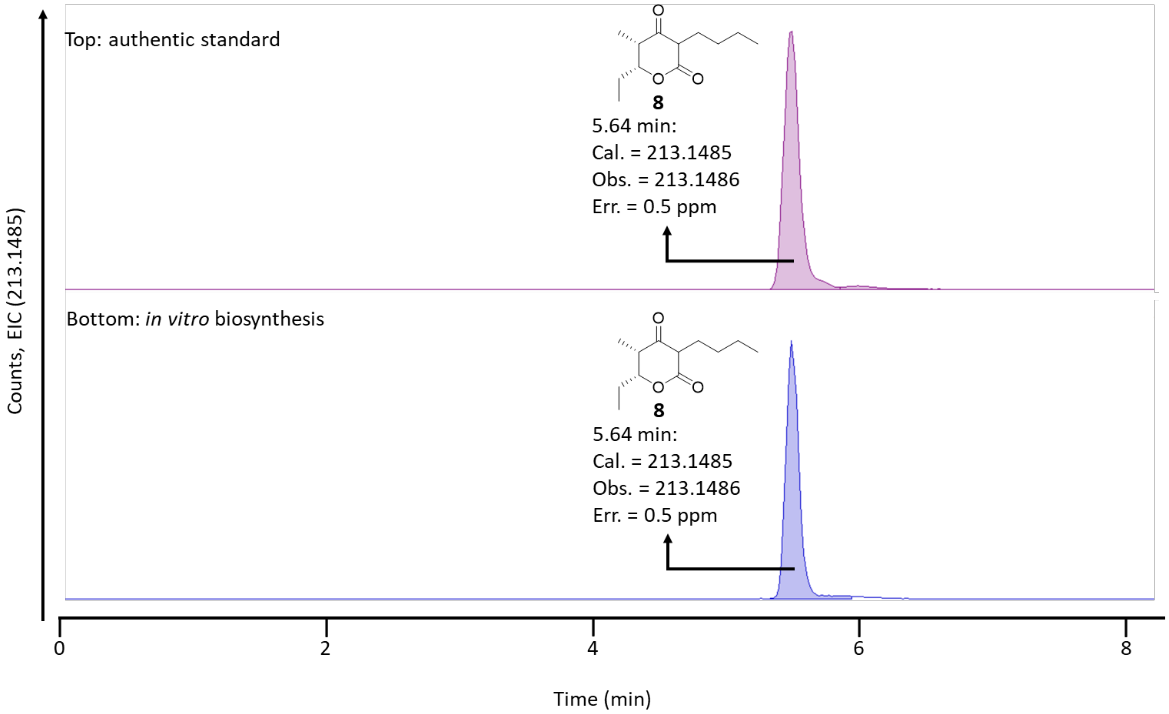


Figure S6. *In vitro* production of polyketides **17** and **18** by Ans-8. Extracted ion chromatograms (EIC) of extracts from the corresponding *in vitro* reactions were overlayed. Observed mass errors for producing **17** and **18** are 2.6 ppm and 3.4 ppm, respectively.

(a)


Counts, EIC (185.1172)
Top: authentic standard
7
4.97 min:
Cal. = 185.1172
Obs. = 185.1174
Err. = 1.1 ppm
Bottom: *in vitro* biosynthesis
7
4.97 min:
Cal. = 185.1172
Obs. = 185.1171
Err. = 0.5 ppm
0
2
4
6
8
Time (min)

(b)


Counts, EIC (213.1485)
Top: authentic standard
8
5.64 min:
Cal. = 213.1485
Obs. = 213.1486
Err. = 0.5 ppm
Bottom: *in vitro* biosynthesis
8
5.64 min:
Cal. = 213.1485
Obs. = 213.1486
Err. = 0.5 ppm
0
2
4
6
8
Time (min)

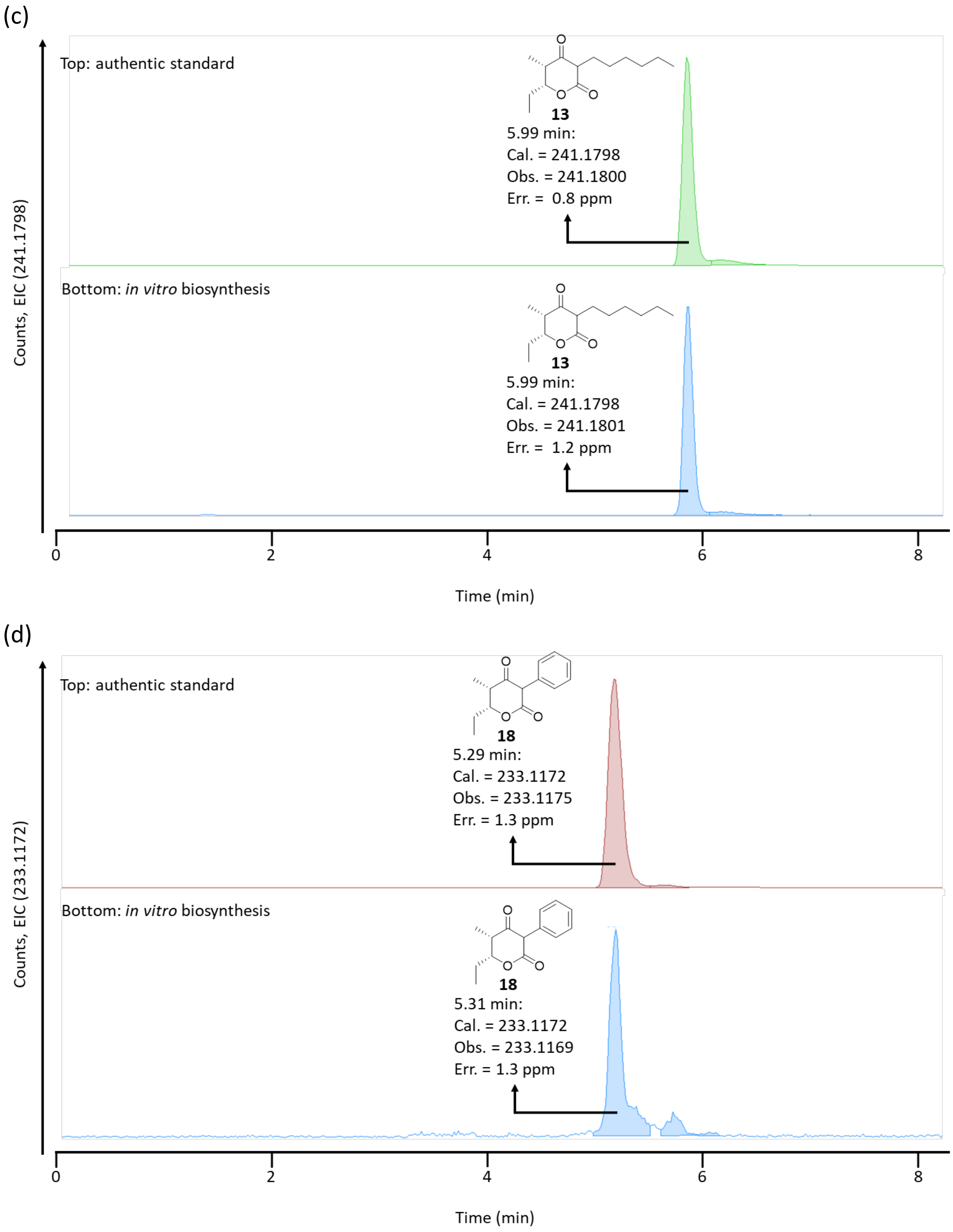
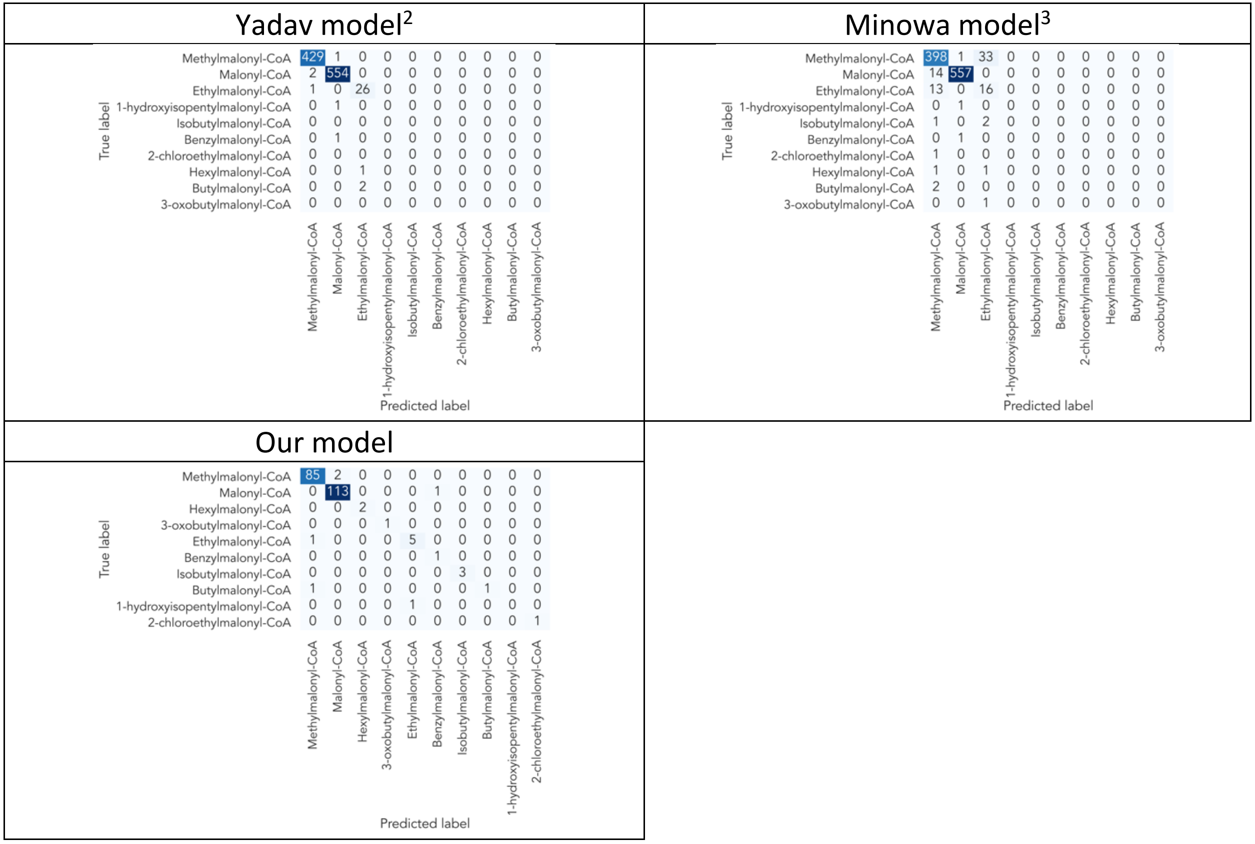


Figure S7. *In vitro* production of polyketides **7**, **8**, **13** and **18** with authentic standards. (A) *In vitro* production of polyketides **7** by Epo-4. Extracted ion chromatograms (EIC) of an authentic standard of **7** (top) and an extract from the *in vitro* reaction (bottom). (B) *In vitro* production of polyketides **8** by Epo-4. EIC of an authentic standard of **8** (top) and an extract from the *in vitro* reaction (bottom). (C) *In vitro* production of polyketides **13** by Rev-4. EIC of an authentic standard of **13** (top) and an extract from the *in vitro* reaction (bottom). (D) *In vitro* production of polyketides **18** by Nid-5. EIC of an authentic standard of **18** (top) and an extract from the *in vitro* reaction (bottom). The observed mass errors were within 5 ppm.

(a)

	Accuracy	**F1 score**
Yadav model[2]	96.6%	0.974
Minowa model[3]	93.3%	0.932
Our model on testing set	97.2%	0.970

(b)



Yadav model[2]

	Methylmalonyl-CoA	Malonyl-CoA	Ethylmalonyl-CoA	1-hydroxyisopentylmalonyl-CoA	Isobutylmalonyl-CoA	Benzylmalonyl-CoA	2-chloroethylmalonyl-CoA	Hexylmalonyl-CoA	Butylmalonyl-CoA	3-oxobutylmalonyl-CoA
Methylmalonyl-CoA	429	1	0	0	0	0	0	0	0	0
Malonyl-CoA	2	554	0	0	0	0	0	0	0	0
Ethylmalonyl-CoA	1	0	26	0	0	0	0	0	0	0
1-hydroxyisopentylmalonyl-CoA	0	1	0	0	0	0	0	0	0	0
Isobutylmalonyl-CoA	0	0	0	0	0	0	0	0	0	0
Benzylmalonyl-CoA	0	1	0	0	0	0	0	0	0	0
2-chloroethylmalonyl-CoA	0	0	0	0	0	0	0	0	0	0
Hexylmalonyl-CoA	0	0	1	0	0	0	0	0	0	0
Butylmalonyl-CoA	0	0	2	0	0	0	0	0	0	0
3-oxobutylmalonyl-CoA	0	0	0	0	0	0	0	0	0	0

Minowa model[3]

	Methylmalonyl-CoA	Malonyl-CoA	Ethylmalonyl-CoA	1-hydroxyisopentylmalonyl-CoA	Isobutylmalonyl-CoA	Benzylmalonyl-CoA	2-chloroethylmalonyl-CoA	Hexylmalonyl-CoA	Butylmalonyl-CoA	3-oxobutylmalonyl-CoA
Methylmalonyl-CoA	398	1	33	0	0	0	0	0	0	0
Malonyl-CoA	14	557	0	0	0	0	0	0	0	0
Ethylmalonyl-CoA	13	0	16	0	0	0	0	0	0	0
1-hydroxyisopentylmalonyl-CoA	0	1	0	0	0	0	0	0	0	0
Isobutylmalonyl-CoA	1	0	2	0	0	0	0	0	0	0
Benzylmalonyl-CoA	0	1	0	0	0	0	0	0	0	0
2-chloroethylmalonyl-CoA	1	0	0	0	0	0	0	0	0	0
Hexylmalonyl-CoA	1	0	1	0	0	0	0	0	0	0
Butylmalonyl-CoA	2	0	0	0	0	0	0	0	0	0
3-oxobutylmalonyl-CoA	0	0	1	0	0	0	0	0	0	0

Our model

	Methylmalonyl-CoA	Malonyl-CoA	Hexylmalonyl-CoA	3-oxobutylmalonyl-CoA	Ethylmalonyl-CoA	Benzylmalonyl-CoA	Isobutylmalonyl-CoA	Butylmalonyl-CoA	1-hydroxyisopentylmalonyl-CoA	2-chloroethylmalonyl-CoA
Methylmalonyl-CoA	85	2	0	0	0	0	0	0	0	0
Malonyl-CoA	0	113	0	0	0	1	0	0	0	0
Hexylmalonyl-CoA	0	0	2	0	0	0	0	0	0	0
3-oxobutylmalonyl-CoA	0	0	0	1	0	0	0	0	0	0
Ethylmalonyl-CoA	1	0	0	0	5	0	0	0	0	0
Benzylmalonyl-CoA	0	0	0	0	0	1	0	0	0	0
Isobutylmalonyl-CoA	0	0	0	0	0	0	3	0	0	0
Butylmalonyl-CoA	1	0	0	0	0	0	0	1	0	0
1-hydroxyisopentylmalonyl-CoA	0	0	0	0	1	0	0	0	0	0
2-chloroethylmalonyl-CoA	0	0	0	0	0	0	0	0	0	1

Figure S8. A comparison between existing and our computational models. (a) Summary statistics of each model predicting AT substrate specificity. (b) Confusion matrices of each model predicting AT substrate specificity.

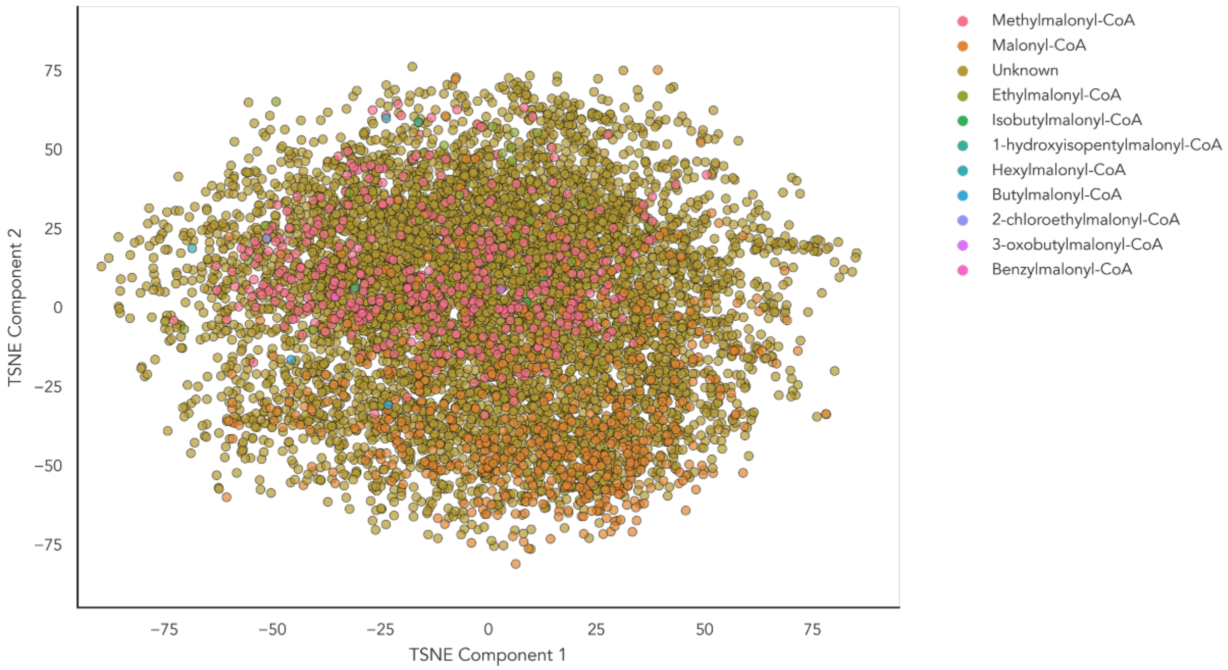


Figure S9. Analysis of the active site shape for 6000+ ATs with and without substrate annotations. Two-dimensional decomposition of active site shape using t-SNE colored by annotated substrate.

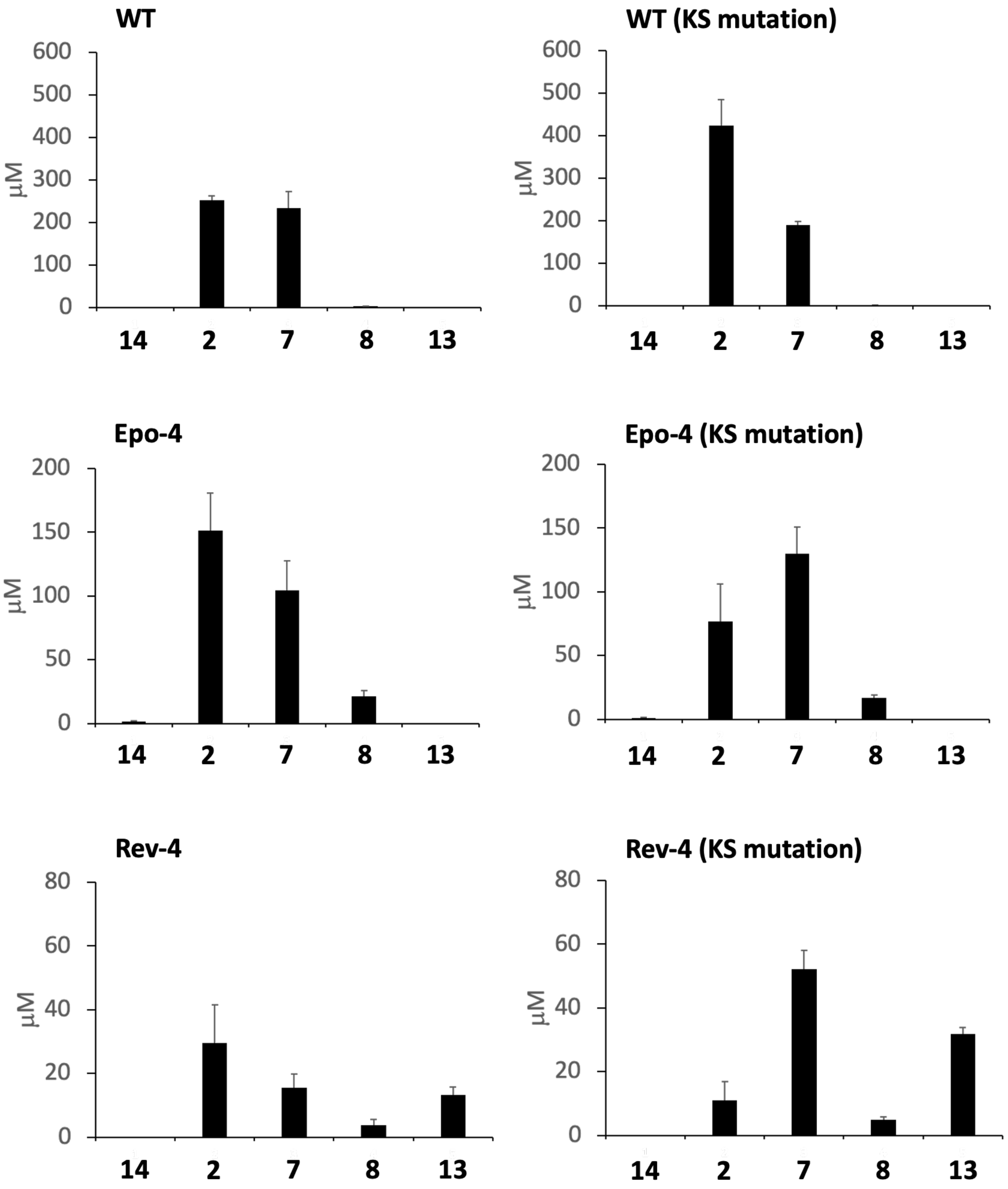


Figure S10. Production of polyketides **2**, **7**, **8**, **13**, and **14** by KS-mutated AT-exchanged PKSs. Polyketides were quantified at 16 h using the corresponding authentic standards. Each value and error are calculated from three independent experiments. Abbreviations (see Figure 1 and Table 1).

2. Supplementary tables

Table S1. Amino acid sequences of DEBS M6+TE and the AT exchanged mutants (amino acid sequences from WT = black, amino acid sequences from donor PKS modules = red).

WT	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVIIAEPPEPEPLPEPGPVGVLAAANSVPVLLSARTETALAAQARLLESAVDDSVPLTALASALATGRAHLPRRAALLAGDHEQLRGQLRAVAEGVAAPGATTGTASAGGSVFVFPGQGAQWEGMARGLLSVPVFAESIAECDAVLSEVAGFSASEVLEQRPDAPSLERVDVVQPVLFSVMVSLARLWGACGVSPSAVIGHSQGEIAAAVVAGVLSLEDGVRVVALRAKALRALAGKGGMVSLAAPGERARALIAPWEDRISVAAVNSPSSVVVSGDPEALAELVARCEDEGVRAKTLPVDYASHSRHVEEIRETILADLDGISARRAIPLYSTLHGERRDGADMGPRYWYDNLRSQVRFDEAVSAAVADGHATFVEMSPHPVLTAAVQEIAADAVAIGSLHRDTAEEHLIAELARAHVHGVAVDWRNVFPAAPPVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Epo-4	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVVLEEAPAVELWPAAPERSAELLVLSGKSEGALDAQAARLREHLDMHPELGLGDVAFSLATTRSAMNHRLAVAVTSREGLLAALSAVAQGQTPPGAARCIASSSRGKLAFLFTGQGAQTPGMGRGLCAAWPAFREAFDRCVALFDRELDRPLCEVMWAEPGSAESLLLDQTAFTQPALFTVEYALTALWRSWGVEPELVAGHSAGELVAACVAGVFSLEDGVRLVAARGRLMQGLSAGGAMVSLGAPEAEVAAAVAPHAAWVSIAAVNGPEQVVIAGVEQAVQAIAAGFAARGVRTKRLHVSHASHSPLMEPMLEEFGRVAASVTYRRPSVSLVSNLSGKVVTDELSAPGYWVRHVREAVRFADGVKALHEAGAGTFLEVGPKPTLLGLLPACLPEAEPTLLASLRAGREEAAGVLEALGRLWAAGGSVSWPGVFPTAGRRVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Mon-5	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVILEEAPPEEAAAAETPAEGTGAVVPWVVSGRGEEALRAQAAQLAEHVRDDDQRPASPLEVGWSLATTRSVFENRAVVVGDDRDALLDGLRSLAAGEASPDVVSGAVGPTGPGPVMVFPGQGGQWVGMARLLDESPVFAARIAECEQALSAYVDWSLTDVLRGDGSELARIDVVQPVLWAVMVALAAVWADQGIEPAAVVGHSQGEIAAACVVGAISLDEAARI

	VAVRSVLLRQLSGRGGMASLGMGQEQAADLIDGHPGVVVAAVNGPSSTVISGPPEGIAAVVADAQERGLRARAVASDVAGHGPQLDAILDQLTEGLAGIRPAATDVAFYSTVTAGHLTDTTELDTAYWVRNVRRTVRFADTIDALLADGYRLFIEVSPHPVLNLALEGLIERAAVPATVVPTLRRDHGDTTQLARAAAHAFAAGADVDWRRWFPADPAPRTVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Nid-5	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVVIEEPPPTAVPESPEPSPAEAPPRQEQDRDRWEGVTVPLMLSAHSEAALREQARRLCAQLLARPEQRPADVGHALLSTRARFPRRAAVVGESMTELAEALDAVAEGGPHPLAATGTAGTADRVVFVFPGQGSQWAGMAEGLLERSGAFRSAADSCDAALRPYLGWSVLSVLRGEPDAPSLDRVDVVQPVLFTMMVSLAAVWRALGVEPAAVVGHSQGEIAAAHVAGALSLDDSARIVALRSRAWLGLAGKGGMVAVPMPAEELRPRLVTWGDRLAVAAVNSPGSCAVAGDPEALAELVALLTGEGVHARPIPGVDTAGHSPQVDALRAHLLEVLAPVAPRPADIPFYSTVTGGLLDGTELDATYWYRNMREPVEFERATRALIADGHDVFLETSPHPMLAVALEQTVTDAGTDAAVLGTLRRRHGGPRALALAVCRAFAHGVEVDPEAVFGPGARPVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Rev-4	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVIIEAAPETEAEPPAADRPGDEDPGLFAPHTAMAWTLSARSAKALAGQAGRLLERVQDAPELDPADVGWSLLRSRALFEHRAVVVGADRAELTAGLAALAAGEPAANVVTGAARSGGRAVFVFPGQGSHWEGMAKELLATSPVFAAKVQECAEALDPLVDWSLLEVLRHPEESAELLSRIDVYHPVFFTMMVALAEVWRALGVEPAAVVGHSQGEVAAAHVAGALSLSDAYRVVLVRGNIFENVLLGKGAIASVKLGQEAVEEQIAGYERLSVAGVNSRSGVTVSGSMEDVKAYLAECEAAGVPARILGMAASHSPALEPLRERLLGELSFVRPRAGTIPMYSTVDAALVDTATLDAEYWYRNLRSPVLFEQTTRVLVDAGFSAFVEASSHPVLTVPLQETLDTFYPDLAADAAVTGTLRRNEGGPARMLASAAHLFAHGVPVVWDGLFAGRPPRRVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*

Div-4	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVIVEQAPEPAAPEPVSPEPATLEPAAPGPAVAEPVSPGPAGPEPADNRPVFATAPAPLLVSGRGESALRAQARRLHAHLDTHLDTHLDPHPDPRPDGASDVGPGDLGPGGLEPGGVELGDVAWSLATTRAVHDRRAVVLADDRDEALAALTALAEGTPSPSLVPGSAPDADPQVVFVFPGQGSQWPGMAARLLDESPVFADRMAECDRAVGELVDWSVLDVVTGAAGAPSPERIEILQPVLFAVNVSLAAVWQAAGVEPAAVVGHSQGEVAAAFVAGALSLEDAARTVVLRSALFAAELVGRGAVVSVALGSEEVERRIAAHDGRLALGGRNSPAASTVVGDTEALTEFVARCKADGIRAQVVGSTVASHCAQVDPLHDRIVEMLAGIAPKPARVPFYSTVDAAEIDTESLTGEYWFRNARFPVEFDRTVRALLADGHQHFVECSAHPVLTVATQATSEDFGAEAVAVGSLRRQEGGARRLLTSFAEGFVRGLPVDWAAVLGGGRRVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Ans-8	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVILEQAPEPTSVNASDEKARVLGDSVVPLVLSARGEAGLAGQARRLGAFLRQRQELDLLEVGRSLVQSRGLLPDRAIVLAGGREEALTALDAVAGGESATGVVKGTAASVVGGTVFVFPGQGSHWAGMGRELLETSPVFATRMAECAEALDPLTGWSLLDVVRQGQGTPSLDDLDVVQPVSWALMLSLAALWEACGVVPDAVVGHSQGEIAAACFAGALPLPDAARLVVHRARAIRAELSGHGGMASLVASVKAVSVLVEELPGLEIAAVNGPSSVVVSGELPALEELLARCRTEGIHARRIHGANAAGHSSQMEVLRDSFLEAFAAVSGGPSRVPLYSTVTGRLQDTTELDVEYWYRNLRQTVQFDPAIRSLAADGHGVFIEVSSHPVLAAGVQDVLEELQAPAVVTGSLHRDEGGPRRFLASLAHLHTHGVQVSWEAVLGRGTERPVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
San-13	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVILEQAPAEDAHPAPEPAPGEDSHPTPETAPGEDAPRTAPEPARPVVWPVHGRTRDALRAQAARLRTHLETRPDARPADVGWTLAAGRAVFDHRAVVLGADRAELLRGLDAVAAGTPDPAVADGAAQGADRAVFVFPGHGAQWPGMARRLFDDFPVFRESVLQCADAFAEFVDWSLLDVLRDEEGAPPLHRVDVVQPALFTMMVSLAALWRSYGVEPSAVVGHSQGEIAAAYVAGALDLRDAARIVATRGKAWLTLAGTGGMASVALPRAEAAERLRPFGHRLDIAAVNDPRSVTVAGDLDALEEFLTGLETEGVRVRRVRQIVGAGHTAHVDALRDQLIETLAPTAPRSAPIAFCSTVTGGLLDTAGLDHHYWYRNARRTVLFEQAVRTLAEQGYGPFLEISAHPMFTVAVQETLEDAGVGAAVLATLRRDEGGPDRFLRAAAEAHTAGVTVDWRPAFAGAGARTVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAG

	TALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Leu-2	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVVLEEAPRAPARPAPEHASDHVLALSARSDAALDALIERYAAAIEQQQDVDLASLCFTAAAGRAHFERRIACVAPSAPKMLELLRAARAGSNARGIARATLSSRRERRVAFLFSGFGSESVGMGRELYETEPAFREAMDRCADLLAPHLPRRLTDVLYPARDAAGGAAASLGDLSYAQPALFALEYCLAELWKSWGITPSAVVGHSLGECVAACVAGVFSLEDALTLVAARGRLMESLAGEGETFLVSADEATVRRVIASDPVSIGSINGPANIVISGAPAGVKSVVERLSQEGIEVKKLDVRRAAHSPLMDPMLEAFGKVARSIRYARPTIDLVANLTGEVAGEEIATPEYWCRQIRETVRMSACLRTLHDALGFEVFLELGPSPALVWNGMQCVPKRSGAWIASLRPGRPDRAQILAALASLYANGVDVNWTSVAREEQRRRVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Div-6	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVIIEQAPPAPDPAGDADALDPEAVGGGIVPLVVTGRGTAGRTARAAQLAAWLTDGPEQPVGDVARALIHNVAVLPDRAVVLAGGGPGTPGAGEGAVSGAEGVGASAANPPAASAVDGLVALAGDRAAAGVVRGDGPLLTGDVAFVFPGQGSQWLGMGAELLASSSVFAAAMAECDAALGDYVGWSVIDVIRQDPAAPDPNLIEVVQPSLFAVHVSLAALWQHVGVRPAAVVGHSQGEIAAAVVSGALSLSDGARVIVARSALLAEELLGKGAMAWIGTSADDVEDRLAQWADRLSVAGRNSPRAVTVVGETEALHELVAGCEADGIRTRIVGSSVASHCAQIEPLRDRLLAMFDEVTPRAARVPFYSSVTGTVIDTTGMDAEYWYRNAREPVDLEAAVRALLADGYAFFVELSAHPVLTVPVQETAEAVGADVAAVGSLRRDDGGPRRFLTSMAEGFVRGLPVDWSVLFDAGRRAHVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Sal-1	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGT

	NAHVILEPQAAIGPATARAEETPLSLLPVTAHSAEALRDTCRELSNHVERNAAPWLPDLAYTLATRRTPLPHRIAFVVRDRDDLLDGLAHISAGRSYPGAVKGTVAGGGARRVALVFSGGGTHWAGMGRALMDWHAGFRASMHECDAVFRELIGWSVIDELSLPAERSRLDATDIQQPVLFTLQVSLARLWMELGIEPEAFVGHSIGEVAAVCVAGGLSVRDAARVTIARSHLIQHRAAKAAMIAVQAGDEEIIPFLAPYGGRVAIAALNSPTSSAVSGPPEEIRALEVALNRAGISSRAVRVDRPGHSPGMDPLLSPLREALTNIEPRAFWARFHSTALDGAVDPVVNADYWAHNLRNQVRFAPTVAALADAGIDTFVEISPHGTLRGAIEEITQAQGASVVVADSIRRGEDDNRCFLNAAASLFVHGVPLSLETLFSSDAQVVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Sta-12	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHTILEQALPEPAAASPGTDGGSEVDLPWLLSARTPAALRAQARRLAAHLDADPAPAGHDVAHSLAATRSRFEHRAVLLGPDHHAQLTAFAEGAPTPGLVTGTAGRTGRVAFVLPGQGSQWPGMADRLLAESATFRNTLRTCAQALEEHLDWSVEDTLRGLPGAGNMERAEVIQPVLFATMVALAALWREHGVEPEAVVGHSQGEIAAAHLAGALSLEDAARVVTHRSRLLSRVVGQGAVASVSLPAQEALARLERWGDALSIAAVNGVSSVSVAGDEAPLDEFLAELETEGVRCRKLRIKGAAHSAVVEPLREEALAVLAPVRPRASRIPFYSTVTGGLLDTTELDAEYWYRNMRQTVQFAPATRALLADGFGVFVECSPHPALAGAVQETAEDAGASDPVLLASLRREEGGLERFSVSLAEAFVRGVGPSWASRGSVVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Spl-3	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVILEEAPPVAPAPPRPSEEGRRLVLPVSARTSGALRGQAHALARRLEERPGLRLDDVAGALRADRPALRHRLTVSASSVPEAVEALRAAVPAVPPVPDEPPKVAFLLPGGGTQYVGMGSGLYRENDVYRDTVDRCAAVLRPALGSDLRTALFEEVEPGSTAAFMALFVTEYALARTLMEEGVRPDALIGHSLGEYTAACLAGVMEIDEALPVVAERIRLIASSGGATVGVAACADTVLPLLGEGLSLAAVNSPVACTVAGDTDAVDRLEAELTRRGVPFRRLRMPAAAHSHVLDPILESFAGHLRTLTLRPPRIPYVTNVTGDWATDAQATDVGHWVDHTRRTVRFADGIAALWERERPVLVEIGPGDSLTKLARARLDGEGPVTVTTMRHAKAQAADGFVLAEALGRLWSAGVDAALPHVPRPPRGAGRVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*

Las-1	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVILEDVLDDQEPSSPEDDASATPLVLSADDPQALRAQAARLHSFVEQRPDIPLSDVRFTLLHGREALDQRAAVVGHDRADVLAALADLAGGEAGAGVLTGGVGGVGKVVFVFPGQGSQWPGMGRELLDTSPVFATHIAECEAALTPYVDWSLTDVLRQGEPLDRIEILQPVLFALMVSLARLWQHHGIHPDAVTGHSQGEIAAAHIAGALTLDDATRIVVLRSQLFADHLTGHGAIASLTLPATQVTHQLAQYDGRLTIAGINSPTTCTVAGPHTDLTTLTHWARQQGARARIIDTTVASHSPHVEPLHDDLIHLLADISPQAGTIPIYSTVTTEPIDGTQLTAEYWYDNCRHPVRFHDTLHTLTTHGHTHYLEISPHPVLIPAITETHPTATTIPTLHRNQGTTTDLHTSLAHAWTTGLPTTWTRPRSGDTHIVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
506-4	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVILEAPAAPDSPSAASPSVAPREPLFLTERTPLPVSARTPEAVEGQIQRLRAHLAEHPGDDPRTVAAALFSTRTEFPHRAVLLGEGAVTGTALTRPRTVFVFPGQGSQWLGMGLKLMAESPVFAARMRECADALAEHTGRDLIAMLEDPAVKSRVDVVHPVCWAVMMSLAAVWEAAGVRPDAVIGHSQGEIAAACVAGAITLEDGARLVALRSALLQRELAGHGAMGSIAFPAADVEAAAAQVDNVWVAGRNGTGTTIVSGRPDAVETLIARYEARGVWVTRLVVDCPTHTPFVDPLYDEFQRIAAATTSRTPRIPWFSTADERWIDSPLDDEYWFRNLRNPVGFAAAVAAAREPGDTVFVEVSAHPVLLPAINGTTVGTLRRGGGADQVVDSLAKAYTAGVAVDWPTVVAAPGTAHDTTRTASGPVPGPAVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
520-4	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVLLEAHPAGEPPAEEPSASKPGEPLIATPLTPLPVSARTATALDGQVRRLREHLAARPGHDPRAIAAGLLARRTTFPHRAVLLDDDVVTGTALTEPRTVFVFPGQGPQWRGMGVELMAASPVFAARMRQCADALIPHTGWDPIAMLDDPEVTRRVDVVHPVCWAVMVSLAAVWEAAGVRPDAVIGHSQGEIAAACVAGALTLEDGARLVALRSALLLRELAGRGAMGSVALPAADVEADAARIDGVWVAGRNGATTTTVAGRPDAVETLIADYEARGVWVRRIAVDCPTHTPFVDPLYDELQRIVADTTSRTPEIPWFSTADERWIDAPLDDEYWFRNMRHPVGFATAVTAAREPGDTVFVEVSAHPVLLPAIDGATVATLRRGGGVHRLLTALAEAHTTGVPVDWAAVVPATATAVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRA

	LHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
506-4_2	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVILEAHAAPEPPALDSPVVEPSASLFATELTPLPVSARTSEAVDGQVQRLREHLATHPGDDPRAVAAALLATRTDFPHRAVLLGDGVVTGTALTAPRTVFVFPGQGSQWLGMGRKLMAESPVFAARMRQCADALAEHTGRDLIAMLDDPAVKSRVDVVHPVCWAVMVSLAAVWEAAGVRPDAVIGHSQGEIAAACVAGAISLEDGARLVALRSALLVRELAGRGAMGSIAFAAADVEAAAARIDGVWVAGRNGTATTIVSGRPDAVETLIADYETRGVWVTRLVVDCPTHTPFVDPLYDELQRIVAATTSRAPEIPWFSTADERWIDAPLDDEYWFRNMRNPVGFAAAVAAAREPGDTVFIEVSAHPVLLPAINGTTVGTLRRGGGADRLLDSLAKAHTVGVAVDWPTVVAATGAAHDTARTADGAATGTAVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*
Thu-11	MSGDNGMTEEKLRRYLKRTVTELDSVTARLREVEHRASDPIAIVGMACRFPGGVHNPGELWEFIVGGGDAVTEMPTDRGWDLDALFDPDPQRHGTSYSRHGAFLDGAADFDAAFFGISPREALAMDPQQRQVLETTWELFENAGIDPHSLRGSDTGVFLGAAYQGYGQDAVVPEDSEGYLLTGNSSAVVSGRVAYVLGLEGPAVTVDTACSSSLVALHSACGSLRDGDCGLAVAGGVSVMAGPEVFTEFSRQGGLAVDGRCKAFSAEADGFGFAEGVAVVLLQRLSDARRAGRQVLGVVAGSAINQDGASNGLAAPSGVAQQRVIRKAWARAGITGADVAVVEAHGTGTRLGDPVEASALLATYGKSRGSSGPVLLGSVKSNIGHAQAAAGVAGVIKVVLGLNRGLVPPMLCRGERSPLIEWSSGGVELAEAVSPWPPAADGVRRAGVSAFGVSGTNAHVLLERAPEPAATAPRAAAAPATWLPLVLSGRTGKALQAQAAKLRAHLDSHPDLALADLACSLAGTRTHFARRAAVVARDRAALLDALDALAQGSAAPGVVLGEARAQGKVVFVFPGQGSQWPHMAKALLESSDVFRERIEACARALERHVDWSPLAVLRGDEGAPSLERIDVMQPLLFAVMVSLSALWRSMGVEPDAVIGNSQGEIAAACVAGALSLDDAAMVVARRSRLLTRLVGQGAMIVVDLPAAELGERLARWGERLAIAAVNSPRSTVVAGEKDAVEELLRELQPAQVVARRVRADGATHCAQVEVLREEVLDRLAGIEPRSSTLPLYSTVTGDRLDGSELGTAYWYRNMRQPVRLLDAVQRLLADGHRFFVEVSPHPLSLLALRETFTATGVPAAVVGSLRRDEGDLRRFLLSLSDLWAQGFPLDWARVLPEGRRVDLPNYPFEPQRYWLAPEVSDQLADSRYRVDWRPLATTPVDLEGGFLVHGSAPESLTSAVEKAGGRVVPVASADREALAAALREVPGEVAGVLSVHTGAATHLALHQSLGEAGVRAPLWLVTSRAVALGESEPVDPEQAMVWGLGRVMGLETPERWGGLVDLPAEPAPGDGEAFVACLGADGHEDQVAIRDHARYGRRLVRAPLGTRESSWEPAGTALVTGGTGALGGHVARHLARCGVEDLVLVSRRGVDAPGAAELEAELVALGAKTTITACDVADREQLSKLLEELRGQGRPVRTVVHTAGVPESRPLHEIGELESVCAAKVTGARLLDELCPDAETFVLFSSGAGVWGSANLGAYSAANAYLDALAHRRRAEGRAATSVAWGAWAGEGMATGDLEGLTRRGLRPMAPERAIRALHQALDNGDTCVSIADVDWERFAVGFTAARPRPLLDELVTPAVGAVPAVQAAPAREMTSQELLEFTHSHVAAILGHSSPDAVGQDQPFTELGFDSLTAVGLRNQLQQATGLALPATLVFEHPTVRRLADHIGQQLDSGTPAREASSALRDGYRQAGVSGRVRSYLDLLAGLSDFREHFDGSDGFSLDLVDMADGPGEVTVICCAGTAAISGPHEFTRLAGALRGIAPVRAVPQPGYEEGEPLPSSMAAVAAVQADAVIRTQGDKPFVVAGHSAGALMAYALATELLDRGHPPRGVVLIDVYPPGHQDAMNAWLEELTATLFDRETVRMDDTRLTALGAYDRLTGQWRPRETGLPTLLVSAGEPMGPWPDDSWKPTWPFEHDTVAVPGDHFTMVQEHADAIARHIDAWLGGGNSSSVDKLAAALEHHHHHH*

Table S2. Plasmids and strains used in this study.

Plasmids	Summary	Source of references
pSY121 (JPUB_005999)	DEBS M6+TE-His (= WT), KanR	[4]
pSY122 (JPUB_006001)	AT-exchanged DEBS M6+TE, AT from module 4 of the epothilone PKS (= Epo-4), KanR	[4]
pSY150 (JPUB_020896)	AT-exchanged DEBS M6+TE, AT from module 5 of the niddamycin PKS[5] (= Nid-5), KanR	This study
pSY151 (JPUB_020898)	AT-exchanged DEBS M6+TE, AT from module 1 of the lasalocid PKS[6], KanR	This study
pSY152 (JPUB_020900)	AT-exchanged DEBS M6+TE, AT from module 4 of the FK506 PKS (*Streptomyces* sp. KCTC 11604BP)[7], KanR	This study
pSY153 (JPUB_020902)	AT-exchanged DEBS M6+TE, AT from module 4 of the FK520 PKS[7], KanR	This study
pSY154 (JPUB_020904)	AT-exchanged DEBS M6+TE, AT from module 4 of the FK506 PKS (*Streptomyces kanamyceticus* KCTC9225)[7], KanR	This study
pSY155 (JPUB_020906)	AT-exchanged DEBS M6+TE, AT from module 11 of the thuggacin PKS[8], KanR	This study
pSY156 (JPUB_020908)	AT-exchanged DEBS M6+TE, AT from module 8 of the ansalactam PKS[9] (= Ans-8), KanR	This study
pSY157 (JPUB_0209010)	AT-exchanged DEBS M6+TE, AT from module 13 of the sanglifehrin PKS[10] (= San-13), KanR	This study
pSY158 (JPUB_020912)	AT-exchanged DEBS M6+TE, AT from module 2 of the leupyrrin PKS[11] (= Leu-2), KanR	This study

pSY159 (JPUB_020914)	AT-exchanged DEBS M6+TE, AT from module 6 of the divergolide PKS[12] (= Div-6), KanR	This study
pSY160 (JPUB_020916)	AT-exchanged DEBS M6+TE, AT from module 4 of the divergolide PKS[12] (= Div-4), KanR	This study
pSY161 (JPUB_020918)	AT-exchanged DEBS M6+TE, AT from module 1 of the salinosporamide PKS[13] (= Sal-1), KanR	This study
pSY162 (JPUB_020920)	AT-exchanged DEBS M6+TE, AT from module 5 of the monensin PKS[14] (= Mon-5), KanR	This study
pSY164 (JPUB_020922)	AT-exchanged DEBS M6+TE, AT from module 12 of the stambomycin PKS[15] (= Sta-12), KanR	This study
pSY165 (JPUB_020924)	AT-exchanged DEBS M6+TE, AT from module 4 of the reveromycin PKS[16] (= Rev-4), KanR	This study
pSY166 (JPUB_020926)	AT-exchanged DEBS M6+TE, AT from module 3 of the splenocin PKS[17] (= Spl-3), KanR	This study
pEE1 (JPUB_020934)	WT, A162W, KanR	This study
pEE2 (JPUB_020929)	Epo-4, A162W, KanR	This study
pEE3 (JPUB_020931)	Rev-4, A162W, KanR	This study
pLK54 (JPUB_020894)	MatB T207G/M306I, KanR	[18]

Strains	**Summary**	**Source of references**
E. coli DH10B + pSY121 (JPUB_005998)	Successfully produced WT when *E. coli* K207-3 was transformed with pSY121	[4]
E. coli DH10B + pSY122 (JPUB_006000)	Successfully produced Epo-4 when *E. coli* K207-3 was transformed with pSY122	[4]
E. coli DH10B + pSY150 (JPUB_020895)	Successfully produced Nid-5 when *E. coli* K207-3 was transformed with pSY150	This study

E. coli DH10B + pSY151 (JPUB_020897)	Protein production was not successful.	This study
E. coli DH10B + pSY152 (JPUB_020899)	Protein production was not successful.	This study
E. coli DH10B + pSY153 (JPUB_020901)	Protein production was not successful.	This study
E. coli DH10B + pSY154 (JPUB_020903)	Protein production was not successful.	This study
E. coli DH10B + pSY155 (JPUB_020905)	Protein production was not successful.	This study
E. coli DH10B + pSY156 (JPUB_020907)	Successfully produced Ans-8 when *E. coli* K207-3 was transformed with pSY156	This study
E. coli DH10B + pSY157 (JPUB_020909)	Successfully produced San-13 when *E. coli* K207-3 was transformed with pSY157	This study
E. coli DH10B + pSY158 (JPUB_020911)	Successfully produced Leu-2 when *E. coli* K207-3 was transformed with pSY158	This study
E. coli DH10B + pSY159 (JPUB_020913)	Successfully produced Div-6 when *E. coli* K207-3 was transformed with pSY159	This study
E. coli DH10B + pSY160 (JPUB_020915)	Successfully produced Div-4 when *E. coli* K207-3 was transformed with pSY160	This study
E. coli DH10B + pSY161 (JPUB_020917)	Successfully produced Sal-1 when *E. coli* K207-3 was transformed with pSY161	This study
E. coli DH10B + pSY162 (JPUB_020919)	Successfully produced Mon-5 when *E. coli* K207-3 was transformed with pSY162	This study
E. coli DH10B + pSY164 (JPUB_020921)	Successfully produced Sta-12 when *E. coli* K207-3 was transformed with pSY164	This study
E. coli DH10B + pSY165 (JPUB_020923)	Successfully produced Rev-4 when *E. coli* K207-3 was transformed with pSY165	This study
E. coli DH10B + pSY166 (JPUB_020925)	Successfully produced Spl-3 when *E. coli* K207-3 was transformed with pSY166	This study
E. coli DH10B + pEE1 (JPUB_020927)	Successfully produced WT A162W when *E. coli* K207-3 was transformed with pEE1	This study

E. coli DH10B + pEE2 (JPUB_020930)	Successfully produced Epo-4 A162W when *E. coli* K207-3 was transformed with pEE2	This study
E. coli DH10B + pEE3 (JPUB_020932)	Successfully produced Rev-4 A162W when *E. coli* K207-3 was transformed with pEE3	This study
E. coli DH10B + pLK54 (JPUB_020893)	Successfully produced MatB T207G/M306I when *E. coli* BL21(DE3) was transformed with pLK54	18

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Table S3. Polyketide production by Epo-4 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Epo-4) , Natural substrates = Malonyl-CoA/Methylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	171127/182787	-
Methylmalonyl-CoA	2304095/2239351	1471130/1316948	0.61
Ethylmalonyl-CoA	1865023/2026810	1345308/1437711	0.72
Propylmalonyl-CoA	79814/83584	1756713/1825373	21.92
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	1097955/1122949	1.57
Allylmalonyl-CoA	1536761/1955323	4222400/4356072	2.46
Butylmalonyl-CoA	285677/318832	3655044/3816523	12.36
Isobutylmalonyl-CoA	n.d.	9758/10593	-
Pentylmalonyl-CoA	21927/20665	169249/169653	7.96
Isopentylmalonyl-CoA	n.d.	16278/17311	-
2-Methylbutylmalonyl-CoA	n.d.	n.d.	-
Hexylmalonyl-CoA	27431/23733	12436/12502	0.49
Phenylmalonyl-CoA	n.d.	n.d.	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S4. Polyketide production by Mon-5 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Mon-5), Natural substrates = Methylmalonyl-CoA/Ethylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	478154/447721	0.20
Ethylmalonyl-CoA	1865023/2026810	50451/46250	<0.1
Propylmalonyl-CoA	79814/83584	110575/104542	1.32
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	29510/31174	<0.1
Allylmalonyl-CoA	1536761/1955323	121033/101002	<0.1
Butylmalonyl-CoA	285677/318832	33268/30961	1.06
Isobutylmalonyl-CoA	n.d.	12280/12019	-
Pentylmalonyl-CoA	21927/20665	381319/344181	17.03
Isopentylmalonyl-CoA	n.d.	187593/176570	-
2-Methylbutylmalonyl-CoA	n.d.	24302/25601	-
Hexylmalonyl-CoA	27431/23733	229580/208193	8.56
Phenylmalonyl-CoA	n.d.	50834/44713	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S5. Polyketide production by Nid-5 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Nid-5) , Natural substrate = Ethylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	n.d.	-
Ethylmalonyl-CoA	1865023/2026810	46761/47250	<0.1
Propylmalonyl-CoA	79814/83584	294360/306481	3.68
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	56174/46441	<0.1
Allylmalonyl-CoA	1536761/1955323	131064/215105	0.10
Butylmalonyl-CoA	285677/318832	1192008/1221287	3.99
Isobutylmalonyl-CoA	n.d.	37026/35593	-
Pentylmalonyl-CoA	21927/20665	1856123/2454148	101.20
Isopentylmalonyl-CoA	n.d.	1204497/1149175	-
2-Methylbutylmalonyl-CoA	n.d.	97527/101511	-
Hexylmalonyl-CoA	27431/23733	1459940/1629903	56.16
Phenylmalonyl-CoA	n.d.	47539/52863	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S6. Polyketide production by Rev-4 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Rev-4) , Natural substrates = Butylmalonyl-CoA/Hexylmalonyl-CoA etc.	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	164132/154758	<0.1
Ethylmalonyl-CoA	1865023/2026810	81413/79781	<0.1
Propylmalonyl-CoA	79814/83584	181361/192556	2.29
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	5606/22348	<0.1
Allylmalonyl-CoA	1536761/1955323	132330/129377	<0.1
Butylmalonyl-CoA	285677/318832	431294/444164	1.45
Isobutylmalonyl-CoA	n.d.	20251/20067	-
Pentylmalonyl-CoA	21927/20665	648949/693084	31.50
Isopentylmalonyl-CoA	n.d.	376906/371944	-
2-Methylbutylmalonyl-CoA	n.d.	36727/36584	-
Hexylmalonyl-CoA	27431/23733	1876211/899567	54.25
Phenylmalonyl-CoA	n.d.	n.d.	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S7. Polyketide production by Div-4 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Div-4) , Natural substrate = Ethylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	17027/23813	<0.1
Ethylmalonyl-CoA	1865023/2026810	126044/77745	<0.1
Propylmalonyl-CoA	79814/83584	1455398/1810511	19.99
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	247947/262075	0.36
Allylmalonyl-CoA	1536761/1955323	542400/138016	0.19
Butylmalonyl-CoA	285677/318832	270677/279028	0.91
Isobutylmalonyl-CoA	n.d.	60440/55669	-
Pentylmalonyl-CoA	21927/20665	10990/8936	0.47
Isopentylmalonyl-CoA	n.d.	n.d.	-
2-Methylbutylmalonyl-CoA	n.d.	n.d.	-
Hexylmalonyl-CoA	27431/23733	3847/7393	0.22
Phenylmalonyl-CoA	n.d.	n.d.	-

Mass counts < 5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S8. Polyketide production by Ans-8 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Ans-8) , Natural substrate = Isobutylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	336884/366112	0.15
Ethylmalonyl-CoA	1865023/2026810	1146284/1173116	0.60
Propylmalonyl-CoA	79814/83584	627106/655794	7.85
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	2240/26242	<0.1
Allylmalonyl-CoA	1536761/1955323	22187/56360	<0.1
Butylmalonyl-CoA	285677/318832	854202/913005	2.92
Isobutylmalonyl-CoA	n.d.	45779/45399	-
Pentylmalonyl-CoA	21927/20665	2646684/2514213	121.17
Isopentylmalonyl-CoA	n.d.	760387/826935	-
2-Methylbutylmalonyl-CoA	n.d.	88500/80608	-
Hexylmalonyl-CoA	27431/23733	3032390/2891943	115.79
Phenylmalonyl-CoA	n.d.	64633/66129	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S9. Polyketide production by San-13 relative to WT.

Extender substrates	**Peak area (WT)**	**Peak area (San-13) , Natural substrate = 3-oxobutylmalonyl-CoA**	**Production levels (relative to WT)**
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	5819/5342	<0.1
Ethylmalonyl-CoA	1865023/2026810	104510/103818	<0.1
Propylmalonyl-CoA	79814/83584	360647/362517	4.43
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	26061/23209	<0.1
Allylmalonyl-CoA	1536761/1955323	248801/282425	0.15
Butylmalonyl-CoA	285677/318832	463660/466082	1.54
Isobutylmalonyl-CoA	n.d.	62303/63295	-
Pentylmalonyl-CoA	21927/20665	411994/342234	17.70
Isopentylmalonyl-CoA	n.d.	387413/404778	-
2-Methylbutylmalonyl-CoA	n.d.	62434/62061	-
Hexylmalonyl-CoA	27431/23733	118778/121966	4.71
Phenylmalonyl-CoA	-	-	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S10. Polyketide production by Leu-2 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Leu-2) , Natural substrate = 1-hydroxyisopentylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	n.d.	-
Ethylmalonyl-CoA	1865023/2026810	87276/87517	<0.1
Propylmalonyl-CoA	79814/83584	338600/639709	5.99
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	48604/48556	<0.1
Allylmalonyl-CoA	1536761/1955323	389718/369816	0.22
Butylmalonyl-CoA	285677/318832	1031688/1040048	3.43
Isobutylmalonyl-CoA	n.d.	81870/92879	-
Pentylmalonyl-CoA	21927/20665	845451/800461	38.64
Isopentylmalonyl-CoA	n.d.	941081/996046	-
2-Methylbutylmalonyl-CoA	n.d.	114278/127554	-
Hexylmalonyl-CoA	27431/23733	384898/402621	15.39
Phenylmalonyl-CoA	n.d.	n.d.	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S11. Polyketide production by Div-6 relative to WT

Extender substrates	Peak area (WT)	Peak area (Div-6) , Natural substrate = Isobutenylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	n.d.	-
Ethylmalonyl-CoA	1865023/2026810	n.d.	-
Propylmalonyl-CoA	79814/83584	n.d.	-
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	n.d.	-
Allylmalonyl-CoA	1536761/1955323	n.d.	-
Butylmalonyl-CoA	285677/318832	7130/8126	<0.1
Isobutylmalonyl-CoA	n.d.	73303/56791	-
Pentylmalonyl-CoA	21927/20665	18373/17726	0.85
Isopentylmalonyl-CoA	n.d.	1599751/1250115	-
2-Methylbutylmalonyl-CoA	n.d.	267937/302102	-
Hexylmalonyl-CoA	27431/23733	36387/32455	1.35
Phenylmalonyl-CoA	n.d.	n.d.	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S12. Polyketide production by Sal-1 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Sal-1) , Natural substrate = 2-chloroethylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	n.d.	-
Ethylmalonyl-CoA	1865023/2026810	19838/11216	<0.1
Propylmalonyl-CoA	79814/83584	107821/114295	1.36
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	28550/34344	<0.1
Allylmalonyl-CoA	1536761/1955323	102653/50940	<0.1
Butylmalonyl-CoA	285677/318832	575432/566416	1.89
Isobutylmalonyl-CoA	n.d.	37001/19636	-
Pentylmalonyl-CoA	21927/20665	1601468/1506859	72.98
Isopentylmalonyl-CoA	n.d.	329974/344156	-
2-Methylbutylmalonyl-CoA	n.d.	36176/37379	-
Hexylmalonyl-CoA	27431/23733	267900/666300	18.26
Phenylmalonyl-CoA	n.d.	n.d.	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S13. Polyketide production by Sta-12 relative to WT

Extender substrates	**Peak area (WT)**	**Peak area (Sta-12), , Natural substrates = Hexylmalonyl-CoA/Isoheptylmalonyl-CoA etc.**	**Production levels (relative to WT)**
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	n.d.	-
Ethylmalonyl-CoA	1865023/2026810	4598/4568	<0.1
Propylmalonyl-CoA	79814/83584	14018/13004	0.17
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	n.d.	-
Allylmalonyl-CoA	1536761/1955323	n.d.	-
Butylmalonyl-CoA	285677/318832	34735/10016	<0.1
Isobutylmalonyl-CoA	n.d.	n.d.	-
Pentylmalonyl-CoA	21927/20665	28105/32359	1.42
Isopentylmalonyl-CoA	n.d.	101402/96617	-
2-Methylbutylmalonyl-CoA	n.d.	12108/14369	-
Hexylmalonyl-CoA	27431/23733	12040/39889	1.01
Phenylmalonyl-CoA	n.d.	n.d.	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S14. Polyketide production by Spl-3 relative to WT.

Extender substrates	Peak area (WT)	Peak area (Spl-3), Natural substrates = Benzylmalonyl-CoA	Production levels (relative to WT)
Malonyl-CoA	n.d.	n.d.	-
Methylmalonyl-CoA	2304095/2239351	n.d.	-
Ethylmalonyl-CoA	1865023/2026810	n.d.	-
Propylmalonyl-CoA	79814/83584	19711/15117	0.21
Isopropylmalonyl-CoA	n.d.	n.d.	-
Propargylmalonyl-CoA	692500/726575	n.d.	-
Allylmalonyl-CoA	1536761/1955323	n.d.	-
Butylmalonyl-CoA	285677/318832	31791/27497	<0.1
Isobutylmalonyl-CoA	n.d.	n.d.	-
Pentylmalonyl-CoA	21927/20665	25029/22488	1.12
Isopentylmalonyl-CoA	n.d.	20805/17082	-
2-Methylbutylmalonyl-CoA	n.d.	n.d.	-
Hexylmalonyl-CoA	27431/23733	n.d.	-
Phenylmalonyl-CoA	n.d.	n.d.	-

Mass counts <5000 were shown as n.d. These experiments were repeated at least twice. The results of the first measurements were shown in left and the results of second measurements were shown in right. Relative production levels were calculated using averaged peak area.

Table S15. Amino acid sequences that are predicted to form AT active sites.

ATs	β1-α1	α4	β2-α5	β6-α9
Erythromycin AT6 (WT)	GQGA	RVDVVQP	GHSQGEI	TLPVDYASH
Epothilone AT4	GQGA	QTAFTQP	GHSAGEL	RLHVSHASH
Monensin AT5	GQGG	RIDVVQP	GHSQGEI	AVASDVAGH
Niddamycin AT5	GQGS	RVDVVQP	GHSQGEI	IPGVDTAGH
Reveromycin AT4	GQGS	RIDVYHP	GHSQGEV	RILGMAASH
Divergolide AT4	GQGS	RIEILQP	GHSQGEV	VVGSTVASH
Ansalactam AT8	GQGS	DLDVVQP	GHSQGEI	IHGANAAGH
Sanglifehrin AT13	GHGA	RVDVVQP	GHSQGEI	VRQIVGAGH
Leupyrrin AT2	GFGS	DLSYAQP	GHSLGEC	KLDVRRAAH
Divergolide AT6	GQGS	LIEVVQP	GHSQGEI	IVGSSVASH
Salinosporamide AT1	GGGT	ATDIQQP	GHSIGEV	AVRVDRPGH
Stambomycin AT12	GQGS	RAEVIQP	GHSQGEI	KLRIKGAAH
Splenocin AT3	GGGT	GSTAAFM	GHSLGEY	RLRMPAAAH

3. Supplementary methods

Acyl-CoA detection. Acyl-CoAs were analyzed as previously described[19]. Briefly, acyl CoA compounds were analyzed via LC-MS (1290 Infinity II UHPLC system and 6545 quadrupole TOF-MS; Agilent technologies) on a SeQuant ZIC-HILIC column (150 mm length, 2.1 mm internal diameter, 5 µm particle size; Sigma-Millipore) at 35 °C. The mobile phase was composed of 10 mM NH_4OAc + 0.8% NH_4OH in 54.9% acetonitrile in water. Sample injection volume of 1 µL was used throughout. Electrospray ionization conditions for the MS were as follows: Negative ion mode, drying gas temperature = 300 °C, drying gas flow rate = 10 L/min, sheath gas temperature = 350 °C, sheath gas flow rate = 12 L/min, nebulizer = 20 lb/in^2, VCap = 3500 V, nozzle voltage = 2000 V, fragmentor = 100 V, skimmer = 50 V, and OCT 1 RF Vpp = 300 V. A mass range of 70-1100 *m/z* was used. We also used the following reported method to analyze acyl-CoA production[1]. Briefly, acyl CoA compounds were analyzed via LC-MS (1290 Infinity II UHPLC system and 6545 quadrupole TOF-MS; Agilent technologies) on a Poroshell 120 HILIC-Z (100 mm length, 2.1 mm internal diameter, 2.7 µm particle size; Agilent technologies) at 30 °C. The mobile phase (A) was composed of 10 mM NH_4OAc + 0.2% NH_4OH + 5 µM mendronic acid in water. The mobile phase (B) was composed of 10 mM NH_4OAc + 0.2% NH_4OH + 5 µM mendronic acid in 90% acetonitrile in water. Sample injection volume of 1 µL was used throughout. Electrospray ionization conditions for the MS were as follows: Negative ion mode, drying gas temperature = 300 °C, drying gas flow rate = 10 L/min, sheath gas temperature = 350 °C, sheath gas flow rate = 12 L/min, nebulizer = 20 lb/in^2, VCap = 3500 V, nozzle voltage = 2000 V, fragmentor = 100 V, skimmer = 50 V, and OCT 1 RF Vpp = 300 V. A mass range of 70-1100 *m/z* was used.

Polyketide detection. LC separation of all polyketides was conducted at 50°C with a Phenomenex Kinetex XB-C18 column (100 mm length, 2.1 mm internal diameter, 2.6 µm particle size) using an Agilent Technologies 1260 high performance liquid chromatography system. The mobile phase was composed of 0.1% formic acid in LC-MS grade water (solvent A) and 0.1% formic acid in LC-MS grade acetonitrile (solvent B). Polyketide products were separated using the following gradient: 15% to 100% B for 3.96 min, held at 100% B for 1.5 min, 100% to 15% B for 0.1 min, held at 15% B for 2.86 min. A flow rate of 0.31 mL/min was used until 5.46 min, increased to 0.45 mL/min in 0.1 min, and held at 0.45 mL/min for 2.86 min. The total LC run time was 8.42 min. The LC system was coupled to either an Agilent 6210 time-of-flight mass spectrometer (TOF-MS) system or a 6520 quadrupole TOF-MS (QTOF-MS) system. Electrospray ionization (ESI) was used to facilitate the transfer of polyketide productions from the LC to the MS system. Nitrogen gas was used as both the nebulizing and drying gas to facilitate the production of gas-phase ions. The drying and nebulizing gases were set to 10 L/min and 30 lb/in^2, respectively, and a drying gas temperature of 330°C was used throughout. ESI was conducted in the positive-ion mode for TKLs with a capillary voltage of 4 kV. The Fragmentor, skimmer and Oct 1 RF Vpp voltages were set to 140 V, 50 V, and 250 V, respectively. The acquisition rate was set to 0.86 spectra/s.

4. Supplementary references

(1) Amer, B.; Kakumanu, R.; Baidoo, E.E.K. HILIC-MS analysis of central carbon metabolisms in Gram negative bacteria. https://dx.doi.org/10.17504/protocols.io.4r3l2opzxv1y/v1

(2) Yadav, G.; Gokhale, R. S.; Mohanty, D. Computational approach for prediction of domain organization and substrate specificity of modular polyketide synthases. *J Mol Biol* **2003**, *328* (2), 335-363.

(3) Minowa, Y.; Araki, M.; Kanehisa, M. Comprehensive analysis of distinctive polyketide and nonribosomal peptide structural motifs encoded in microbial genomes. *J Mol Biol* **2007**, *368* (5), 1500-1517.

(4) Yuzawa, S.; Deng, K.; Wang, G.; Baidoo, E. E.; Northen, T. R.; Adams, P. D.; Katz, L.; Keasling, J. D. Comprehensive in Vitro Analysis of Acyltransferase Domain Exchanges in Modular Polyketide Synthases and Its Application for Short-Chain Ketone Production. *ACS Synth Biol* **2017**, *6* (1), 139-147.

(5) Kakavas, S. J.; Katz, L.; Stassi, D. Identification and characterization of the niddamycin polyketide synthase genes from Streptomyces caelestis. *J Bacteriol* **1997**, *179* (23), 7515-7522.

(6) Migita, A.; Watanabe, M.; Hirose, Y.; Watanabe, K.; Tokiwano, T.; Kinashi, H.; Oikawa, H. Identification of a gene cluster of polyether antibiotic lasalocid from Streptomyces lasaliensis. *Biosci Biotechnol Biochem* **2009**, *73* (1), 169-176.

(7) Mo, S.; Kim, D. H.; Lee, J. H.; Park, J. W.; Basnet, D. B.; Ban, Y. H.; Yoo, Y. J.; Chen, S. W.; Park, S. R.; Choi, E. A.; et al. Biosynthesis of the allylmalonyl-CoA extender unit for the FK506 polyketide synthase proceeds through a dedicated polyketide synthase and facilitates the mutasynthesis of analogues. *J Am Chem Soc* **2011**, *133* (4), 976-985.

(8) Buntin, K.; Irschik, H.; Weissman, K. J.; Luxenburger, E.; Blöcker, H.; Müller, R. Biosynthesis of thuggacins in myxobacteria: comparative cluster analysis reveals basis for natural product structural diversity. *Chem Biol* **2010**, *17* (4), 342-356.

(9) Wilson, M. C.; Nam, S. J.; Gulder, T. A.; Kauffman, C. A.; Jensen, P. R.; Fenical, W.; Moore, B. S. Structure and biosynthesis of the marine streptomycete ansamycin ansalactam A and its distinctive branched chain polyketide extender unit. *J Am Chem Soc* **2011**, *133* (6), 1971-1977.

(10) Qu, X.; Jiang, N.; Xu, F.; Shao, L.; Tang, G.; Wilkinson, B.; Liu, W. Cloning, sequencing and characterization of the biosynthetic gene cluster of sanglifehrin A, a potent cyclophilin inhibitor. *Mol Biosyst* **2011**, *7* (3), 852-861.

(11) Kopp, M.; Irschik, H.; Gemperlein, K.; Buntin, K.; Meiser, P.; Weissman, K. J.; Bode, H. B.; Müller, R. Insights into the complex biosynthesis of the leupyrrins in Sorangium cellulosum So ce690. *Mol Biosyst* **2011**, *7* (5), 1549-1563.

(12) Li, S. R.; Zhao, G. S.; Sun, M. W.; He, H. G.; Wang, H. X.; Li, Y. Y.; Lu, C. H.; Shen, Y. M. Identification and characterization of the biosynthetic gene cluster of divergolides from Streptomyces sp. W112. *Gene* **2014**, *544* (1), 93-99.

(13) Eustáquio, A. S.; McGlinchey, R. P.; Liu, Y.; Hazzard, C.; Beer, L. L.; Florova, G.; Alhamadsheh, M. M.; Lechner, A.; Kale, A. J.; Kobayashi, Y.; et al. Biosynthesis of the salinosporamide A polyketide synthase substrate chloroethylmalonyl-coenzyme A from S-adenosyl-L-methionine. *Proc Natl Acad Sci U S A* **2009**, *106* (30), 12295-12300.

(14) Oliynyk, M.; Stark, C. B. W.; Bhatt, A.; Jones, M. A.; Hughes-Thomas, Z. A.; Wilkinson, C.; Oliynyk, Z.; Demydchuk, Y.; Staunton, J.; Leadlay, P. F. Analysis of the biosynthetic gene cluster for the polyether antibiotic monensin in Streptomyces cinnamonensis and evidence for the role of monB and monC genes in oxidative cyclization. *Molecular Microbiology* **2003**, *49* (5), 1179-1190.
(15) Laureti, L.; Song, L.; Huang, S.; Corre, C.; Leblond, P.; Challis, G. L.; Aigle, B. Identification of a bioactive 51-membered macrolide complex by activation of a silent polyketide synthase in Streptomyces ambofaciens. *Proc Natl Acad Sci U S A* **2011**, *108* (15), 6258-6263.
(16) Takahashi, S.; Toyoda, A.; Sekiyama, Y.; Takagi, H.; Nogawa, T.; Uramoto, M.; Suzuki, R.; Koshino, H.; Kumano, T.; Panthee, S.; et al. Reveromycin A biosynthesis uses RevG and RevJ for stereospecific spiroacetal formation. *Nat Chem Biol* **2011**, *7* (7), 461-468.
(17) Chang, C.; Huang, R.; Yan, Y.; Ma, H.; Dai, Z.; Zhang, B.; Deng, Z.; Liu, W.; Qu, X. Uncovering the formation and selection of benzylmalonyl-CoA from the biosynthesis of splenocin and enterocin reveals a versatile way to introduce amino acids into polyketide carbon scaffolds. *J Am Chem Soc* **2015**, *137* (12), 4183-4190.
(18) Koryakina, I.; McArthur, J.; Randall, S.; Draelos, M. M.; Musiol, E. M.; Muddiman, D. C.; Weber, T.; Williams, G. J. Poly specific trans-acyltransferase machinery revealed via engineered acyl-CoA synthetases. *ACS Chem Biol* **2013**, *8* (1), 200-208.
(19) (a) Baidoo, E. E. K.; Wang, G.; Joshua, C. J.; Benites, V. T.; Keasling, J. D. Liquid Chromatography and Mass Spectrometry Analysis of Isoprenoid Intermediates in Escherichia coli. *Methods Mol Biol* **2019**, *1859*, 209-224. (b) Kim, J.; Baidoo, E. E. K.; Amer, B.; Mukhopadhyay, A.; Adams, P. D.; Simmons, B. A.; Lee, T. S. Engineering Saccharomyces cerevisiae for isoprenol production. *Metab Eng* **2021**, *64*, 154-166.