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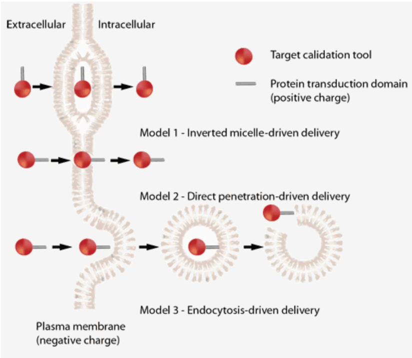
Table 1 Selection of cell-penetrating peptides

(Reference: https://doi.org/10.1007/978-981-13-8747-0, Ülo Langel, CPP, Cell-Penetrating Peptides, 2019)

Most of the presented peptides have been synthesized and tested as C-terminal amides (not indicated), although in several cases it is impossible to certify; cysteamide modifications are indicated. The L-amino acids are presented in capital letters, D-amino acids are presented in lowercase letters
Ac indicates acetyl; Ahx or X is aminohexanoic acid; Aib is aminoisobutyric acid; B is β-alanine; Bpg is bishomopropargylglycine; Dmt is dimethyltyrosine; O is ornithine; pT is a phosphoryl-Thr; pS is a phosphoryl-Ser; Φ is l-2-naphthylalanine; ri denotes retro-inverso; * denotes staple tethering site



There are three proposed routes of CPP entry:

Model 1: The inverted micelle model.

Model 2: The direct penetration (pore formation) mechanism.

Model 3: An endocytic mechanism of uptake.

Source: Cell-permeable peptides and their therapeutic applications, Victoria Sebbage, BioscienceHorizons, Volume 2, Number 1, March 2009.

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Name	Sequence
2	DSLKSYWYLQKFSWR (Kondo et al. 2012)
18A	DWLKAFYDKVAEKLKEAF (Datta et al. 2000)
α1H	KSKTEYYNAWAVWERNAP (Gomarasca et al. 2017)
α2H	GNGEQREMAVSRLRDCLDRQA (Gomarasca et al. 2017)
A22p	HTPGNSNKWKHLQENKKGRPRR (Shin et al. 2014)
Ac-18A-NH_2	DWLKAFYDKVAEKLKEAF) (Wimley and White 2000)
aCPP	Typical sequence R9GPLGLAGE8 (Li et al 2015)
AdVpVI(33-55)	Ac-GAFSWGSLWSGIKNFGSTVKNYG (Murayama et al. 2016)
AIP6	RLRWR (Wang et al. 2011)
all-d DsC18	Glrkrlrkfrnkikek (Bergmann et al. 2017)
αgliadin(31-43)	LGQQQPFPPQQPY (Paolella et al. 2018)
Alyteserin-2a	ILGKLLSTAAGLLSNL (Conlon et al. 2013)
ANG	TFFYGGSRGKRNNFKTEEY (Demeule et al. 2008)
ApoE(141–150)	Ac-LRKLRKRLLRX-Bpg-G (Shabanpoor et al. 2017)
ApoE-derived	Ac-LRKLRKRLLR (Tailhades et al. 2017)
Arf(1-22)	MVRRFLVTLRIRRACGPPRVRV (Johansson et al. 2008)
AT1002	FCIGRL (Gopalakrishnan et al. 2009)
AT1AR(304-318)	FLGKKFKKYFLQLLK (Östlund et al. 2005)

(continued)

Table 1 (continued)

Bac7	RRIRPRPPRLPRPRPRPLPFPRPGPRPIPRPL (Sadler et al. 2002)
BGPC7-FHV	RRRRNRTRRNRRRVR-RRFYGPV (Wongso et al. 2017)
Bim	EIWIAQELRRIGDEFNAYYARLLC (Kim et al. 2017)
BP16	KKLFKKILKKL (Soler et al. 2014)
BP100	KKLFKKILKYL (Eggenberger et al. 2009)
BPP13a	GGWPRPGPEIPP (Sciani et al. 2017)
bPrPp(1-30)	MVKSKIGSWILVLFVAMWSDVGLCKKRPKP (Magzoub et al. 2006)
BR2	RAGLQFPVGRLLRRLLR (Lim et al. 2013)
Buforin II	TRSSRAGLQFPVGRVIIRLLRK (Park et al.1998)
Buforin IIb	RAGLQFPVG[RLLR]$_3$ (Lee et al. 2008)
C6M1	RLWRLLWRLWRRLWRLLR (Jafari et al. 2014)
C105Y	CSIPPEVKFNKPFVYLI (Rhee and Davis 2006)
CADY	GLWRALWRLLRSLWRLLWRA cycteamide (Crombez et al. 2009a)
CAR	CARSKNKDC (Toba et al. 2014)
CA-Tat	KWKLFKKYGRKKRRQRRR (Lv et al. 2017)
CB5005 M	KLKLALALALA (Zhang et al. 2016)
CDB3	REDEDEIEW (Issaeva et al. 2003)
CendR	RPARPAR (Hu et al. 2014)
cFΦR4	cyclic FΦRRRRQ (Qian et al. 2014)
CGKRK	CGKRK (Griffin et al. 2017)
CIGB-300	cyclic CWMSPRHLGTC-Tat (Perera et al. 2012)
CIGB-552	Ac-HARIKpTFRRlKWKYKGKFW (Fernandez Masso et al. 2013)
CLIP6	KVRVRVRVpPTRVRERVK (Soudah et al. 2017)
CooP	ACGLSGLGVA (Hyvonen et al. 2014)
CpMTP	ARLLWLLRGLTLGTAPRRA (Jain and Chugh 2016)
CPNT	STSGTGKMTRAQRRAAARRNRA (Qi et al. 2011)
CPP1	(KFF)$_3$K (Patel et al. 2017)
CPP33	RLWMRWYSPRTRAYG (Lin et al. 2018)
CPP-C	PIEVCMYREP (Nakayama et al. 2011)
CPPecp	NYRWRCKNQN (Fu et al. 2017)
C-peptide	GPGLWERQAREHSERKKRRRESECKAA (Fan et al. 2016)
CRGDK	CRGDK (Zhao et al. 2018)
Crotamine	YKQCHKKGGHCFPKEKICLPPSSDFGKMDCRWRWKCCKKGSG (Rodrigues et al. 2012)
cSN50	AAVALLPAVLLALLAPVQRKRQKLMP (Torgerson et al. 1998)
65-2CTS	CPYVNQRPQKARYRNG (Percipalle et al. 2003)
CWR$_8$K	CWR$_8$K (Sasaki et al. 2008)
CyLoP-1	CRWRWKCCKK (Ponnappan et al. 2017)

(continued)

Table 1 (continued)

Cyt c(77–101)	GTKMIFVGIKKKEERADLIKKA (Howl and Jones 2015)
DAG	cyclic CDAGRKQKC (Mann et al. 2017)
D-JNKI-1	RPKRPTTLNLFPQVPRSQDT (Bonny et al. 2001)
DK17	DRQIKIWFQNRRMKWKK (Bera et al. 2016)
DLP	ACKTGSHNQCG (Kumar et al. 2015)
DMBT1-derived	GRVEVLYRGSW and GRVRVLYRGSW (Tuttolomondo et al. 2017)
dNP2	KIKKVKKKGRK-KIKKVKKKGRK (Lim et al. 2015)
DPV3	RKKRRRESRKKRRRES (Tacken et al. 2008)
DPV1047	CVKRGLKLRHVRPRVTRMDV (De Coupade et al. 2005)
DRTTLTN	DRTTLTN (Gennari et al. 2016)
DS4.3	RIMRILRILKLAR (Jeong et al. 2014)
Dynorphin A	YGGFLRRIRPKLKWDNQ (Marinova et al. 2005)
EA	GLKKLAELAHKLLKLGC (Yang et al. 2014)
EB1	LIRLWSHLIHIWFQNRRLKWKKK (Lundberg et al. 2007)
EF	GLKKLAELFHKLLKLGC (Yang et al. 2014)
EHB	RCSHYTGIRCSHMAATTAGIYTGIRCQHVVL-C6H (Cao et al. 2018)
EPRNEEK	EPRNEEK (Orihuela et al. 2009)
F3**	diphosphorylated dipeptide (Miao et al. 2016)
$G_4R_9L_4$	$G_4R_9L_4$ (Ramakrishna et al. 2014)
GALA	WEAALAEALAEALAEHLAEALAEALEALAA (Li et al. 2004)
GeT	KIAKLKAKIQKLKQKIAKLK (Rakowska et al. 2014)
gH625	HGLASTLTRWAHYNALIRAF (Galdiero et al. 2015)
Gi3α(346-355)	KNNLKECGLY (Jones et al. 2005)
Glu-Lys	EEEAAKKK (Lewis et al. 2010)
GV1001	EARPALLTSRLRFIPK (Kim et al. 2016a)
GWH1	GYNYAKKLANLAKKFANALW (Serna et al. 2017)
H2A derived	SGRGKQGGKARAKAKTRSSRAGLQFPVGRVHRLLRKG (Rosenbluh et al. 2004)
H6R6	H6R6 (Sun et al. 2017)
H16	H16 (Iwasaki et al. 2015)
HA2(1-23)	GLFGAIAGFIENGWEGMIDGWYG (Esbjörner et al. 2007)
HAIYPRH	HAIYPRH (Shteinfer-Kuzmine et al. 2017)
hBD3-3	GKCSTRGRKCCRRKK (Lee et al. 2015b)
HBP	GKRKKKGKGLGKKRDPCLRKYK (Luo et al. 2016)
hLF	KCFQWQRNMRKVRGPPVSCIKR (Duchardt et al. 2009)
Hph-1	YARVRRRGPRR (Jung et al. 2011)
HR9	CH_5-R_9-H_5C (Liu et al. 2013a)

(continued)

Table 1 (continued)

Hst5	DSHAKRHHGYKRKFHEKHHSHRGY (Luque-Ortega et al. 2008)
I1WL5W	WKKIWSKIKKLLK (Bi et al. 2014)
I4WL5W	IKKWWSKIKKLLK (Bi et al. 2014)
ID No.2	MAAWMRSLFSPLKKLWIRMH (Eudes and Macmillan 2014)
IMT-P8	RRWRRWNRFNRRRCR (Gautam et al. 2016)
INF	GLFEAIEGFIENGWEGMIDGWYGC (Pichon et al. 1997)
iNGR	CRNGRGPDC (Alberici et al. 2013)
isl-1	RVIRVWFQNKRCKDKK (Kilk et al. 2001)
JB9	cskc (Basu and Wickstrom, 1997)
JB434	R_9GGLAA-Aib-SGWKH_6 (Sangtani et al. 2018)
KAFAK	KAFAKLAARLYRKALARQLGVAA (Bartlett et al. 2013)
KALA	WEAKLAKALAKALAKHLAKALAKALKACEA (Wyman et al. 1997)
Kalata B1	polycyclic CGETCVGGTCNTPGCTCSWPVCTRNGLPV (Daly et al. 1999)
$(KFF)_3$K	$(KFF)_3$K (Rownicki et al. 2017)
K-FGF	AAVLLPVLLAAP (Lin et al. 1995)
KH	$(KH)_9$ (Chuah et al. 2016)
KLA	KLAKLAKKLAKLAK (Huang et al. 2017)
KLAK	KLALKLALKALKAALKLA (Oehlke et al. 1998)
KLA-R7	KLAKLAKKLAKLAKGGRRRRRRR (Lemeshko, 2013)
KP	MAPTKRKGSCPGAAPNKKP (Villa-Cedillo et al. 2017)
KST peptide	STGKANKITITNDKGRLSK (Adachi et al. 2017)
L1−6	PLILLRLLR (Schmidt et al. 2017)
L5a	RRWQW (Liu et al. 2016a)
L17E	IWLTALKFLGKHAAKHEAKQQLSKL (Akishiba et al. 2017)
lactoferrampin(265-284)	DLIWKLLSKAQEKFGKNKSR (Reyes-Cortes et al. 2017)
lactoferricin(17-30)	FKCRRWQWRMKKLG (Reyes-Cortes et al. 2017)
lactoferrin(19-40)	KCFMWQEMLNKAGVPKLRCARK (Duchardt et al. 2009)
LAH1	KKLALALALALHALALALALKKA (Moulay et al. 2017)
LALF(31-52)	HYRIKPTFRRLKWKYKGKFW (Yanez et al. 2017)
LB	FKCRRWQWRMKKLGAPSITCVRRAF) (Liu et al. 2013b)
L-CPP	LAGRRRRRRRRRK (Liu et al. 2006)
LDP-NLS	KWRRKLKKLRPKKKRKV (Ponnappan and Chugh, 2017)
LE10	LELELELELELELELELELE (Antunes et al. 2013)
LF chimera	FKCRRWQWRMKKLG-K-RSKNKGFKEQAKSLLKWILD (Reyes-Cortes et al. 2017)

(continued)

Table 1 (continued)

linTT1	AKRGARSTA (Hunt et al. 2017)
LK	LKKLLKLLKKLLKLAG (Kim et al. 2016b)
LL37	LLGDFFRKSKEKIGKEFKRIVQRIKDFLRNLVPRTES (Kim et al. 2016b)
LLIIL	LLIIL (Alaybeyoglu et al. 2017)
LMWP	VSRRRRRRGGRRRR (Chen et al. 2017d)
LP-12	HIITDPNMAEYL (Kumar et al. 2015)
LPAs	RC_nRC_nK (Gupta et al. 2011)
LTV	LTVSPWY (Chopra 2012)
lycosin-I	RKGWFKAMKSIAKFIAKEKLKEHL (Tan et al. 2017)
Lyp1	CGNKRTRGC (Fogal et al. 2008)
M918	MVTVLFRRLRIRRACGPPRVRV (El-Andaloussi et al. 2007)
Maurocalcine	GDCLPHLKLCKENKGCCSKKCKRRGTNIEKRCR (Poillot et al. 2010)
MAP	KLALKLALKALKAALKLA (Oehlke et al. 1998)
MAP12	LKTLTETLKELTKTLTEL (Oehlke et al. 2002)
MCoTI-I	polycyclic SGSDGGVCPKILQRCRRDSDCPGACICRGNGYCG (Camarero, 2017)
MCoTI-II	polycyclic CPKILKKCRRDSDCPGACICRGNGYCGSGSDGGV (Huang et al. 2015)
MFK	MFKLRAKIKVRLRAKIKL (Samuels et al. 2017)
Mgpe9	CRRLRHLRHHYRRRWHRFRC (Vij et al. 2016a)
MitP	INLKKLAKL(Aib)KKIL (Howl et al. 2018)
m(KLA)-iRGD	klaklakklakla-K-GG-iRGD (Qifan et al. 2016)
MMGP1	MLWSASMRIFASAFSTRGLGTRMLMYCSLPSRCWRK (Pushpanathan et al. 2013)
MPER fragment	ELDKWASLWNWFDITNWLWYIK (Song et al. 2009)
MPG	GALFLGFLGAAGSTMGA cysteamide (Morris et al. 1997)
MPG	GALFLGFLGAAGSTMGASQPKKKRKV cycteamide (Deshayes et al. 2005)
MPG-8	AFLGWLGAWGTMGWSPKKKRK (Crombez et al. 2009b)
mRVG	YTIWMPENPRPGTPCDIFTKSRGKRASNGGGRRRRRRRRR (Villa-Cedillo et al. 2017)
MT23	LPKQKRRQRRRM (Zhou et al. 2017)
mtCPP1	r-Dmt-OF (Cerrato et al. 2015)
MTM	AAVALLPAVLLALLAP (Fletcher et al. 2010)
MTD84	AVALVAVVAVA (Lim et al. 2014)
MTP	MLSLRQSIRFFK (Chuah et al. 2015a, b)
MTS	KGEGAAVLLPVLLAAPG (Zhao et al. 2001)
MTS1	AAVLLPVLLAAP (Rojas et al. 1998)
Mut3DPT-C9h	VKKKKIKAEIKIYVETLDDIFEQWAHSEDL (de la Torre et al. 2017)

(continued)

Table 1 (continued)

Myr-ApoE	Myr-LRKLRKRLLR (Tajik-Ahmadabad et al. 2017)
New modalities	Polycyclic, hairpin, stapled peptides for delivery (Valeur et al. 2017, Waldmann et al. 2017)
NF1	Stearyl-AGY(PO3)LLGKTNLKALAALAKKIL (Arukuusk et al. 2013)
NF51	δ-(Stearyl-AGYLLG)OINLKALAALAKKIL (Arukuusk et al. 2013)
NF55	δ-(Stearyl-AGYLLG)OINLKALAALAKAIL (Freimann et al. 2016)
NLS	PKKKRKV (Yoneda et al. 1992).
NLS-StAx-h	stapled RRWPRXILDXHVRRVWR (Dietrich et al. 2017)
NoLS	KKRTLRKNDRKKRC (Yao et al. 2015)
Novicidin	KNLRRIIRKGIHIIKKYF (Milosavljevic et al. 2016)
NPFSD	VLTNENPFSDP (Gong et al. 2016)
NYAD-1	stapled ITFEDLLDYYGP (Zhang et al. 2008)
Oct4-PTD	DVVRVWFCNRRQKGKR (Adachi et al. 2017)
P007	Ac-$(RAhxR)_4$-Ahx-βAla (Greer et al. 2014)
P1	LRRWSLG (Peng et al. 2017b)
P2	WKRTLRRL (Peng et al. 2017b)
P3	YGRKKRRQR (Tan et al. 2006)
P7	RRMKWKK (Watson et al. 2017)
P11	YGRKKRRQRRR (Zhao et al. 2011)
P11	HSDVHK (Bang et al. 2011)
P11LRR	P11LRR (Li et al. 2010)
P14LRR	$(P_LP_RP_R)_4$ (Brezden et al. 2016)
p18	LSTAADMQGVVTDGMASG (Taylor et al. 2009)
P21	KRKKKGKGLGKKRDPCLRKYK (Dixon et al. 2016)
P28	LSTAADMQGVVTDGMASGLDKDYLKPDD, Leu^{50}-Asp^{77} of azurin (Yamada et al. 2016)
p28	FLHSGTAVTCTYPALTPQWEGSDCTHRL (Signorelli et al. 2017)
p53 peptide MO6	Stapled TSF*EYWYLL* (Chee et al. 2014)
PAF26	Ac-rkkwfw (Lopez-Garcia et al. 2002)
PAS	GKPILFF (Woldetsadik et al. 2017)
pCLIP6	KVRVRVRVpP(pT)RVRERVK (Chen et al. 2017b)
pD-SP5	riPRPSPKMGV(pS)VS (Chen et al. 2017b)
PenetraMax	KWFKIQMQIRRWKNKR, L- and D- (Khafagy el et al. 2015)
Penetratin	RQIKIWFQNRRMKWKK (Derossi et al. 1994)
Pep-1	KETWWETWWTEWSQPKKKRKV cysteamide (Morris et al. 1997)
pepM	KLFMALVAFLRFLTIPPTAGILKRWGTI (Freire et al. 2014)
pepR	LKRWGTIKKSKAINVLRGFRKEIGRMLNILNRRRR (Freire et al. 2014)
Pept1	PLILLRLLRGQF (Marks et al. 2011)

(continued)

Table 1 (continued)

Peptide 599	GLFEAIEGFIENGWEGMIDGWYGGGGRRRRRRRRRK (Alexander-Bryant et al. 2015)
Pep42	Cyclic CTVALPGGYVRVC (Kim et al. 2006)
PepNeg	SGTQEEY (Neves-Coelho et al. 2017)
PepFect6	Stearyl-AGYLLGK(εTMQ)INLKALAALAKKIL, PF6 (El-Andaloussi et al. 2011)
PepFect14	Stearyl- AGYLLGKLLOOLAAAALOOLL (Ezzat et al. 2011)
PG1	RGGRLCYCRRRFCVCVGR (Liu et al. 2013b)
pHLIP	AEQNPIY-WARYADWLFTTPLLLLDLALLV-DADEGT (Andreev et al. 2010)
PHPs	H6-H10 peptides (Kimura et al. 2017)
PIP1	RXRRXRRXRIKILFQNRRMKWKK (Ivanova et al. 2008)
Pip5e	RXRRBRRXRILFQYRXRBRXRB (Betts et al. 2012)
Pip6a	Ac-RXRRBRRXRYQFLIRXRBRXRB (Lehto et al. 2014)
POD	CGGG(ARKKAAKA)$_4$ (Dasari et al. 2017)
PR9	FFLIPKG-R$_9$ (Liu et al. 2013a)
PTD	YARVRRRGPRRR (Dong et al. 2016)
PTD3	R9-ETWWETWWTEW (Kizaka-Kondoh et al. 2009)
PTD4	YARAAARQARA (McCusker et al. 2007)
Poly-Arg	Most popular R7 - R12 (Mitchell et al. 2000, Futaki, 2006)
pVEC	LLIILRRRIRKQAHAHSK (Elmquist et al. 2001)
Pyrrhocoricin	VDKGSYLPRPTPPRPIYNRN (Otvos et al. 2000)
R4K1	Stapled Ac-RRRRKS*LHRS*LQDS (Speltz et al. 2018)
R6dGR	R6dGR (Wang et al. 2017)
R8	R8 (Wender et al. 2001)
R8-dGR	R8dGR (Liu et al. 2016b)
R9-H4A2	Ac-YR9-HAHAHH (Okitsu et al. 2017)
R_6W_3	R_6W_3 (Bechara et al. 2013)
$R_{10}W_6$	$R_{10}W_6$ (Bechara et al. 2013)
RA9	RRAARRARR (Alhakamy et al. 2013)
RALA	WEARLARALARALARHLARALARALRACEA (McCarthy et al. 2014)
RDP	CKSVRTWNEI IPSKGCLRVG GRCHPHVNGG GRRRRRRRRC (Xiao et al. 2017)
REDV	REDV (Yang et al. 2016)

(continued)

Table 1 (continued)

RF	GLKKLARLFHKLLKLGC (Yang et al. 2014)
cRGDfC	Cyclic RGDfC (Wada et al. 2017)
iRGD	Cyclic CRGDKGPDC (Peng and Kopecek, 2015)
RGE	RGERPPR (Yu et al. 2017)
RH9	RRHHRRHRR (Alhakamy et al. 2013)
RL9	RRLLRRLRR (Alhakamy et al. 2013)
RL16	RRLRRLLRRLLRRLRR (Joanne et al. 2009)
RT53	RQIKIWFQNRRMKWKKAKLNAEKLKDFKIRLQYFARGLQV YIRQLRLALQGKT (Jagot-Lacoussiere et al. 2016)
RTP004	RKKRRQRRRG-K15-GRKKRRQRRR) (Lee et al. 2015a)
RV24	RRRRRRRRRGPGVTWTPQAWFQWV (Lo and Wang, 2012)
RVG	YTIWMPENPRPGTPCDIFTNSRGKRASNG (Kumar et al. 2007)
RVG-9R	YTIWMPENPRPGTPCDIFTNSRGKRASNGGGGRRRRRRRRR (Rassu et al. 2017)
RVG29	YTIWMPENPRPGTPCDIFTNSRGKRASNGGGGRRRRRRRRR (Villa-Cedillo et al. 2017)
RW9	RRWWRRWRR (Alhakamy et al. 2013)
RW16	RRWRRWWRRWWRRWRR (Jobin et al. 2013)
$(RXR)_4$	$(R\text{-}Ahx\text{-}R)_4$ (Saleh et al. 2010)
$(rXr)_4$	$(r\text{-}Ahx\text{-}r)_4$ (Vij et al. 2016b)
S155	VKKKKIKREI-KIAAQRYGRELRRMADEFHV (Haidar et al. 2017)
S4(13)-PV	ALWKTLLKKVLKAPKKKRKV (Mano et al. 2007)
SAP	VRLPPPVRLPPPVRLPPP (Pujals et al. 2006)
SAP(E)	VELPPPVELPPPVELPPP (Martin et al. 2011)
all-D-SAP	$(vrlppp)_3$ (Pujals et al. 2007)
SAPSp-lipo	stearyl-GGGGHGAHEHAGHEHAAGEHHAHE (Suzuki et al. 2017)
SAR6EW	SAR6EW (Im et al. 2017)
sC18	GLRKRLRKFRNKIKEK (Oren et al. 1999)
$(sC18)_2$	$(GLRKRLRKFRNKIKEK)_2$ (Gronewold et al. 2017)
SMTP motif,	LRLLR (Fuselier and Wimley, 2017)
SPACE	Cyclic ACTGSTQHQCG (Hsu and Mitragotri, 2011)
SRCRP2-11	GRVEVLYRGSW (Tuttolomondo et al. 2017)
STR-KV	$H_3K_3V_6$ (Pan et al. 2016)
SS-02	Dmt-r-FK (ALTA et al. 2017)
SS-20	F-r-FK (Alta et al. 2017)
SS-31	r-Dmt-KF (Zhao et al. 2005)
SynB1	RGGRLSYSRRRFSTSTGR (Rousselle et al. 2000)
T2	LVGVFH (Kumar et al. 2012)

(continued)

Table 1 (continued)

Tat(49-57)	RKKRRQRRR (Vives et al. 1997a)
Tat(48-60)	GRKKRRQRRRPPQ (Vives et al. 1997b)
Tat(44-57)	CGISYGRKKRRQRRR (Niesner et al. 2002)
Tat(37-72)	CFITKALGISYGRKKRRQRRRPPQGSQT-HQVSLSKQ (Fawell et al. 1994)
Tat analog	GRKKRRQR (Nguyen et al. 2008)
Tat-LK15	Tat-KLLKLLLKLLLKLLK (Peng et al. 2017a)
TCTP	MIIFRALISHKK (Bae et al. 2016)
TD-1	ACSSSPSKHCG (Chen et al. 2006)
TD2.2	SYWYRIVLSRTGRNGRLRVGRERPVLGESP (Heffernan et al. 2012)
TH peptide	GYLLGHINLHHLAHL-Aib-HHIL (Chen et al. 2017a)
TM2	PKKGSKKAVTKAQKKDGA (Kochurani et al. 2015)
Transportan	GWTLNSAGYLLGKINLKALAALAKKIL, TP (Pooga et al. 1998)
TP10	AGYLLGKINLKALAALAKKIL (Soomets et al. 2000)
TPk	VRRFkWWWkFLRR (Bahnsen et al. 2015)
Tpl	KWCFRVCYRGICYRRCRGK (Jain et al. 2015)
TPP	TKDNNLLGRFELSG (Gehrmann et al. 2014)
TT1	CKRGARSTA (Paasonen et al. 2016)
vAMP 059	INWKKWWQVFYTVV (Dias et al. 2017)
vCPP 0769	RRLTLRQLLGLGSRRRRRSR (Dias et al. 2017)
vCPP 2319	WRRRYRRWRRRRRWRRRPRR (Dias et al. 2017)
VDAC(1-26)	MAVPPTYADLGKSARDVFTKGYGFGL (Smilansky et al. 2015)
VP22	NAATATRGRSAASRPTQRPRAPARSASRPRRPVQ (Elliott and O'Hare, 1997)
V peptide	TVDNPASTTNKDKLFAVRK (Manosroi et al. 2014)
VT5	DPKGDPKGVTVTVTVTVTGKGDPKPD (Oehlke et al. 1997)
$W(RW)_4$	$W(RW)_4$ (Nasrolahi Shirazi et al. 2013)
Xentry	LCLR (Montrose et al. 2014)
X-pep	MAARLC (Adachi et al. 2017)
YKA	YKALRISRKLAK (Desai et al. 2014)
YTA2	YTAIAWVKAFIRKLRK (Lindgren et al. 2006)
YTA4	IAWVKAFIRKLRKGPLG (Lindgren et al. 2006)
Z2	FWIGGFIKKLKRSKLA (Chen et al. 2017c)
Z3	FKIKKFIGGLWRSKLA (Chen et al. 2017c)
Z12	KRYKNRVASRKCRAKFKQLLQHYREVAAAKSSENDRLRLLLK (Derouazi et al. 2015)
ZXR-1	FKIGGFIKKLWRSKLA (Chen et al. 2017c)

Table 2 Selection of cell-penetrating peptides classified at different levels

1.	**Protein derived**	**Designed**
	Penetratin, Arf(1-22), M918, Cyt c(77–101), Tat, Xentry	Poly-Arg, TP, MPG, Pep-1, CADY, Pip
2.	**Classified by physico-chemical properties**	**Classified by structural properties**
	Amphipathic **Primary**: MPG, Pep-1, TP, TP10, KLAK, VP22 **Secondary**: MAP, pVEC, M918 **Metabotropic** Pep-1, pVEC, VT5, C105Y, TP, TP10, MPG, gH625, INF, CADY, GALA **Cationic** Penetratin, Tat, Poly-Arg **Hydrophobic** K-FGF, Pept1 **Anionic** MAP12, SAP(E)	**Branched** NF51 **Phosphate containing** NF1 **Nanoparticle-forming** PepFects, NickFects, CADY, stearyl-Poly-Arg
3.	**Predicted**	**Random: screened and deduced**
	Arf(1-22), M918, Cyt c(77-101), AT1AR(304-318), YTA2	Penetratin, Tat, TP, TP10
4.	**Linear**	**Cyclic**
	Penetratin, Tat, KLAK, MAP, VP22, TP10, CADY, MPG, L5a, F3, PEG-ylated CPPs **Fatty acid modified** Stearyl-Poly-Arg, Stearyl-TP10, PepFects, STR-KV **pH-responsive cell-penetrating peptides** HA2(1-23), EB1, GALA, pHLIP	Bicyclic peptides Cyclorasins Cyclotides: Kalata B1, MCoTI-II β-Peptoids iRGD peptides Stapled: p53 peptide MO6 cFΦR4 new modalities e.g. new generation bicyclic, hairpin, stapled peptides
5.	**Protein mimics**	**Cargo delivery vectors**
	M918, bPrPp(1-30), Cyt c(77-101), AT1AR(304-318), pepducins, CPP-C, P28, 65-2CTS, aptamers fused to CPPs	penetratin, Tat, TP, TP10, Pip, $(RXR)_4$, Pep-3, MPG, R_{15}, PepFects, NickFects, dNP2, Chol-R_9 GALA, KALA, MPG, Pep-1, CADY. KFGF, C105Y, Lys(Get) peptides, $G_4R_9L_4$, L5a, RALA stearyl-Arg_9, Chol-Arg_9, stearyl-$(RXR)_4$, stearyl-TP10, STR-KV
6.	**Nonspecific**	**Targeted**

(continued)

Table 2 (continued)

	Penetratin, Tat	YTA2, R8-dGR, aCPP, NF55 **Homing**: iRGD, Lyp1,TT1, iNGR etc.
7.	**"Direct" translocators**	**Endocytosis enhancers**
	penetratin, Tat, R_9, R_5/W_3, lipopeptides S4(13)-PV; pVEC and TP (in plant cells) CADY (in complex with siRNA	C105Y, EB1, GALA, HA2, INF, MPG, Pep-1, pVEC, PepFect, Peptide 599, TP, TP10, VT5
8.	**"Non-toxic"**	**Antimicrobial**
	All CPPs, likely, depending on the dose or concentration	pyrrhocoricin, hLF peptide, Bac7, SynB1, sC18, LL37, buforin II, Tat, penetratin, pVEC, Pep-1, TP10, MAP

Fig. 1 Classification possibilities of CPPs (**a**), and an example of overlapping physico-chemical properties of CPPs, modified from Stalmans et al. (2013), Milletti (2012) (**b**)

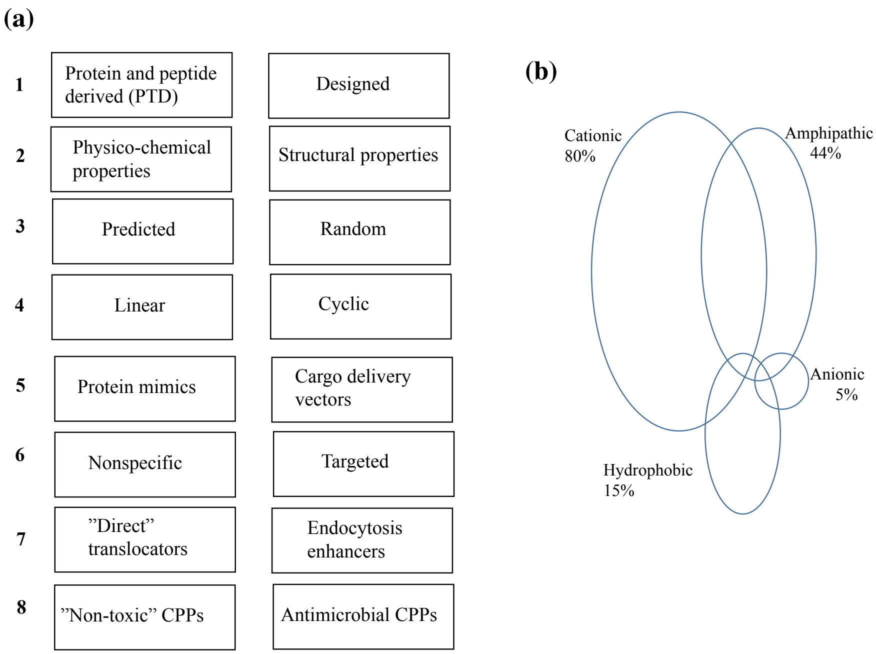

Table 3 Estimation of internalization of CPPs into different to cell lines, micelle models and by calculations

CPP	Label/cargo	Cells and models	$t_{0.5}$ (min)	References
Cells				
Tat	Pentapeptide Fluorescein Peptide chelator for ^{99m}Tc Rhodamine FITC Alexa Fl. quenching	Bowes Jurkat Jurkat HeLa Fibroplasts HeLa, BHK	30 20[a] 2 1[a] 1.8 <80[a] <30[b]	Hällbrink et al. (2001), Zorko and Langel (2005), Richard et al. (2003a), Polyakov et al. (2000), Suzuki et al. (2002b) , Ziegler et al. (2005), Al Soraj et al. (2012), Cheung et al. (2009)
Tat	Poly(lactic-co-glycolic acid) (PLGA) nanoparticles, PTX	MDR	<180[b]	Gullotti and Yeo (2012)
Myr-Tat	Fluorophore	BA/F3	<20	Nelson et al. (2007)
Tat-calmodulin	Calmodulin-binding proteins	HEK, HT3, BHK21	<60[b]	Salerno et al. (2016)
Penetratin	Pentapeptide NBD NBD	Bowes K562 K562	60 45[a] 20	Hällbrink et al. (2001), Zorko and Langel (2005), Drin et al. (2003), (2001a), Zorko and Langel (2005)
Penetratin	– (mass-spectrometry)	CHO	<10	Alves et al. (2011)
MAP	Pentapeptide	Bowes	10	Hällbrink et al. (2001), Zorko and Langel (2005)
Transportan	Pentapeptide Abz ^{125}I	Bowes Caco-2 Bowes	10 15[a] 3	Hällbrink et al. (2001), Zorko and Langel (2005), Lindgren et al. (2004), Pooga et al. (1998b)

(continued)

Table 3 (continued)

CPP	Label/cargo	Cells and models	$t_{0.5}$ (min)	References
Transportan10	Abz	HeLa	25[a]	Lindgren et al. (2004), Zorko and Langel (2005)
R8	Alexa	HeLa	<80[a]	Al Soraj et al. (2012)
Histatin 5	–	*L. donovani*	10–20[a]	Luque-Ortega et al. (2008)
DKP, cyclic dipeptide	Diclofenac	Human epidermis	<120[a]	Mohammed et al. (2016)
Guanidinium peptoid	Fluorophores	A549	<10[a]	Schroder et al. (2008)
Pep-1	β-Galactosidase	HeLa	<30[a]	Henriques and Castanho (2008)
Arg8	Transferrin-Alexa594	CHO	4 s[c]	Lee et al. (2008)
NrTPs	Rhodamine B	Several cells	<30	Rodrigues et al. (2015)
Tyr-maurocalcine	^{125}I–	F98	~10[a]	Tisseyre et al. (2014)
ECP(32-41)	FITC	Beas-2B cells	<10[a]	Fang et al. (2013)
PepM	Rhodamine-B	BHK-21, 37°	4.6	Freire et al. (2014)
	ssDNA, non-covalent coupling	BHK-21, 37°	2.7	Freire et al. (2014)
TP10, pVEC, M918	Pentapeptide	HeLa	15–30	Mäger et al. (2010)
Arg8 analog	cyclo[Cys-Pro-Xaa-Lys-Gln-Glu(-CO-)-NH_2]	Jurkat	<5[a]	Sasaki et al. (2008)
Tat, MAP, TP10, pVEC, M918, EB1	Luciferin	HeLa pLuc705	Seconds (fast) Minutes (slow)	Eiriksdottir et al. (2010)
Simulations				
Arg8	–	Lipid membranes	Nanoseconds[b]	Sun et al. (2015)
Tat	–	Lipid membrane	Nanoseconds[b]	Lin and Alexander-Katz (2013)
Penetratin	–	Lipid micelle	Nanoseconds	Wang et al. (2010)
RW9, RL9	–	LUV	Nanoseconds	Walrant et al. (2012)
Model membrane Vesicles				

(continued)

Table 3 (continued)

CPP	Label/cargo	Cells and models	$t_{0.5}$ (min)	References
Tat	*p*-cyanophenylalanine	LUV	10–12	Pazos et al. (2015)
GALA	–	GUV	20[a] (leakage time)	Schach et al. (2015)
Pep-1	β-Galactosidase	LUV	<1[a]	Henriques and Castanho (2008)
Transportan 10	–	LUV	<10[a]	Yandek et al. (2007)

Values of $t_{0.5}$ were calculated from first-order rate constants or assessed from the figures, as indicated

[a]The value was recalculated or estimated from the kinetic data presented in the figure from the indicated reference

[b]The value estimated from text

[c]Residence time