Organometallic Half-Sandwich Complexes Promote the Formation of Linear Oligopeptides from Amino Acid Esters**

Roland Krämer, Michael Maurus, Kurt Polborn, Karlheinz Sünkel, Christian Robl and Wolfgang Beck*

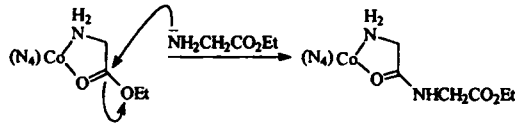
Dedicated to Professor Erwin Weiss on the occasion of his 70th birthday

Abstract: Organometallic dipeptide ester complexes of the general formula $[(L)M(Cl)(\kappa^2\text{-}NH_2CH_2CONCH_2CO_2R)]$ (**1**: L = Cp*, M = Rh, **2**: L = Cp*, M = Ir, **3**: L = η^6-C_6Me_6, M = Ru) react smoothly with various α-L-amino acid esters in the presence of NEt_3 to yield the tripeptide ester complexes $[(L)M(Cl)(\kappa^2\text{-}NH_2CHR'CONCH_2CONHCH_2CO_2R)]$ (**5**–**7**). In the same fashion chloro κ^2-tetrapeptide ester complexes **10** and **11** are obtained either from tripeptide ester complexes or by subsequent addition of two equivalents of amino acid ester to a dipeptide ester complex. When the strong base NaOMe is used in the reaction of the diglycine ester compounds with amino acid esters, κ^3-tripeptide ester complexes **12** and **13** are produced, in which one of the two coordinated peptide nitrogen atoms is pyramidal. The hexamethylbenzene ruthenium complexes **13** with tripeptide ligands are formed with very high diastereoselectivity. A plausible reaction mechanism for the metal-promoted peptide synthesis is presented. Synthesis and isolation of the peptide esters proceeds without racemization.

Keywords
half-sandwich complexes · peptide syntheses · peptides · rhodium complexes · ruthenium complexes

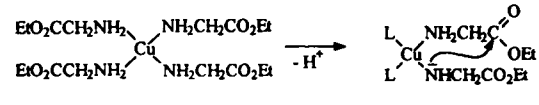
Introduction

In 1967 Buckingham[1] and Collman[2] discovered that kinetically inert Co^{III} complexes efficiently promote the formation of dipeptide esters from amino acid esters. Co^{III} strongly polarizes a coordinated ester carbonyl group and facilitates nucleophilic attack by the amino group of a free amino acid ester molecule (Scheme 1). Early on, it was recognized that metal-mediated peptide synthesis is an interesting alternative to classical synthetic methods. Buckingham et al. have developed the cobalt(III) methodology for the stepwise construction of oligopeptides further.[1b] A racemization-free synthesis of the biologically active peptide (Leu^5)enkephaline was described. However, the method is rather laborious since each elongation step requires demetallation and isolation of the peptide.



Scheme 1. Mechanism of Co^{III}-promoted dipeptide formation.

Bush et al. have reported the stepwise formation of a Co^{III}-coordinated tripeptide ester without isolation of the dipeptide ester intermediate.[3] A significant problem lies in the kinetic stability of the cobalt complex, which prevents liberation of the intact tripeptide ester. Yamada's group has observed oligopeptide formation from amino acid esters in the presence of copper(II) salts.[4] The reaction mechanism appears to be basically different from that of cobalt(III)-mediated peptide synthesis. The peptide bond is formed by nucleophilic attack of a coordinated amide anion; the metal ion acts as a reaction template (Scheme 2). Peptide yield decreases dramatically with increasing chain length; tetrapeptides are formed in <3% yield. Because



Scheme 2. Mechanism of Cu^{II}-promoted dipeptide formation.

[*] Prof. Dr. W. Beck, Dr. M. Maurus, Dr. K. Sünkel (X-ray structure analysis)
Institut für Anorganische Chemie der Universität München
Meiserstr. 1, D-80333 München (Germany)
Fax: Int. code +(89)5902-451
e-mail: wbe@anorg.chemie.uni-muenchen.de
Dr. Roland Krämer
Anorganisch-Chemisches Institut der Universität
Wilhelm-Klemm-Str. 8, D-48149 Münster (Germany)
Dr. K. Polborn (X-ray structure analysis)
Institut für Organische Chemie der Universität München
Karlstr. 21, D-80333 München (Germany)
Prof. Dr. C. Robl (X-ray structure analysis)
Institut für Anorganische und Analytische Chemie
der Friedrich-Schiller-Universität
August-Bebel-Str. 2, D-07743 Jena (Germany)

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of the kinetic lability of Cu^{II}, the directed construction of oligopeptides with a specific amino acid sequence is not possible. Instead, mixtures of peptides having different lengths and amino acid sequences are obtained.

In a remarkable study, Rode and coworkers have established the possible role of copper(II) ions for peptide formation under prebiotic conditions. Cu^{II} catalyzes the generation of di- and tripeptides directly from amino acids in aqueous systems at high NaCl concentration and 60 °C.[5a] A dipeptide synthesis from *N*-protected alaninate activated by coordination to $(\eta^5\text{-}C_5H_5)_2Ti(IV)$ and AlaOMe has been reported.[5b]

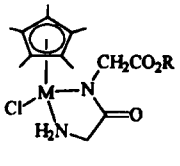
We have recently discovered that organometallic Cp^*M^{III} complexes (M = Rh, Ir) mediate formation of linear oligopeptides from amino acid esters.[6] A unique and fascinating feature of this novel method is that, in principle, peptide chains of any length can be formed at the metal complex simply by stepwise addition of amino acid esters and without isolation of intermediates. In this paper we will demonstrate that the reaction is more generally applicable to organometallic half-sandwich complexes that have three available *fac*-oriented coordination sites. The crystal structures of important intermediates and products of the metal-promoted peptide synthesis will be described. Organometallic peptide complexes themselves are of interest for the selective labelling of amino acids in peptides.[7]

Experimental Section

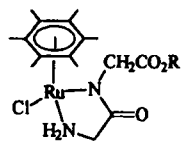
Spectroscopy and analyses: The ^1H NMR and ^{13}C NMR spectra were measured on Jeol EX400 and GSX270 spectrometers. Chemical shifts are given relative to solvent peak or TMS. Infrared spectra were recorded with Perkin Elmer 841, 325 and Nicolet 520 FT-IR and ZDX5 apparatus. Microanalyses were carried out in the microanalytical laboratories of the Institut für Anorganische und Organische Chemie der Universität München. Amino acid analyses were performed with a Durrum D500 or Biotronic LC6001 amino acid analyzer after hydrolysis of the peptide esters in 6 M HCl (24 h). The D-amino acid ratio was determined by gas chromatography of the *N*-(pentafluoropropionyl)amino acid propyl esters on a Carlo-Erba Fractovap 4160 equipped with a Chirasil-Val column [8].

Materials and methods: Reactions were carried out in Schlenk tubes under N_2 or argon. Methanol (puriss., <0.05% H_2O) was saturated with N_2 and stored over molecular sieve (3 Å). Amino acid ester hydrochlorides and GlyGlyOEt·HCl were commercially available. For workup and crystallization procedures technical grade solvents were used. The free α-amino acid esters were prepared from the hydrochlorides by treatment with NEt_3 in methanol [9]. They were stored at −30 °C under argon for no longer than one week. Compounds $[Cp^*MCl_2]_2$ [10] (M = Rh,Ir), $[(\eta^6\text{-}C_6Me_6)RuCl_2]_2$ [11] and $[(\eta^6\text{-}p\text{-}Me_2CHC_6H_4Me)RuCl_2]_2$ [11] were prepared according to literature procedures.

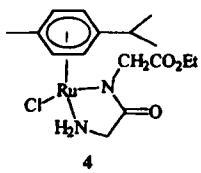
Preparation of the complexes: Complexes **1a**·H_2O, **1b**·0.5H_2O, **2**·0.5H_2O, **3a**·0.5H_2O, **3b**·H_2O, **4**·0.5H_2O and **8**·H_2O were prepared as described in ref. [12].



	M	R
1a	Rh	Me
1b	Rh	Et
2a	Ir	Et



	R
3a	Me
3b	Et



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General procedure for the preparation of complexes 5–7 and 9: The dipeptide ester complex was dissolved in methanol (5 mL). The amino acid ester (ca. 1.05 equiv) and triethylamine (5 equiv) were added and the clear solution was stirred under N_2 at room temperature (see below for reaction times). The volume of the solution was reduced in vacuo to ca. 0.5 mL. Diethyl ether or a diethyl ether/hexane mixture (50 mL) was added with stirring and the suspension was kept at −30 °C for 1 h. The orange powder was centrifuged off.

[Cp*Rh(Cl)(κ²-Gly-H⁺GlyGlyOMe)] (5a): From **1a**·H_2O (87 mg, 0.20 mmol) and GlyOMe (19 mg, 0.21 mmol), triethylamine (140 μL, 1.0 mmol), reaction time 3 h. Precipitation with diethyl ether yielded an orange powder (95 mg), which was a mixture of **1a** (ca. 30%, determined by ^1H NMR), **5a** (ca. 60%) and probably some complexes of higher peptide esters. Compound **5a** can be prepared in analytically pure form by reaction of $[Cp^*RhCl_2]_2$ with GlyGlyGlyOMe·HCl [12]. ^1H NMR (270 MHz, [D₄]methanol, 25 °C): δ = 4.23 (brs, 2H; CH_2CONH), 3.87 (s, 2H; CH_2CO_2Me), 3.71 (s, 3H; CO_2CH_3), 3.23 (s, 2H; NH_2CH_2), 1.70 (s, 15H; Cp*); IR (KBr, <300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3243, 3128 cm^{-1} (NH_2), 1761 (CO_2Me), 1657, 1563 (free amide), 1580 (coordinated amide), 263 (Rh–Cl).

[Cp*Rh(Cl)(κ²-L-AlaGly-H⁺GlyOEt)] (5b):

Method a: From **1b**·0.5H_2O (88 mg, 0.20 mmol) and L-AlaOMe (22 mg, 0.21 mmol), triethylamine (140 μL, 1.0 mmol), reaction time 5 h. Precipitation with diethyl ether yielded a powder that was recrystallized from dichloromethane/hexane. Red crystals, yield 76 mg (74%). ^1H NMR (270 MHz, [D₄]methanol, 25 °C): δ = 4.45, 3.98 (brd, ^2J(H,H) = 17 Hz, 1H each; CH_2CONH), 4.17 (q, ^3J(H,H) = 7 Hz, 2H; $CO_2CH_2CH_3$), 3.94, 3.76 (d, ^2J(H,H) = 17 Hz, 1H each; CH_2CO_2Et), 3.41 (q, ^3J(H,H) = 7 Hz, 1H; $CHCH_3$), 1.70 (s, 15H; Cp*), 1.29 (t, ^3J(H,H) = 7 Hz, 3H; $CO_2CH_2CH_3$), 1.25 (d, ^3J(H,H) = 7 Hz, 3H; $CHCH_3$); IR (KBr, <300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3220 cm^{-1} (NH_2), 1758 (CO_2Me), 1652, 1545 (free amide), 1572 (coordinated amide), 252 (Rh–Cl); $C_{19}H_{31}ClN_3O_4Rh\cdot H_2O$ (512.9): calcd C 44.50, H 6.49, N 8.19; found C 44.04, H 6.36, N 7.80.

Method b: A mixture of $[(Cp^*RhCl_2)_2]$ (93 mg, 0.15 mmol), GlyGlyOEt·HCl (59 mg, 0.30 mmol) and Na_2CO_3 (95 mg, 0.90 mmol) in methanol (5 mL) was stirred at room temperature for 1 h. L-AlaOMe (34 mg, 0.32 mmol) was added and stirring was continued for 3 h. Dichloromethane (20 mL) was added and the white precipitate was centrifuged off. The orange solution was evaporated to dryness. The residue was redissolved in dichloromethane (5 mL) containing a few drops of methanol. The solution was layered with hexane. After 4 days red crystals were obtained; yield 126 mg (82%).

[Cp*Rh(Cl)(κ²-L-LeuGly-H⁺GlyOMe)] (5c): From **1a**·H_2O (87 mg, 0.20 mmol) and L-LeuOMe (30 mg, 0.21 mmol), triethylamine (140 μL, 1.0 mmol), reaction time 15 h. An orange powder was obtained by precipitation with diethyl ether/hexane (2:3); it was centrifuged off and dried in vacuo at 60 °C for 2 h. Yield 101 mg (92%). ^1H NMR (270 MHz, [D₄]methanol, 25 °C): δ = 4.51, 4.01 (brd, ^2J(H,H) = 16 Hz, 1H each; CH_2CONH), 3.98, 3.78 (d, ^2J(H,H) = 17 Hz, 1H each; CH_2CO_2Et), 3.72 (s, 1H; OCH_3), ≈3.3 (m; NH_2CH), 1.72 (s, 15H; Cp*), 1.4–1.9 (m; CH, CH_2), 0.97, 0.92 (d, ^3J(H,H) = 6.6 Hz, 3H each, $CH(CH_3)_2$); IR (KBr): $\tilde{\nu}$ = 3255, 3137 cm^{-1} (NH_2), 1755 (CO_2Me), 1668 (free amide), 1571 (coordinated amide); $C_{21}H_{35}ClN_3O_4Rh\cdot H_2O$ (549.9): calcd C 45.87, H 6.78, N 7.64; found C 45.05, H 6.92, N 8.00.

[Cp*Rh(Cl)(κ²-L-Asp(β-OMe)Gly-H⁺GlyOEt)] (5d): From **1b**·0.5H_2O (88 mg, 0.20 mmol) and L-Asp(OMe)₂ (34 mg, 0.21 mmol), triethylamine (140 μL, 1.0 mmol), reaction time 15 h. Precipitation with diethyl ether/hexane (1:4) afforded a powder, which was recrystallized from methanol/diethyl ether/hexane. Red crystals, yield 88 mg (77%). ^1H NMR (270 MHz, [D₄]methanol, 25 °C): δ = 4.42, 3.99 (brd, ^2J(H,H) = 17 Hz, 1H each; CH_2CONH), 4.17 (q, ^3J(H,H) = 7 Hz, 2H; $CO_2CH_2CH_3$), 3.90, 3.80 (d, ^2J(H,H) = 17 Hz, 1H each; CH_2CO_2Et), 3.68 (s, 3H; OCH_3), 3.60 (brm, 1H; NH_2CH), 2.81, 2.75 (dd, ^2J(H,H) = 17 Hz, ^3J(H,H) = 4 Hz, 1H each, NH_2CHCH_2), 1.71 (s, 15H; Cp*), 1.26 (t, ^3J(H,H) = 7 Hz, 3H; $CO_2CH_2CH_3$); IR (KBr, <300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3279, 3231 cm^{-1} (NH_2), 1743, 1750 (CO_2Me), 1648, 1544 (free amide), 1604 (coordinated amide), 239, 224 (Rh–Cl); $C_{21}H_{33}ClN_3O_6Rh\cdot 0.5H_2O$ (570.9): calcd C 44.18, H 6.00, N 7.36; found C 44.18, H 6.10, N 7.29.

[Cp*Rh(Cl)(κ²-L-SerGly-H⁺GlyOEt)] (5e): From **1b**·0.5H_2O (88 mg, 0.20 mmol) and L-Ser(OMe) (25 mg, 0.21 mmol), triethylamine (140 μL, 1.0 mmol), reaction time 5 h. Precipitation with diethyl ether afforded a powder, which was recrystallized from methanol/diethyl ether/hexane. Orange crystals, yield 84 mg (81%). ^1H NMR (270 MHz, [D₄]methanol, 25 °C): δ = 4.39, 4.09 (brd, ^2J(H,H) = 16 Hz, 1H each; CH_2CONH), 4.17 (q, ^3J(H,H) = 7 Hz, 2H; $CO_2CH_2CH_3$), 3.94, 3.80 (d, ^2J(H,H) = 18 Hz, 1H each; CH_2CO_2Et), 3.75, 3.62 (brdd, 1H and dd, ^2J(H,H) = 11 Hz, ^3J(H,H) = 4 Hz, 1H; CH_2OH), 3.38 (brm, 1H; NH_2CH), 1.72 (s, 15H; Cp*), 1.26 (t, ^3J(H,H) = 7 Hz, 3H; $CO_2CH_2CH_3$); IR (KBr): $\tilde{\nu}$ = 3293, 3226 cm^{-1} (NH_2), 1745 (CO_2Me), 1642, 1589 (free amide), 1585 (coordinated amide); $C_{19}H_{31}ClN_3O_5Rh$ (519.8): calcd C 43.90, H 6.01, N 8.08; found C 43.50, H 6.09, N 7.94.

[Cp*Ir(Cl)(κ²-GlyGly-H⁺GlyOEt)] (6a): From **2**·0.5H_2O (106 mg, 0.20 mmol) and GlyOEt (22 mg, 0.21 mmol), triethylamine (140 μL, 1.0 mmol), reaction time 20 h. Precipitation with diethyl ether/hexane (3:2) yielded a yellow powder, which

was dried at 60 °C for 2 h. Yield 98 mg (85%). ^{1}H NMR (270 MHz, [D$_4$]methanol, 20 °C): δ = 4.30 (brs, 2H; CH_2CONH), 4.17 (q, ^3J(H,H) = 7 Hz, 2H; CO$_2$CH_2CH$_3$), 3.86 (s, 2H; CH_2CO$_2$Et), 3.45 (s, 2H; NH$_2$CH_2), 1.70 (s, 15H; Cp*), 1.26 (t, ^3J(H,H) = 7 Hz, 3H; CO$_2$CH$_2$CH_3); IR (KBr, < 300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3247, 3225 cm^{-1} (NH$_2$), 1757 (CO$_2$Me), 1658, 1544 (free amide), 1587 (coordinated amide), 243 (Ir–Cl). C$_{18}$H$_{29}$ClN$_3$O$_4$Ir (579.1): calcd C 37.33, H 5.05, N 7.25; found C 36.49, H 5.27, N 7.11.

[Cp*Ir(Cl)(κ^2-L-SerGly–H$^+$GlyOEt)] (6b): From **2**·0.5 H$_2$O (106 mg, 0.20 mmol) and L-Ser(OMe) (25 mg, 0.21 mmol), triethylamine (140 μL, 1.0 mmol), reaction time 15 h. Precipitation with diethyl ether/hexane (2:3) afforded a bright yellow powder. Yield 104 mg (85%). ^{1}H NMR (270 MHz, [D$_4$]methanol, 25 °C): δ = 4.46, 4.11 (brd, ^2J(H,H) = 16 Hz, 1H each; CH_2CONH), 4.16 (q, ^3J(H,H) = 7 Hz, 2H; CO$_2$CH_2CH$_3$), 3.94, 3.80 (d, ^2J(H,H) = 18 Hz, 1H each; CH_2CO$_2$Et), 3.80, 3.68 (br, 1H and dd, ^2J(H,H) = 11 Hz, ^3J(H,H) = 4 Hz, 1H; CH_2OH); ≈3.36 (br m, 1H; NH$_2$CH), 1.71 (s, 15H; Cp*), 1.26 (t, ^3J(H,H) = 7 Hz, 3H; CO$_2$CH$_2$CH_3); IR (KBr): $\tilde{\nu}$ = 3243, 3220 cm^{-1} (NH$_2$), 1748 (CO$_2$Me), 1642, 1544 (free amide), 1592 (coordinated amide); C$_{19}$H$_{31}$ClN$_3$O$_5$Ir (609.1): calcd C 37.47, H 5.13, N 6.90; found C 37.32, H 5.32, N 6.76.

[(η^6-C$_6$Me$_6$)Ru(Cl)(κ^2-GlyGly–H$^+$GlyOMe)] (7a): From **3a** (111 mg, 0.25 mmol) and free GlyOEt (26 μL, 0.27 mmol), triethylamine (175 μL, 1.25 mmol), reaction time 22 h. Precipitation with diethyl ether yielded an orange powder, which was dried in vacuo for 6 h. Yield 100 mg (80%). Orange crystals could be obtained from methanol/diethyl ether. ^{1}H NMR (270 MHz, [D$_4$]methanol, 25 °C): δ = 3.72 (s, 3H; OCH$_3$), 3.05 (s, 2H; NH$_2$CH_2), 2.14 (s, 18H; C$_6$Me$_6$); the signals of the two other glycyl CH$_2$ groups were very broad; IR (KBr, < 300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3287, 3255, 3137 cm^{-1} (NH$_2$), 1753 (CO$_2$Me), 1658, 1542 (free amide), 1580 (coordinated amide), 229 (Ru–Cl). C$_{19}$H$_{30}$ClN$_3$O$_4$Ru (501.0): calcd C 45.55, H 6.04, N 8.39; found C 45.21, H 6.15, N 8.36.

[(η^6-C$_6$Me$_6$)Ru(Cl)(κ^2-GlyGly–H$^+$GlyOEt)] (7b): From **3b** (115 mg, 0.25 mmol) and GlyOEt (27 mg, 0.27 mmol), triethylamine (175 μL, 1.25 mmol), reaction time 18 h. Precipitation with diethyl ether yielded a reddish powder, which was dried in vacuo for 6 h. Yield 102 mg (77%). Pale orange needles were obtained from chloroform/ethanol/pentane. ^{1}H NMR (400 MHz, [D$_4$]methanol, 20 °C): δ = 4.18 (q, ^3J(H,H) = 7 Hz, 2H; CO$_2$CH_2CH$_3$), 3.06 (s, 2H; NH$_2$CH_2), 2.15 (s, 18H; C$_6$Me$_6$), 1.28 (t, ^3J(H,H) = 7 Hz, 3H; CO$_2$CH$_2$CH_3), the signals of the two other glycyl CH$_2$ groups were very broad; low-temperature ^{1}H NMR (400 MHz, [D$_4$]methanol, −60 °C): δ = 4.67, 3.84 (d, ^2J(H,H) = 17 Hz, 1H each; CH_2CONH), 4.17 (q, ^3J(H,H) = 7 Hz, 2H; CO$_2$CH_2CH$_3$), 4.06, 3.58 (d, ^2J(H,H) = 18 Hz, 1H each; CH_2CO$_2$Et), 3.06, 2.96 (d, ^2J(H,H) = 16 Hz, 1H each; NH$_2$CH_2), 2.16 (s, 18H; C$_6$Me$_6$), 1.29 (t, ^3J(H,H) = 7 Hz, 3H; CO$_2$CH$_2$CH_3); IR (KBr, < 300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3253, 3152 cm^{-1} (NH$_2$), 1751 (CO$_2$Me), 1658, 1541 (free amide), 1610, 1595, 1578 (coordinated amide), 228 (Ru–Cl); C$_{20}$H$_{32}$ClN$_3$O$_4$Ru·H$_2$O (533.0): calcd C 45.07, H 6.43, N 7.88; found C 45.31, H 6.37, N 7.95.

[(η^6-C$_6$Me$_6$)Ru(Cl)(κ^2-L-AlaGly–H$^+$GlyOMe)] (7c): From **3a** (178 mg, 0.40 mmol) and L-AlaOMe (43 mg, 0.42 mmol), triethylamine (278 μL, 2.0 mmol), reaction time 20 h. Precipitation with diethyl ether yielded a red oil, which was converted to an orange powder upon being stirred for several hours. The product was centrifuged off and vacuum dried. Yield 185 mg (90%). Dark red crystals were obtained from methanol/diethyl ether. ^{1}H NMR (400 MHz, [D$_4$]methanol, 20 °C): δ = 3.70 (s, 3H; OCH$_3$), 3.17 (q, ^3J(H,H) = 7 Hz, 1H; CHCH$_3$), 2.14 (s, 18H; C$_6$Me$_6$), 1.24 (d, ^3J(H,H) = 7 Hz, 3H; CHCH_3), the signals of the two glycyl CH$_2$ groups were very broad; low-temperature ^{1}H NMR (400 MHz, [D$_4$]methanol, −60 °C) revealed two sets of signals corresponding to the diastereoisomers in 2:1 relative abundance, e.g. δ = 1.24 (d, ^3J(H,H) = 7 Hz, 3H; CHCH_3, 30%), 1.16 (d, ^3J(H,H) = 7 Hz, 3H; CHCH_3, 70%); IR (nujol, < 300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3266, 3140 cm^{-1} (NH$_2$), 1752 (CO$_2$Me), 1662, 1537 (free amide), 1609, 1586 (coordinated amide), 242, 217 (Ru–Cl); C$_{20}$H$_{32}$ClN$_3$O$_4$Ru (515.0): calcd C 46.64, H 6.26, N 8.16; found C 45.64, H 6.35, N 8.15.

[(η^6-C$_6$Me$_6$)Ru(Cl)(κ^2-L-ValGly–H$^+$GlyOMe)] (7d): From **3a** (133 mg, 0.30 mmol) and L-ValOMe (44 mg, 0.32 mmol), triethylamine (209 μL, 1.5 mmol), reaction time 98 h. Precipitation with diethyl ether yielded an orange powder, which was dried in vacuo. Yield 80 mg (88%). Dark red prisms were obtained from methanol/diethyl ether. ^{1}H NMR (270 MHz, [D$_4$]methanol, 20 °C): δ = 3.70 (brs, 3H; OCH$_3$), 2.15 (s, 18H; C$_6$Me$_6$), 1.01, 0.73 (d, ^3J(H,H) = 7 Hz and 5 Hz, 3H each; CH(CH_3)$_2$), other signals were either very broad or hidden; IR (KBr, < 300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3269, 3136 cm^{-1} (NH$_2$), 1756 (CO$_2$Me), 1661, 1538 (free amide), 1597, 1583 (coordinated amide), 260, 221 (Ru–Cl); C$_{22}$H$_{36}$ClN$_3$O$_4$Ru (543.1): calcd C 48.66, H 6.68, N 7.74; found C 48.43, H 6.85, N 7.69.

[Cp*Rh(Cl)(κ^2-L-Asp(β-OMe)GlyNH$_2$–H$^+$)] (9): From **8**·H$_2$O (72 mg, 0.20 mmol) and L-Asp(OMe)$_2$ (34 mg, 0.21 mmol), triethylamine (140 μL, 1.0 mmol), reaction time 5 h. Precipitation with diethyl ether/hexane (3:2) afforded a powder that was recrystallized from methanol/diethyl ether/hexane. Orange needles, yield 66 mg (67%). ^{1}H NMR (270 MHz, [D$_4$]methanol, 25 °C): δ = 4.26, 4.07 (brd, ^2J(H,H) = 17 Hz, 1H each; CH_2CONH$_2$), 3.57, 2.82 (d, ^2J(H,H) = 5.4 Hz, 1H each; CH_2CO$_2$Me), 1.69 (s, 15H; Cp*), the NH$_2$CH_2 signal was not observed (very broad?); IR (KBr): $\tilde{\nu}$ = 3360, 3280, 3225 cm^{-1} (NH$_2$), 1738 (CO$_2$Me), 1661, 1565 (free amide), 1605, 1580 (coordinated amide); C$_{17}$H$_{27}$ClN$_3$O$_4$Rh·H$_2$O (493.8): calcd C 41.35, H 5.92, N 8.51; found C 40.92, H 6.12, N 8.68.

[Cp*Rh(Cl)(κ^2-L-SerGly–H$^+$GlyGlyOMe)] (10):

Method a: A solution of **5a** (96 mg, 0.20 mmol), L-SerOMe (1.05 equiv) and triethylamine (140 μL, 1.0 mmol) in 5 mL MeOH was stirred at room temperature for 25 h. The solution was reduced to dryness and the residue was dissolved in 2 mL dichloromethane. Precipitation with 40 mL diethyl ether afforded an orange powder, which was recrystallized from methanol/diethyl ether. The product contained ≈7% **5a** as an impurity (detected by ^{1}H NMR). Yield 86 mg (72%). ^{1}H NMR (270 MHz, [D$_4$]methanol, 20 °C): δ = 4.21, 4.03 (brd, ^2J(H,H) = 15 Hz, 1H each; CON(Rh)CH_2CONH), 3.89, 3.88 (s?, 1H each; CH_2CO$_2$Me), 3.70 (s, 3H; OMe), ≈3.8 (2H, CONHCH_2CONH) 3.65, ≈3.8 (dd, ^2J(H,H) = 11 Hz, ^3J(H,H) = 4 Hz, 1H each; CH_2OH); 3.38 (dd, ^3J(H,H) = 4 Hz, 1H; NH$_2$CH), 1.71 (s, 15H; Cp*); IR (KBr): $\tilde{\nu}$ = 3302, 3233, 3142 cm^{-1} (NH$_2$), 1761 (CO$_2$Me), 1668, 1646, 1561 (free amide), 1589 (coordinated amide); C$_{20}$H$_{32}$ClN$_4$O$_6$Rh·CH$_3$OH (594.9): calcd C 42.40, H 6.10, N 9.41; found C 41.94, H 6.07, N 9.47.

Method b: A solution of **1a**·H$_2$O (87 mg, 0.20 mmol), GlyOMe (27 mg, 0.30 mmol) and triethylamine (140 μL, 1.0 mmol) in 5 mL MeOH was stirred at RT for 21 h. L-SerOMe (36 mg, 0.30 mmol) was added and stirring was continued for 25 h. The volume of the solution was reduced in vacuo to 0.5 mL and diethyl ether/hexane (3:2, 50 mL) was added with stirring. The suspension was kept at −30 °C for 2 h and the precipitate was centrifuged off. Recrystallization from methanol/diethyl ether/hexane afforded orange crystals that contained ≈15% other peptide ester complexes (**1a** and **5a**, identified by ^{1}H NMR). Yield 74 mg (62%).

[(η^6-C$_6$Me$_6$)Ru(Cl)(κ^2-L-AlaGly–H$^+$GlyGlyOMe)] (11): A solution of **7a** (120 mg, 0.24 mmol), L-AlaOMe (26 mg, 0.25 mmol) and triethylamine (35 μL, 0.25 mmol) in 5 mL MeOH was stirred at room temperature for 42 h. The solution was reduced in vacuo to dryness and the residue was redissolved in 3 mL dichloromethane containing a few drops of methanol. Precipitation with pentane (50 mL) yielded a red oil, which was converted to an orange powder upon being stirred for several hours. The raw product contained other peptide ester complexes (mainly **7a**) as impurities. When the powder was recrystallized twice from methanol/diethyl ether and then chloroform/methanol/pentane, orange crystals of pure **11** were obtained. Yield 30 mg (20%). ^{1}H NMR (400 MHz, [D$_4$]methanol, 20 °C): δ = 3.68 (s, 3H; OCH$_3$), 3.2 (brq, ^3J(H,H) = 7 Hz, 1H; CHCH$_3$), 2.14 (s, 18H; C$_6$Me$_6$), 1.22 (d, ^3J(H,H) = 7 Hz, 3H; CHCH_3), the signals of the three glycyl CH$_2$ groups were very broad; IR (nujol, < 300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3235, 3156 cm^{-1} (NH$_2$), 1745 (CO$_2$Me), 1660, 1522 (free amide), 1581 (coordinated amide); C$_{22}$H$_{33}$ClN$_4$O$_5$Ru·0.4 CHCl$_3$ (619.8): calcd C 43.41, H 5.76, N 9.04; found C 42.58, H 6.40, N 8.87.

[Cp*Rh(κ^3-L-Asp(β-OMe)Gly–H$^+$GlyOEt–H$^+$)] (12): NaOMe (0.10 mL of a 1.0 M solution in methanol) was added slowly with stirring to an orange solution of **1b**·0.5 H$_2$O (44 mg, 0.10 mmol) and L-Asp(OMe)$_2$ (18 mg, 0.11 mmol) in 3 mL methanol. After 1 h the yellow solution was reduced to dryness and the residue was redissolved in 3 mL dichloromethane. The NaCl precipitate was centrifuged off. The solution was layered with hexane. After 3 d yellow crystals could be isolated. Yield 28 mg (53%). ^{1}H NMR (270 MHz, [D$_4$]methanol, 25 °C): δ = 4.72, ≈3.71 (d, ^2J(H,H) = 18 Hz, 1H each; CH_2CONH), 4.14 (q, ^3J(H,H) = 7 Hz, 2H; CO$_2$CH_2CH$_3$), 4.56, ≈3.62 (d, ^2J(H,H) = 16 Hz, 1H each; CH_2CO$_2$Et), ≈3.68 (m, hidden, NH$_2$CH), 3.66 (s, 3H; OCH$_3$), 2.78, 2.57 (dd, ^3J(H,H) = 6.7 Hz, ^2J(H,H) = 17.5 Hz, 1H each; CHCH_2CO$_2$Me), 1.72 (s, 15H; Cp*), 1.26 (t, ^3J(H,H) = 7 Hz, 3H; CO$_2$CH$_2$CH_3); IR (KBr, < 300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3270, 3227 cm^{-1} (NH$_2$), 1743, 1740, 1727 (CO$_2$Me), 1621, 1563 (coordinated amide); C$_{21}$H$_{32}$N$_3$O$_6$Rh (525.4): calcd C 48.01, H 6.14, N 7.99; found C 47.67, H 6.14, N 7.95.

General procedure for the preparation of 13a–f: A solution of **3a**·0.5 H$_2$O and of the amino acid ester hydrochloride (1.0 equiv) was prepared in 10 mL methanol. A solution of NaOMe (1.0 M, 2.0 equiv) in MeOH, freshly prepared from sodium metal and methanol, was added dropwise with stirring. After 2 h at room temperature the yellow solution was reduced to dryness in vacuo. The residue was redissolved in 5 mL dichloromethane (some drops of methanol were added if necessary for complete dissolution of the yellow complex). The white NaCl precipitate was centrifuged off. Addition of 50 mL pentane to the dichloromethane solution yielded a yellow powder, which was dried in vacuo.

[(η^6-C$_6$Me$_6$)Ru(κ^3-GlyGly–H$^+$GlyOMe–H$^+$)] (13a): From **3a**·0.5 H$_2$O (133 mg, 0.30 mmol) and GlyOMe·HCl (38 mg, 0.30 mmol). The pale yellow powder was vacuum dried at 80 °C for 2 h. Yield 135 mg (93%). Yellow crystals were obtained from methanol/diethyl ether. ^{1}H NMR (400 MHz, [D$_4$]methanol, 25 °C): δ = 4.83, 3.67 (d, ^2J(H,H) = 18 Hz, 1H each; either CONCH_2CON or CH_2CO$_2$Me), 3.68 (s, only ≈0.5H, transesterification with CD$_3$OD; OCH$_3$), 4.50, 3.57 (d, ^2J(H,H) = 16 Hz, 1H each; either CONCH_2CON or CH_2CO$_2$Me), 3.22 (s, 2H; NH$_2$CH_2), 2.12 (s, 18H; C$_6$Me$_6$); IR (nujol, < 300 cm^{-1} polyethylene): $\tilde{\nu}$ = 3264, 3230 cm^{-1} (NH$_2$), 1724 (CO$_2$Me), 1612, 1567 (coordinated amide); C$_{19}$H$_{29}$N$_3$O$_4$Ru·H$_2$O (482.5): calcd C 47.29, H 6.48, N 8.71; found C 47.16, H 6.26, N 8.77.

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[(η^6-C_6Me_6)Ru(κ^3-L-AlaGly-H^+GlyOMe-H^+)] (13b): From **3a**·0.5H_2O (133 mg, 0.30 mmol) and AlaOMe·HCl (41 mg, 0.30 mmol). The pale yellow powder was vacuum dried at 80 °C for 2 h. Yield 135 mg (91%). Yellow crystals were obtained from methanol/diethyl ether. ^{1}H NMR (400 MHz, $CDCl_3$/[D_4]methanol 5:1, 20 °C): δ = 4.99, 3.58 (d, ^2J(H,H) = 18 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 4.65, 3.53 (d, ^2J(H,H) = 16 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 3.65 (s, 3H; OCH_3), 3.08 (m, 1H; C$H$$CH_3$), 2.07 (s, 18H; C_6Me_6), 1.27 (d, ^3J(H,H) = 7 Hz, 3H; CHCH_3); IR (nujol): $\tilde{\nu}$ = 3220, 3080 cm^{-1} (NH_2), 1737 (CO_2Me), 1609, 1559 (coordinated amide); $C_{20}H_{31}N_3O_4Ru \cdot H_2O$ (496.6): calcd C 48.38, H 6.70, N 8.46; found C 48.16, H 6.70, N 8.41.

[(η^6-C_6Me_6)Ru(κ^3-L-ValGly-H^+GlyOMe-H^+)] (13c): From **3a**·0.5H_2O (89 mg, 0.20 mmol) and ValOMe·HCl (36 mg, 0.20 mmol). Pale yellow powder, yield 95 mg (91%). Yellow crystals were obtained from methanol/diethyl ether. ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 5.11, 3.59 (d, ^2J(H,H) = 18 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 4.69, 3.50 (d, ^2J(H,H) = 16 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 3.65 (s, 3H; OCH_3), 2.79 (m, 1H; NH_2CH), ≈2.2 (m, 1H; C$H$$Me_2$) 2.06 (s, 18H; C_6Me_6), 1.06, 0.84 (d, ^3J(H,H) = 7 Hz, 3H each; CH(CH_3)$_2$); IR (nujol): $\tilde{\nu}$ = 3234 cm^{-1} (NH_2), 1737 (CO_2Me), 1611, 1564 (coordinated amide); $C_{22}H_{35}N_3O_4Ru \cdot H_2O$ (524.6): calcd C 50.37, H 7.11, N 8.01; found C 50.68, H 7.09, N 7.90.

[(η^6-C_6Me_6)Ru(κ^3-L-LeuGly-H^+GlyOMe-H^+)] (13d): From **3a**·0.5H_2O (222 mg, 0.55 mmol) and LeuOMe·HCl (99 mg, 0.55 mmol). Pale yellow powder, yield 250 mg (87%). ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ = 5.09, 3.60 (d, ^2J(H,H) = 19 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 4.70, 3.50 (d, ^2J(H,H) = 16 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 3.65 (s, 3H; OCH_3), 2.98 (m, 1H; NH_2CH), 2.07 (s, 18H; C_6Me_6), 1.84 (m, 2H; CH_2CH(CH_3)$_2$), 1.29 (m, 1H; $CH_2CH(CH_3)_2$), 0.99, 0.96 (d, ^3J(H,H) = 6 Hz, 3H each; CH(CH_3)$_2$); ^{13}C NMR (100.5 MHz, ^{1}H decoupled, $CDCl_3$, 20 °C): δ = 181.5, 177.9, 175.4 (2CON, CO_2Me), 91.9 ($C_6(CH_3)_6$), 58.9 (NH_2CH), 55.8 (either CONCH_2CON or CH_2CO_2Me), 51.5 (OCH_3), 48.9 (either CONCH_2CON or CH_2CO_2Me), 43.0 (CH_2CH(CH_3)$_2$), 24.7, 23.3, 21.5 ($CH_2CH(CH_3)_2$), 15.95 ($C_6(CH_3)_6$); IR (nujol): $\tilde{\nu}$ = 3227 cm^{-1} (NH_2), 1736 (CO_2Me), 1612, 1563 (coordinated amide); $C_{23}H_{37}N_3O_4Ru$ (520.6): calcd C 53.06, H 7.16, N 8.07; found C 53.32, H 7.18, N 8.24.

[(η^6-C_6Me_6)Ru(κ^3-L-PheGly-H^+GlyOMe-H^+)] (13e): From **3a**·0.5H_2O (89 mg, 0.20 mmol) and PheOMe·HCl (43 mg, 0.20 mmol). Pale yellow powder, yield 105 mg (93%). ^{1}H NMR (400 MHz, $CDCl_3$, 20 °C): δ = 7.24–7.42 (m, 5H; C_6H_5), 5.10, 3.53 (d, ^2J(H,H) = 19 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 4.72, 3.52 (d, ^2J(H,H) = 16 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 3.64 (s, 3H; OCH_3), 3.37, 2.50 (m, ^2J(H,H) = 15 Hz, ^3J(H,H) = 3 Hz, 11 Hz, 1H each; CH_2Ph), 3.09 (m, 1H; NH_2CH), 1.94 (s, 18H; C_6Me_6); ^{13}C NMR (100.5 MHz, ^{1}H decoupled, $CDCl_3$, 20 °C): δ = 181.3, 176.7, 175.3 (2CON, CO_2Me), 138.5, 128.9, 128.7, 126.7 (C_6H_5), 91.8 ($C_6(CH_3)_6$), 62.6 (NH_2CH), 55.7 (either CONCH_2CON or CH_2CO_2Me), 51.5 (OCH_3), 48.9 (either CONCH_2CON or CH_2CO_2Me), 40.4 (CH_2Ph), 15.6 ($C_6(CH_3)_6$); IR (KBr): $\tilde{\nu}$ = 3218, 3138 cm^{-1} (NH_2), 1741 (CO_2Me), 1615, 1560 (coordinated amide); $C_{26}H_{35}N_3O_4Ru \cdot 0.5H_2O$ (563.7): calcd C 55.40, H 6.44, N 7.46; found C 55.00, H 6.40, N 7.42.

[(η^6-C_6Me_6)Ru(κ^3-L-TrpGly-H^+GlyOMe-H^+)] (13f): From **3a**·0.5H_2O (133 mg, 0.30 mmol) and L-TrpOMe·HCl (77 mg, 0.30 mmol). Pale yellow powder, yield 120 mg (65%). ^{1}H NMR (400 MHz, $CDCl_3$, 20 °C): δ = 7.08–7.57 (m, 5H; C_8H_5NH), 5.12, 3.54 (d, ^2J(H,H) = 18 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 4.86, 3.45 (d, ^2J(H,H) = 15 Hz, 1H each; either CONCH_2CON or CH_2CO_2Me), 3.59 (s, 3H; OCH_3), 1.83 (s, 18H; C_6Me_6), other multiplets between δ = 2.7–3.8 could not be assigned unambiguously; ^{13}C NMR (100.5 MHz, ^{1}H decoupled, $CDCl_3$, 20 °C): δ = 181.3, 177.6, 175.0 (2CON, CO_2Me), 136.9, 126.5, 123.6, 121.6, 118.8, 118.0, 112.1, 110.3 (C_8H_5NH), 91.9 ($C_6(CH_3)_6$), 61.7 (NH_2CH), 55.8 (either CONCH_2CON or CH_2CO_2Me), 51.7 (OCH_3), 49.3 (either CONCH_2CON or CH_2CO_2Me), 30.3 ($CH_2C_8H_5$NH), 15.55 ($C_6(CH_3)_6$); IR (KBr): $\tilde{\nu}$ = 3319, 3225, 3149 cm^{-1} (NH_2), 1731 (CO_2Me), 1591, 1581 (coordinated amide); $C_{28}H_{36}N_4O_4Ru \cdot H_2O$ (611.7): calcd C 54.98, H 6.26, N 9.16; found C 54.96, H 6.23, N 9.12.

[(η^6-p-$Me_2CHC_6H_4Me$)Ru(κ^1-GlyOEt)(κ^2-GlyGlyOEt-H^+)](F_3CSO_3) (14): To a solution of **4** (100 mg, 0.233 mmol) in 6 mL ethanol/dichloromethane (5:1) $Ag(F_3CSO_3)$ (0.233 mmol, 2.33 mL of a 0.1 M solution in ethanol) was added with stirring. The AgCl precipitate was centrifuged off. On addition of GlyOEt (51 μL, 0.50 mmol) the colour of the solution rapidly changed from orange to yellow. After being stirred at room temperature for 10 min, the solution was reduced in volume to ca. 1 mL. Addition of 50 mL diethyl ether afforded an oil that crystallized when stirring was continued for 3 h. Yellow powder, yield 90 mg (59%). ^{1}H NMR (400 MHz, [D_4]methanol, 20 °C): δ = 5.69 (m, 2H; C_6H_4), 5.51 (m, 2H; C_6H_4), 4.66, 4.02 (d, ^2J(H,H) = 17 Hz, 1H each; CONCH_2CO_2Et), 4.25 (q, ^3J(H,H) = 7 Hz, 2H; OCH_2CH_3), 4.17 (q, ^3J(H,H) = 7 Hz, 2H; OCH_2CH_3), 3.68 (s, 2H; $NH_2CH_2CO_2$Et), 3.26 (s, 2H; NH_2CH_2CON), 2.80 (sept, ^3J(H,H) = 7 Hz, 1H; C$H$$Me_2$), 2.21 (s, 3H; $ArCH_3$), 1.23–1.31 (m, 12H; CH(CH_3)$_2$, 2OCH_2CH_3); ^{13}C NMR (100.5 MHz, ^{1}H decoupled, $CDCl_3$, 20 °C): δ = 180.3, 174.0, 172.1 (2CO_2Et, CON), ≈122 (q, ^1J(C,F) = 310 Hz, CF_3SO_3), 106.0, 100.9, 84.1, 83.7, 83.5, 83.2 (p-$Me_2CHC_6H_4Me$), 62.8, 62.3 (2OCH_2CH_3), 54.6 (CONCH_2CO_2Et), 50.2 (either NH_2CH_2CON or $NH_2CH_2CO_2$Et; the other of those signals was probably hidden by the solvent peak at 48.4–49.6), 31.9 (CH(CH_3)$_2$), 23.0, 22.9 (CH(CH_3)$_2$), 18.3 ($ArCH_3$), 14.5, 14.4 (2OCH_2CH_3); IR (nujol): $\tilde{\nu}$ = 3283, 3263, 3180 cm^{-1} (NH_2), 1751, 1725 (CO_2Me), 1579 (coordinated amide); $C_{21}H_{34}F_3N_3O_8RuS \cdot 0.5H_2O$ (655.7): calcd C 38.47, H 5.38, N 6.41; found C 38.41, H 5.39, N 6.66.

Isolation of peptide esters from complexes 5c, 7c and 13f:

L-LeuGlyGlyOMe·HCl: Compound **5c** (114 mg, 0.20 mmol) was added to 5 mL of a methanolic HCl solution (0.2 M) while it was stirred. The volume of the reaction mixture was reduced to 1.5 mL and the suspension was kept at −78 °C for 1 h. The red precipitate of $[Cp^*RhCl_2]_2$ was centrifuged off, washed with 3 mL cold methanol and vacuum dried. The complex was regenerated in 65% yield (40 mg); purity was confirmed by ^{1}H NMR spectroscopy. The methanolic reaction solution which contained the tripeptide ester hydrochloride was reduced in vacuo to 0.5 mL. Diethyl ether (50 mL) was added with stirring. The suspension was frozen at liquid-nitrogen temperature and then allowed to warm up to room temperature with stirring. The pale yellow powder was centrifuged off, redissolved in 15 mL chloroform containing a few drops of methanol and reprecipitated by addition of 15 mL hexane. The pale yellow powder was dried in vacuo at 50 °C for 2 h. Yield (66%). Amino acid analysis: $Leu_{0.87}Gly_{2.0}$; degree of racemization: 1.5% D-Leu.

L-AlaGlyGlyOMe·HCl: Compound **7c** (365 mg, 0.709 mmol) was dissolved in 4 mL methanol. 6 mL of a methanolic HCl solution (0.45 M) was added slowly with stirring. After 30 min the orange precipitate of $[(\eta^6\text{-}C_6Me_6)RuCl_2]_2$ was centrifuged off, washed twice with 5 mL methanol and vacuum dried. The purity of $[(\eta^6\text{-}C_6Me_6)RuCl_2]_2$, which was regenerated in 95% yield (225 mg), was confirmed by ^{1}H NMR and IR spectroscopy. The combined MeOH solutions, which contained the tripeptide ester hydrochloride, were evaporated nearly to dryness. The residue was taken up in 10 mL dichloromethane. To complete the precipitation of the peptide ester diethyl ether (5 mL) was added. The white powder was centrifuged off, washed three times with 10 mL dichloromethane and dried in vacuo. Yield 160 mg (89%). ^{1}H NMR (400 MHz, [D_4]methanol, 25 °C): δ = 4.03, 3.93 (d, ^2J(H,H) = 17 Hz, 1H each; CONHCH_2CONH), 4.01 (q, ^3J(H,H) = 7 Hz, 1H; C$H$$CH_3$), 3.98 (s, 2H; C$H_2CO_2$Me), 3.72 (s, 3H; OCH_3), 1.53 (d, ^3J(H,H) = 7 Hz, 3H; CHCH_3); IR (nujol): $\tilde{\nu}$ = 3330, 3301, 3197, 3160 cm^{-1} (NH_2), 1727 (CO_2Me), 1658, 1553 (free amide); $C_8H_{16}ClN_3O_4$ (253.7): calcd C 37.88, H 6.36, N 16.56; found C 36.95, H 6.34, N 16.25. Peptide content: 100%; amino acid analysis: $Ala_{1.00}Gly_{1.92}$; degree of racemization: 1.2% D-Ala.

L-TrpGlyGlyOMe·HCl: From **13f**, following the procedure for the isolation of L-AlaGlyGlyOMe·HCl. Yield 80%. Peptide content: 86.9%; amino acid analysis: $Trp_{0.99}Gly_{2.01}$; degree of racemization: 4.4(±0.5)% D-Trp.

Crystal structure analysis [13]: The structures of compounds **7c**, **11** and **13a** were determined on an Enraf Nonius CAD4 diffractometer, all at 293(2) K. The crystal of **10** was measured at 193(2) K on a Syntex R3 diffractometer and the crystal of **12** on a Siemens R3 mV diffractometer at 215 K. $Mo_{K\alpha}$ radiation was used in all cases, with a graphite monochromator. Data was collected with the omega scan technique.

The crystal of **11**, a very thin plate, contained MeOH as well as $CHCl_3$, which slowly evaporated during data collection with concomitant crystal decomposition (−16%) leading to an average site occupation factor of 0.81 for chloroform per formula unit. The crystal of **13a** contained one disordered molecule of MeOH.

Empirical absorption corrections by means of psi-scans were performed for **7c**, **11** and **13a**, leading to relative minimum transition factors of 0.908, 0.862 and 0.955, respectively. A face-indexed numerical absorption correction was applied for **12**, giving minimum/maximum transmissions of 0.945 and 0.964. An extinction correction was applied for this crystal as well, with χ = 0.00010(3). Owing to experimental difficulties with the low-temperature device no absorption correction was performed for **10**. The structures were solved with the programs SIR [14] (**7c**, **13a**), SHELXS86 [15] (**11**) and SHELXTL-PLUS 4.11/V (**10**). Refinements were performed for these four structures with the PC version of SHELXL93 [16]. R and wR were refined on $|F|$ and $|F^2|$, respectively. SHELXL93 uses a Flack parameter [17] for a test of the absolute configuration. This parameter refined to a value of −0.01 for **7c** and **10**, indicating the given configurations were true. However, for **11** this parameter refined to 0.37(7), indicating twinning of the crystal. This result might be influenced by the crystal decomposition. Thus, the absolute configuration cannot be given with certainty. The structure of **12** was solved and refined with SHELXTL-PLUS. The absolute configuration parameter n was determined as 1.08(8). Since **13a** contains only glycine residues, no chiral induction could be expected, and the centrosymmetric space group confirmed this expectation. Hydrogen positions were fixed geometrically and refined with the riding model approximation with a temperature factor fixed at 1.3 times the value of the equivalent isotropic displacement parameter of the corresponding carbon atom.

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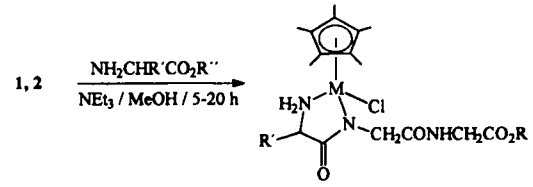
Table 1. Details of the crystal structure determinations.

	7c	10	11	12	13a
formula	$C_{20}H_{32}ClN_3O_4Ru$	$C_{21}H_{36}ClN_4O_7Rh$	$C_{23.3}H_{37.8}Cl_{3.4}N_4O_{5.5}Ru$	$C_{21}H_{32}O_6RhN_3$	$C_{39}H_{62}N_6O_9Ru_2$
M_r	515.0	594.9	685.1	525.4	961.1
crystal system	monoclinic	monoclinic	monoclinic	orthorhombic	triclinic
space group	$P2_1$	$P2_1$	$P2_1$	$P2_12_12_1$	$P\bar{1}$
a (Å)	9.180(3)	8.423(4)	8.841(3)	11.306(2)	12.859(4)
b (Å)	12.843(4)	15.879(5)	15.400(5)	11.937(2)	12.865(4)
c (Å)	18.735(6)	10.474(4)	23.474(7)	17.260(3)	15.947(5)
α (°)					97.28(2)
β (°)	94.84(2)	109.48(3)	100.20(2)		106.35(2)
γ (°)					119.61(2)
V (Å^3)	2201(1)	1320.7(9)	3145(2)	2329.3(8)	2086(1)
Z	4	2	4	4	2
ρ_{calc} (gcm^{-3})	1.554	1.496	1.447	1.498	1.530
μ (mm^{-1})	0.864	0.793	0.829	0.759	0.784
crystal size (mm)	0.47 × 0.40 × 0.10	0.68 × 0.28 × 0.17	0.47 × 0.47 × 0.03	0.60 × 0.06 × 0.06	0.40 × 0.20 × 0.13
2θ range (°)	4.3–46.0	4.1–40.1	4.4–44.0	5.0–50.0	4.4–46.0
index range	$\pm h, \pm k, +l$	$\pm h, \pm k, \pm l$	$+h, \pm k, \pm l$	$+h, +k, \pm l$	$\pm h, \pm k, +l$
collected reflns	6556	2798	8309	4653	6027
independent reflns [R_{int} (%)]	6089 [1.06]	2455 [2.57]	7706 [1.46]	4110 [3.85]	5783 [1.73]
parameters [restraints]	539 [1]	324	706 [115]	285 [0]	542 [2]
$R1/wR2$ [$I > 2\sigma_F$] [a]	0.0361/0.1196	0.0411/0.0950	0.0547/0.1638	0.0401/0.0272	0.0298/0.0763
GoF	1.170	1.056	1.079	1.84	0.981
largest diff. peak and hole (e Å^{-3})	1.72/ − 0.78	0.42/ − 0.35	0.79/ − 0.50	1.17/ − 0.67	0.35/ − 0.29

[a] R, Rw: $|F| > 3\sigma_F$, with $w = \sigma_F^{-2}$, refinement on $|F|$.

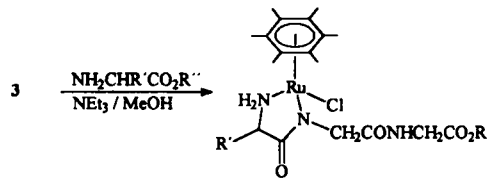
Results and Discussion

Peptide synthesis: The chloro-bridged half-sandwich complexes $[(\eta^6\text{-arene})Ru(\mu\text{-Cl})Cl]_2$ (arene = C_6Me_6, η^6-p-$Me_2CHC_6H_4Me$) and $[Cp^*M(\mu\text{-Cl})Cl]_2$ (M = Rh, Ir) readily react with α-amino acids and peptide esters to form *N*(amine),*O*(carboxylate) and *N*(amine),*N*(peptide) chelate complexes, respectively.[12, 18] These compounds have a pseudooctahedral geometry with a chiral metal atom. The dipeptide ester complexes $[Cp^*M(Cl)(\kappa^2\text{-GlyGlyOR})]$ (**1**: M = Rh, **2**: M = Ir),[12] $[(\eta^6\text{-}C_6Me_6)Ru(Cl)(\kappa^2\text{-GlyGlyOR})]$ (**3**)[12] and $(\eta^6\text{-}p\text{-}Me_2CHC_6H_4Me)Ru(Cl)(\kappa^2\text{-GlyGlyOEt})$ (**4**)[12] were used as starting materials for the synthesis of tri- and tetrapeptide complexes. Reaction of **1**–**3** with various α-amino acid esters in $MeOH/NEt_3$ yields the tripeptide ester compounds **5**–**7** (Schemes 3 and 4), which in most cases can be isolated as crystalline products in 50–90% yield. All tripeptide ester complexes have been characterized by microanalysis, IR and NMR spectroscopy. The amino acid sequence AlaGlyGly in **7c** was confirmed by the crystal structure of the complex. Compounds **5**–**7** display characteristic strong infrared absorbances for both coordinated amide (1570–1600 cm^{-1}) and uncoordinated amide (1640–1670 cm^{-1}). The latter absorbance is not found in the dipeptide ester complexes **1**–**4**. The incorporation of the third amino acid is further confirmed by ^{1}H NMR spectra, which show additional signals for the corresponding side chains. In the case of $Asp(OMe)_2$, peptide bond formation occurs specifically at the α-CO_2Me group and not at the side chain. The same observation was reported by Yamada et al. in Cu^{II}-promoted dipeptide synthesis from $Asp(OMe)_2$.[5e]



	M	R	R'
5a	Rh	Me	H
b	Rh	Et	Me
c	Rh	Me	CH_2CHMe_2
d	Rh	Et	CH_2CO_2Me
e	Rh	Et	CH_2OH
6a	Ir	Et	H
b	Ir	Et	CH_2OH

Scheme 3. Tripeptide ester complexes obtained from **1** and **2**.



	R	R'
7a	Me	H
b	Et	H
c	Me	Me
d	Me	$CHMe_2$

Scheme 4. Tripeptide ester complexes obtained from **3**.

The tripeptide ester complexes might also be prepared in a one-pot procedure from the chloro-bridged complex, the dipeptide ester hydrochloride and the amino acid ester. Thus, [Cp*Rh(Cl)AlaGlyGlyOMe] (**5a**) is obtained in 82% yield by reaction of $[Cp^*RhCl_2]_2$, GlyGlyOMe·HCl and AlaOMe in MeOH, Na_2CO_3 acting as a base.

Compound **4** reacts in the same fashion as **1**–**3** to yield tripeptide complexes, but it was difficult to obtain analytically pure products, since the complexes could not be purified by crystallization. We have identified the complex $[(\eta^6\text{-}p\text{-}Me_2CHC_6H_4Me)Ru(Cl)(\kappa^2\text{-GlyGlyGlyOEt})]$ spectroscopically as a major product of the reaction of **4** with GlyOMe by comparison with the closely related GlyGlyGlyOMe complex, which was prepared directly from $[\{(\eta^6\text{-}p\text{-}Me_2CHC_6H_4Me)RuCl_2\}_2]$ and the tripeptide ester.[12]

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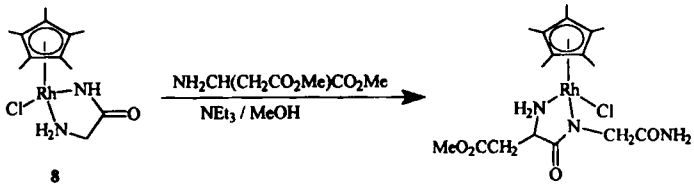
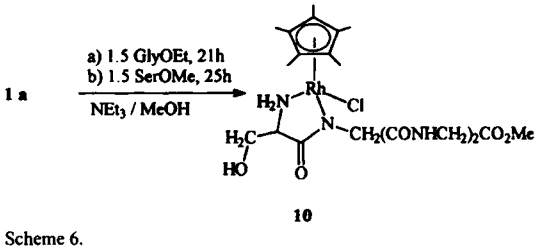
The glycine amide complex [Cp*Rh(Cl)(GlyNH$_2$)] (**8**)[12] reacts with the amino acid ester Asp(OMe)$_2$ in the same fashion as the diglycine ester complex, yielding the dipeptide amide complex Cp*Rh(Cl)(Asp(β-OMe)GlyNH$_2$) (**9**; Scheme 5). A strong IR band of the uncoordinated CONH$_2$ group is observed at 1661 cm^{-1}.

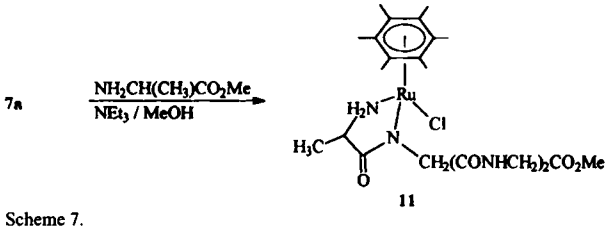


Scheme 5.

In the same fashion in which tripeptide ester complexes form from the dipeptide ester species **1**–**3**, a further elongation of the tripeptide chain in [Cp*Rh(Cl)(κ^2-GlyGlyGlyOMe)] and [(η^6-C$_6$Me$_6$)Ru(Cl)(κ^2-GlyGlyGlyOMe)] is possible by reaction with another equivalent of amino acid ester. With L-SerOMe and L-AlaOMe, respectively, the tetrapeptide ester complexes [Cp*Rh(Cl)(κ^2-L-SerGlyGlyGlyOMe)] (**10**) and [(η^6-C$_6$Me$_6$)-Ru(Cl)(κ^2-L-AlaGlyGlyGlyOMe)] (**11**) are obtained (Schemes 6 and 7, respectively). The structures of **10** and **11** were confirmed



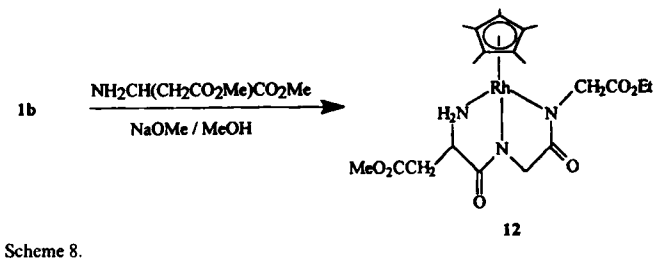
Scheme 6.



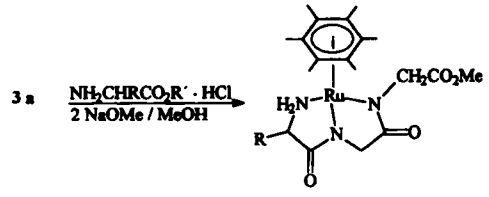
Scheme 7.

by X-ray crystallography. Both compounds are obtained in a good crude yield, but contain a small amount of other peptide ester (mainly unreacted starting compound) as impurities. Analytically pure **11** was obtained after several recrystallizations. Compound **10** was also prepared in a one-pot reaction starting from dipeptide ester complex **1a** by subsequent addition of GlyOMe and SerOMe (1.5 equiv each) in 65% crude yield. The product contained ca. 15% other peptide complexes (estimated by ^{1}H NMR), mainly the triglycine ester compound **5a**.

A different type of peptide ester complex is obtained when the strong base NaOMe is used instead of NEt$_3$ for the reaction of the diglycine ester compounds **1b** and **3a** with amino acid esters (Schemes 8 and 9, respectively). Again the new amino acid is incorporated at the *N*-terminus of the coordinated peptide, but complexes **12** and **13** are formed. The tripeptide ester is κ^3-coordinated by the NH$_2$ group and two deprotonated peptide nitrogen atoms. Whereas this type of peptide coordination is well-known with a planar arrangement of the three donor atoms and



Scheme 8.

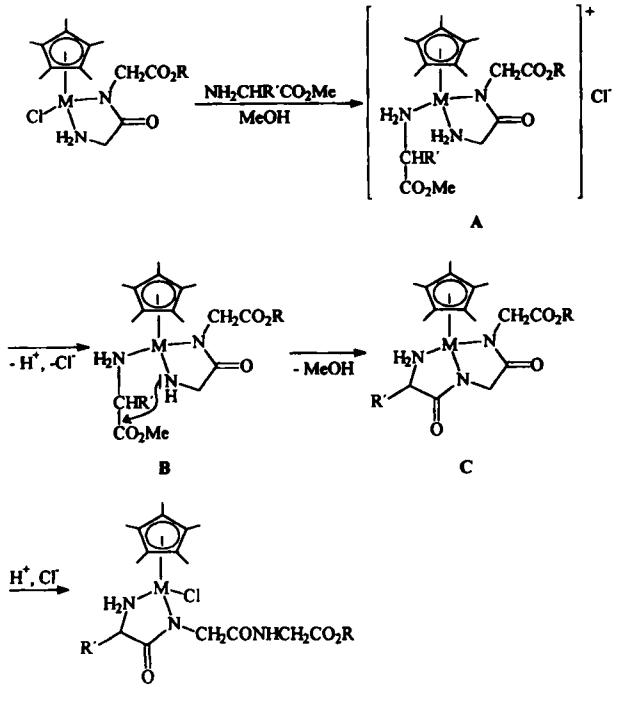


	R
13a	H
b	Me
c	CHMe$_2$
d	CH$_2$CHMe$_2$
e	CH$_2$Ph
f	CH$_2$-indole-3-yl

Scheme 9.

the metal atom,[19] **12** and **13a** represent rare examples of a complex in which the peptide ligand is bound to three orthogonal sites of a (pseudo)octahedral metal ion. As a consequence of this unusual steric arrangement, one of the peptide nitrogens is pyramidal. This remarkable feature will be discussed in detail in the crystallographic section.

It is obvious that the κ^3-peptide ester complexes are intermediates of the peptide elongation reaction in the presence of the weaker base NEt$_3$, which has a catalytic function. Protonation of one of the two coordinated peptide nitrogens by NEt$_3$H$^+$ yields the κ^2-peptide ester complexes (Scheme 10). Interestingly,



Scheme 10. Mechanism of peptide synthesis promoted by Cp*Rh or Cp*Ir complexes ((η^6-C$_6$Me$_6$)Ru complexes, respectively).

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the ^{1}H NMR spectra of **12** and **13b–f** display only one set of sharp signals, indicating the presence of only one diastereoisomer. Whereas the chloro κ^2-peptide ester complexes show broadened signals in [D$_4$]methanol at room temperature owing to rapid epimerization at the metal atom, such behaviour is very unlikely in the case of **12** and **13** because of the tridentate nature of the peptide ligand. In the low-temperature spectrum of **7c**, the epimerization process is frozen and signals of the two diastereoisomers can be observed in a 2:1 ratio. In contrast, **13b** and the other κ^3-tripeptide ester complexes form with very high diastereoselectivity. No second isomer is detectable by NMR spectroscopy. We suggest that the S_CS_M isomer, which is found in the crystal structure of **12**, is formed exclusively. For the S_CR_M form, significant steric hindrance between the amino acid side chain and the Cp* or η^6-arene ligand, respectively, is expected (Fig. 1).

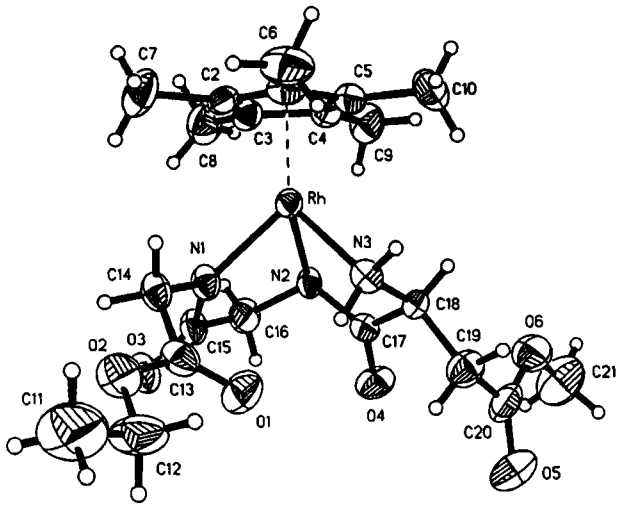
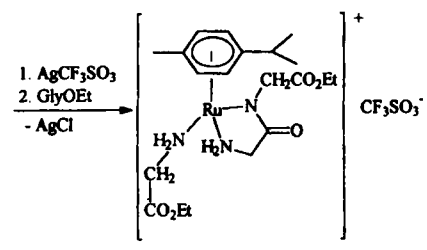


Fig. 1. Structure of [Cp*Rh(κ^3-L-Asp(β-OMe)GlyGlyOMe)] (**12**), S_CS_{Rh} isomer, 50% probability ellipsoids. Selected bond distances [Å] and angles [°]: Rh–N3 2.132(4), Rh–N2 2.046(4), Rh–N1 2.086(4), N2–C17 1.346(5), O4–C17 1.226(7), N1–C15 1.328(6), O3–C15 1.248(7), N3-Rh-N2 77.4(1), N2-Rh-N1 76.0(1), N3-Rh-N1 89.8(2), Rh-N2-C17 118.0(3), Rh-N2-C16 112.0(3), C17-N2-C16 116.1(4), Rh-N1-C15 117.6(4), Rh-N1-C14 125.8(3), C15-N1-C14 116.6(5).

A plausible reaction sequence for peptide bond formation at the metal centre is proposed in Scheme 10. The first step is the formation of intermediate **A** by replacement of Cl^- by the amino acid ester. A complex that corresponds to intermediate **A** was obtained by removal of Cl^- in **4** with $AgCF_3SO_3$ followed by addition of GlyOEt (Scheme 11). [(η^6-*p*-Me$_2$CHC$_6$H$_4$Me)-Ru(GlyGlyOEt)(κ^1-GlyOEt)](CF$_3$SO$_3$) (**14**) was isolated and spectroscopically characterized. Deprotonation of the peptide NH_2 group in **A** leads to intermediate **B**. The immediate H–D exchange in [D$_4$]methanol of the NH_2 protons in **1–4** is a hint



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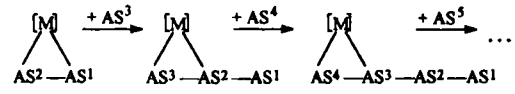
Scheme 11.

of the existence of acidic protons. The new peptide bond is formed by nucleophilic attack of the amide anion at the carbonyl group of the κ^1-bound amino acid ester in a template reaction and subsequent elimination of MeOH. As outlined above, intermediate **C** can be isolated in the presence of strong base. Reprotonation of one peptide group in **C** yields the chloro κ^2-peptide ester complexes.

In principle, the generation of peptide chains of arbitrary length should be possible according to the mechanism outlined in Scheme 10 by subsequent incorporation of amino acid building blocks at the *N*-terminus of the coordinated peptide chain (Scheme 12). The directed synthesis of peptides with desired



Scheme 12. AS = α-amino acid building block. AS^1 = *C*-terminal amino acid. [M] = Cp*Rh, Cp*Ir or (η^6-C$_6$Me$_6$)Ru.

amino acid sequence is complicated by the kinetic lability of intermediate **A**. Owing to exchange processes, the κ^1-amino acid ester (which can be readily replaced by chloride in **14**) not only combines with the dipeptide ester complex but also with the tripeptide ester complex being formed in the reaction solution. Thus, it is not unexpected that **10** is contaminated by significant amounts of other peptide ester complexes when prepared by consecutive addition of GlyOMe and SerOMe to **1a**. A possible reason for the smooth formation of tripeptide ester complexes from diglycine ester compounds is the presence of amino acid substitutents in **5–7** that kinetically hinder further elongation of the peptide chain for steric reasons.

For the preparation of peptides with a well-defined amino acid sequence and in good yield, a modified strategy under investigation in our laboratory might be more promising: intermediate **A** is treated with one equivalent of NaOMe. In the presence of strong base, intermediate **C** is "frozen" and cannot react further. A (κ^2-tripeptide ester–κ^1-amino acid ester) complex of type **A** is regenerated by addition of the triflate salt of the protonated amino acid ester, and the procedure is started all over again.

Isolation of the peptide esters: The coordinated peptide esters are readily liberated by addition of HCl to a methanolic solution of the complexes at room temperature. Treatment of **5c**, **7c** and **13f** with HCl yields the tripeptide ester hydrochlorides LeuGlyGlyOMe·HCl (66%), AlaGlyGlyOMe·HCl (89%) and TrpGlyGlyOMe·HCl, which were characterized by TLC, amino acid analysis and NMR spectroscopy. The chloro-bridged complexes [Cp*RhCl$_2$]$_2$ and [(η^6-C$_6$Me$_6$)RuCl$_2$]$_2$ precipitate from the MeOH solution and are regenerated in 70% and 95% yield, respectively.

Since L-amino acid esters were employed in all cases the enantiomeric purity of the produced peptides was checked. Only about 1% racemization was detected for L-LeuGlyGlyOMe and L-AlaGlyGlyOMe. Peptide synthesis in the presence of NEt$_3$ occured practically without racemization. TrpGlyGlyOMe prepared with the strong base NaOMe contained ca. 4% D-Trp.

Crystal structures of the peptide ester complexes 7c, 10, 11, 12 and 13a: X-ray crystallography unambiguously confirmed the amino acid sequences in the complexes [(η^6-C$_6$Me$_6$)Ru(Cl)-(κ^2-L-AlaGlyGlyOMe)] (**7c**), [Cp*Rh(Cl)(κ^2-L-SerGlyGly-GlyOMe)] (**10**), [(η^6-C$_6$Me$_6$)Ru(Cl)(κ^2-L-AlaGlyGlyGlyOMe)]

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(**11**), [Cp*Rh(κ^3-L-Asp(β-OMe)GlyGlyOEt)] (**12**) and [(η^6-C_6Me_6)Ru(κ^3-GlyGlyGlyOMe)] (**13a**). The L-configuration of the chiral amino acid residue was confirmed in all cases. All complexes contain a chiral metal atom.

Single crystals of **7c** and **11**·0.5MeOH·0.8$CHCl_3$ were grown from MeOH/ether and $CHCl_3$/MeOH/pentane, respectively. The crystal of **7c** contains a 1:1 mixture of the diastereoisomers S_CS_{Ru} and S_CR_{Ru}, which display similar bonding parameters (Fig. 2; only one of the two diastereoisomers is shown). Complex **11** appears to be a racemic twin; however, owing to crystal decomposition (ca. 15%) this assumption has to be regarded with caution (Fig. 3; only one of the two diastereoisomers is shown). The coordinated peptide nitrogen has a trigonal planar environment, since the sum of bond angles around this atom is 359.9°. Similar Ru–N and Ru–Cl bond distances were found in the related complexes [(η^6-C_6H_6)Ru(Cl)(GlyGlyGly)][20] and [(η^6-p-$Me_2CHC_6H_4Me$)Ru(Cl)-(GlyGlyOEt)].[12]

Complex **10**·CH_3OH was crystallized from MeOH/ether. The crystal contained the S_CS_{Rh} diastereoisomer exclusively (Fig. 4). Again the coordinated peptide group is planar (angle sum at nitrogen 360°). The bonding parameters around the Rh atom closely resemble those observed in previously described [Cp*Rh(Cl)(κ^2-GlyGlyGlyOEt)].[12]

The complexes **12** and **13a** display an unusual feature: a κ^3-peptide chain is *N,N,N*-coordinated to three orthogonal sites of the metal ion (Fig. 1, Fig. 5). As a consequence of this stereochemistry one deprotonated peptide nitrogen can no longer retain its trigonal planar conformation but is severely distorted towards a pyramidal conformation. The sum of the bond angles around the pyramidal peptide nitrogens in **12** (N2, Fig. 1) and **13a** (N2, Fig. 5) amounts to 346.1° and 348.7°, respectively. The value for ideal trigonal planarity is of course 360° and for an ideal trigonal pyramidal environment 328°. Usually, an *N*-coor-

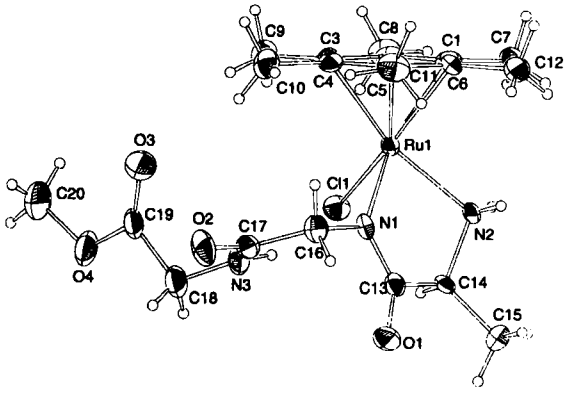

Fig. 2. Structure of [(η^6-C_6Me_6)Ru(Cl)(κ^2-L-AlaGlyGlyOMe)] (**7c**), 50% probability ellipsoids. Only one (S_CS_{Ru}) of the two diastereoisomers is shown. Selected bond distances [Å] and angles [°]: Ru1–Cl1 2.466(2), Ru1–N1 2.088(5), Ru1–N2 2.145(5), Ru1–C (mean C1–C6) 2.204, C13–N1 1.321(9), C17–N3 1.315(8); Cl1-Ru1-N1 86.6(1), Cl1-Ru1-N2 87.8(1), N1-Ru1-N2 76.0(2), Ru1-N1-C13 117.6(4), Ru1-N1-C16 128.1(4), C13-N1-C16 114.2(6), O1-C13-N1 126.8(6), O1-C13-C14 117.9(6), N1-C13-C14 115.3(5).

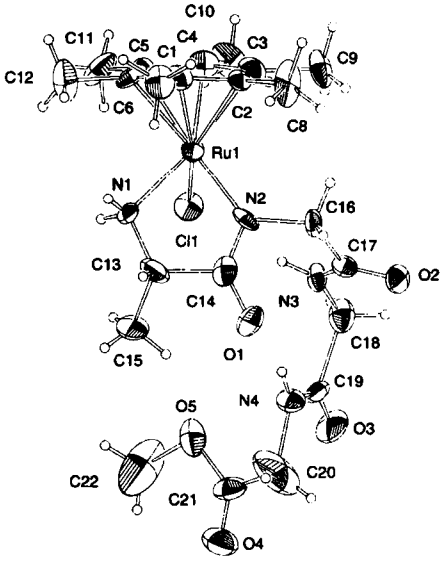

Fig. 3. Structure of [(η^6-C_6Me_6)Ru(Cl)(κ^2-L-AlaGlyGlyGlyOMe)] (**11**), 50% probability ellipsoids. Only one (S_CR_{Ru}) of the diastereoisomers is shown. Selected bond distances [Å] and angles [°]: Ru1–Cl1 2.436(3), Ru1–N1 2.124(12), Ru1–N2 2.049(12), Ru1–C (mean C1–C6) 2.22(1), C14–N2 1.31(2), C17–N3 1.21(2), C19–N4 1.30(2); Cl1-Ru1-N1 83.4(3), Cl1-Ru1-N2 84.6(3), N1-Ru1-N2 78.2(4), Ru1-N2-C14 123.7(10), Ru1-N2-C16 130.0(8), C14-N2-C16 106.2(12), O1-C14-N2 133(2), O1-C14-C13 117.0(14), N2-C14-C13 110.0(14), O2-C17-N3 129.3(14), O2-C17-C16 114.2(12), N3-C17-C16 115.8(14), O3-C19-N4 127.3(14), O3-C19-C18 120(2), N4-C19-C18 111.2(11).

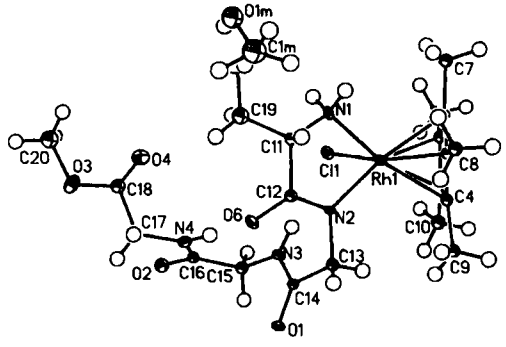

Fig. 4. Structure of [Cp*Rh(Cl)(κ^2-L-SerGlyGlyGlyOMe)] (**10**), S_CS_{Rh} isomer, 50% probability ellipsoids. Selected bond distances [Å] and angles [°]: Rh–Cl 2.445(3), Rh–N1 2.130(11), Rh–N2 2.056(8), N2–C12 1.278(14), N3–C14 1.322(12), N4–C16 1.33(2), O6–C12 1.270(13), Cl-Rh-N1 84.7(3) Cl-Rh-N2 86.9(3), N1-Rh-N2 78.5(4), Rh-N2-C12 120.5(8), Rh-N2-C13 126.5(7).

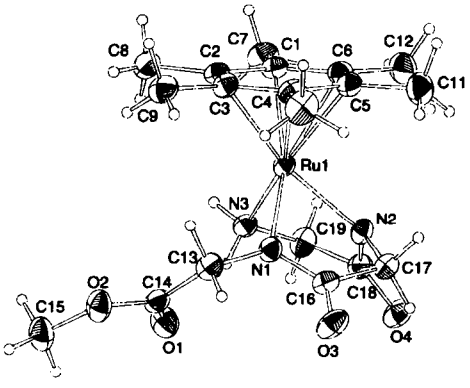

Fig. 5. Structure of [(η^6-C_6Me_6)Ru(κ^3-GlyGlyGlyOMe)] (**13a**), S_{Ru} enantiomer. 50% probability ellipsoids. Selected bond distances [Å] and angles [°]: N1–Ru1 2.109(3), N2–Ru1 2.056(3), N3–Ru1 2.123(3), C–Ru1 (mean C1–C6) 2.206, C16–N1 1.318(5), C18–N2 1.329(5); N2-Ru1-N1 74.7(1), N3-Ru1-N1 88.7(1), N3-Ru1-N2 76.3(1), C13-N1-Ru1 126.9(2), C16-N1-Ru1 115.6(2), C16-N1-C13 116.4(3), C17-N2-Ru1 111.8(2), C18-N2-Ru1 119.1(3), C18-N2-C17 117.8(3), N1-C16-O3 127.0(4), C17-C16-O3 119.0(3), C17-C16-N1 113.9(3), N2-C18-O4 127.2(4), C19-C18-O4 121.1(4), C19-C18-N2 111.6(3).

dinated peptide group is coplanar with the metal ion and, at most, small deviations from planarity at the nitrogen atom are observed.[21] We are aware of only one example comparable to **12** and **13a**. In Sheldrick's [Ru(triphos)(κ^3-GlyGly)] the dipeptide is facially coordinated and the sum of bond angles at the peptide nitrogen is 344°.[22] The M–N2 bond (2.046 Å in **12**, 2.053 Å in **13**) is somewhat shorter than the coordinative bond to the planar peptide nitrogen N1 (2.086 Å in **12**, 2.109 Å in **13a**). This might be a consequence of the pyramidal hybridization of N2, which decreases the resonance of the nitrogen lone pair with the carbonyl group so that the lone pair is more available for interaction with empty d orbitals of the metal.

Conclusion

We have presented a novel metal-promoted peptide synthesis from amino acid esters. Our method permits the elongation of a coordinated peptide chain at the *N*-terminus by consecutive incorporation of several amino acid building blocks in a one-pot reaction without isolation of intermediates. In a forthcoming paper[23] we will report on the formation of significant amounts of hexa, hepta- and octaglycine peptides in the reaction of [(η^6-*p*-$Me_2CHC_6H_4Me$)Ru(Cl)(κ^2-GlyGlyOEt)] with excess GlyOEt.

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