# On the Reactions of Furan-2,3-diones with Oxindole (=1,3-Dihydro-2*H*-indol-2-one) and *Lawesson* Reagent. Synthesis of New 1,3-Dihydro-2*H*-indol-2-ones, Bis-furanones, and Bis-pyrrolones

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Lactone analogues of 3-substituted oxindoles (=1,3-dihydro-2*H*-indol-2-ones) and nonbenzoid oxa-analogous isoindigoid or nonbenzoid isoindigoid dyes were prepared by the reactions of furan-2,3-diones with oxindole and *Lawesson* reagent (*Schemes 1* and *3*), respectively. So, new derivatives of 2-oxobutanoic acid, bis-furanone, and bis-pyrrolone, which are potentially biologically active compounds, were synthesized for the first time.

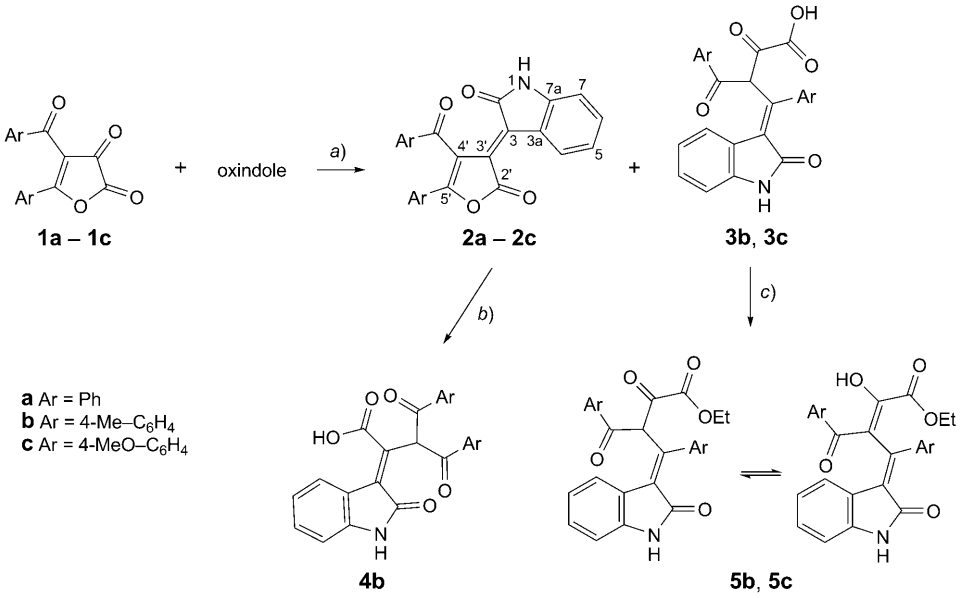
**Introduction.** – Polyfunctionalized heterocyclic compounds play important roles in the drug-discovery process, and an analysis of drugs in late development or on the market shows that 68% of them are heterocycles [1]. Therefore, much work [2] was carried out on the reactivity and synthetic potential of 4-acyl-substituted heterocyclic 2,3-diones **1** and **7**, particularly on addition of nucleophiles leading to a number of polyfunctionalized heterocyclic systems [3]. A convenient method for their synthesis, the mechanism of reactions, and semi-empirical (AM1 and PM3) and *ab initio* (DFT) calculations on the interaction of 4-benzoyl-5-phenylfuran-2,3-dione (**1a**) with several semicarbazones, ureas, thioureas, anilides, hydrazones, and hydrazines have been reported recently [4]. As a further development of our continuing studies in this field, we now report on a new synthetic pathway for the straightforward and effective preparation of derivatives of 3-substituted oxindoles (=1,3-dihydro-2*H*-indol-2-ones) **2**–**5** and oxa analogues of nonbenzoid isoindigoid dyes **6** and **8**.

Functionalized oxindoles represent the core structure of many important pharmacological agents and natural products [5]. For example, the oxindole motif is present in the anti-*Parkinson* drug ropinirole, in nonopioid nociceptin receptor ligands, and in the growth-hormone secretagogues [6]. Moreover, the oxindole moiety constitutes a key structural element in several natural products, including the antibiotic speradine and the cytostatic welwistatin [6]. In addition, the indole moiety is present in a wide variety of natural and synthetic compounds, many of which have proved to be interesting in a chemical and biological context because they exhibit a wide spectrum of pharmacological action [7].

Recently, the reactions of furan-2,3-diones with 2-phenyl-1*H*-indole to yield derivatives of indole were reported by *Şener* and co-workers [8a], but they could not achieve 3-(furan-3-ylidene)-3*H*-indole derivatives. The reaction of furandiones with oxindole have not yet been reported. Herein, we report the first synthesis of 3-

substituted oxindoles **2**–**5** from the reactions of some furan-2,3-diones **1** with oxindole. In particular, the compounds **2** were first synthesized by these reactions (*Scheme 1*), and the results obtained from all experiments are discussed in this study. Our study also presents new bis-furanones **6** and bis-pyrrolones **8** representing nonbenzoid oxa analogues of isoindigoid and nonbenzoid isoindigoid skeletons which are highly colored products and obtained from the reaction of the furan-2,3-diones **1** with the *Lawesson* reagent (see below, *Scheme 3*).

*Scheme 1*




*a*) Reflux in benzene, 24 h. *b*) EtOH, $H_2O$, KOH, reflux, 1 h. *c*) reflux in EtOH, $H_2SO_4$, 6 h.

**Results and Discussion.** – Substituted furan-2,3-diones **1a**–**1c**, which were used as important starting materials in the synthesis of the target heterocycles, were prepared by literature procedures [9]. Furandiones show typical reactions of carbonyl compounds, lactones, and $\alpha,\beta$-unsaturated carbonyl compounds, like *Michael*-type additions, depending on the structures of the nucleophiles [4][10]. An aldol condensation of the compounds **1** with oxindole in benzene under reflux for 24 h led to the formation of corresponding 3-substituted oxindoles **2** and **3**, without opening of the indole ring. Thus the 2*H*-indol-2-ones **2a**–**2c** were formed as main products in moderate yields (39–58%), and in addition, **3b** and **3c** were obtained as by-products in 22% and 30% yields, respectively. The reactions of **1** with oxindole may produce different oxindole derivatives, *e.g.*, **2** and **3** and their (*Z*)- and (*E*)-isomers, *via* the reactions at C(3) and C(5) of furandiones **1**, respectively. However, our experiments (TLC studies) resulted in the formation of only two products, the structures of which were identified as (3*E*)-3-[4-aroyl-5-aryl-2-oxofuran-3(2*H*)-ylidene]-1,3-dihydro-2*H*-

indol-2-one **2** and (4*Z*)-3-aroyl-4-aryl-4-(1,2-dihydro-2-oxo-3*H*-indol-3-ylidene]-2-oxobutanoic acid **3** (*Scheme 1*). Alkaline hydrolysis of **2b** in 10% KOH/EtOH resulted in a new product **4b** (yellow) in 39% yield (*Scheme 1*). Additionally, conversion of the 2-oxobutanoic acids **3b** and **3c** into their corresponding ester derivatives **5b** and **5c** was accomplished by *Fischer* esterification showing the presence of a free COOH group in **3**.

The structures of **2** and **3** were confirmed by analytical and spectroscopic data and agreed with those found for similar compounds [3][8a][11b]. The configuration of the C=C bond between the oxindole and the furan part in compounds **2a**–**2c** was established to be (*E*) by the downfield shifts of the H–C(4) resonance (for the atom numbering, see *Scheme 1*) of these compounds, which are comparable with those of the H-atoms for similar (*E*)-configured isoindigoid derivatives [11]. The IR spectra of **2c** showed absorption bands at 1769, 1700, 1659, and 1598–1456 $cm^{-1}$ due to three C=O and aromatic C=C bonds, respectively. The broad absorption band of the NH group appeared at 3165 $cm^{-1}$, and the C–O–C moiety was observed at 1259 $cm^{-1}$. The $^1$H-NMR spectrum of **2c** exhibited two sharp *s* for the MeO groups at $\delta$ 3.77 and 3.76. The aromatic H-atoms were observed as a set of signals at $\delta$ 6.80–8.73. The $^1$H-decoupled $^{13}$C-NMR spectrum of **2c** showed 23 resonances, in good agreement with the proposed structure (see *Exper. Part*). The $^1$H- and $^{13}$C-NMR spectra of **2a** and **2b** were similar to those of **2c**, except for the signals of the substituents at C(4′) and C(5′), which exhibited characteristic resonances with appropriate chemical shifts.

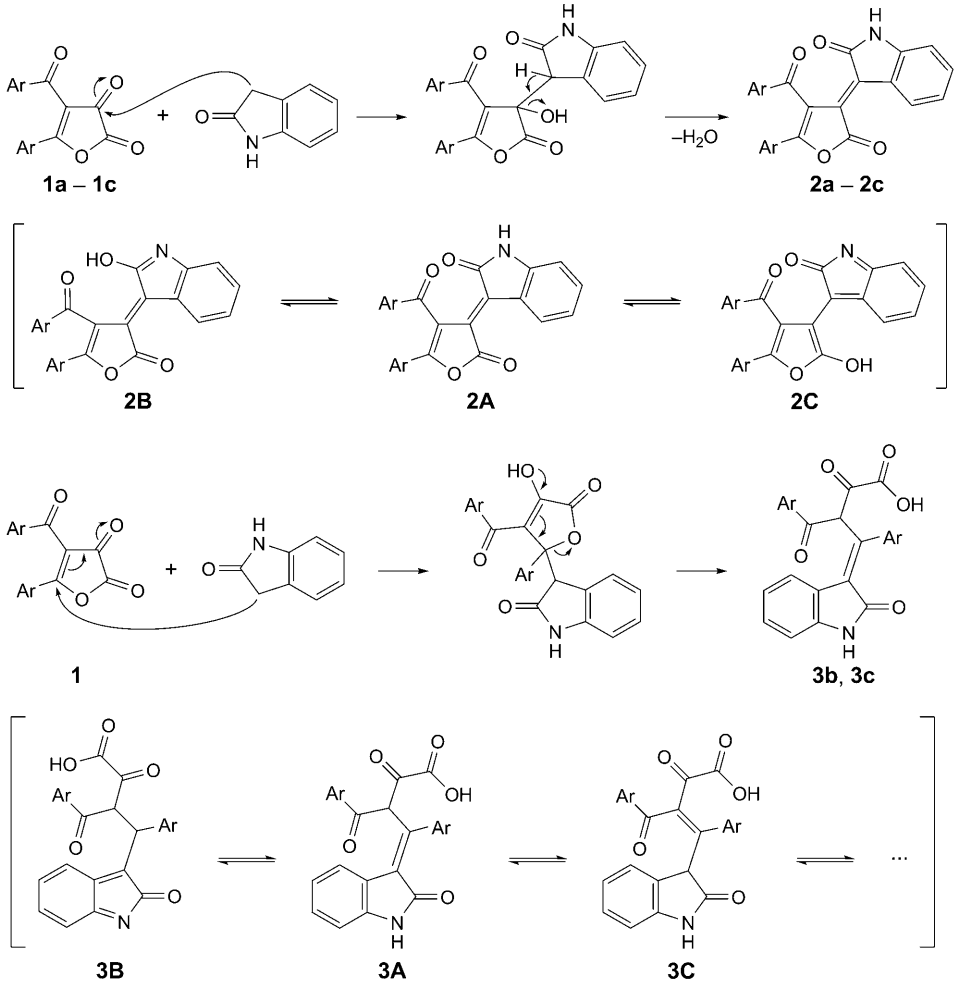
The formation of compounds **3** may be initiated by a *Michael* addition, *via* nucleophilic attack at C(5) of the furan ring of **1** by C(3) of oxindole (*Scheme 2*). Rearrangement of the intermediates thus formed may lead to ring opening to give 2-oxobutanoic acid derivatives **3**. In addition, the dark red compounds **2** may be formed by condensation reactions of oxindole and furandione **1** without opening of the furan or indole rings [3].

In the $^1$H-NMR spectra of **2a**–**2c**, the NH signal revealed the presence of tautomers **2A**–**C**, the tautomer **2A** being the preferred form in ($D_6$)DMSO solution (*Scheme 2*), whereas in $CDCl_3$ solutions, the tautomer **2B** was predominant. On the other hand, the products **3b** and **3c** did not show any tendency to exist in tautomeric forms **3B** and **3C** in ($D_6$)DMSO and $CDCl_3$. Similar observations have also been made with closely related dibenzoylacetic acid, benzoylmalonic acid, dipivaloylacetic acid, and pivaloylmalonic acid derivatives [10a][10b][10c].

In the UV/VIS spectra of the 3-substituted oxindoles **2a**–**2c** (*Table*, *Fig.*), the broad $\lambda_{max1}$ peaks are characteristic for compounds **2a**–**2c** and due to $\pi$–$\pi^*$ electronic transitions in the oxindole skeleton. The sharp $\lambda_{max2}$ peaks at 200–320 nm correspond to n–$\pi^*$ electronic transitions of the C=C, C=N and C=O bonds. The $\lambda_{max1}$ of **2a** at 457 nm undergoes a bathochromic shift to 460 and 485 nm on substitution of the Ph ring by a Me or MeO group at the *para* position ($\Delta\lambda_{max1} = -3$ nm for **2b** and $-28$ nm for **2c**), compatible with the fact that the Me and MeO are electron-donor groups.

While examining the melting point of **2a**, an uncommon behavior was observed. At *ca.* 225°, the dark red crystals in the solid state brightened up into pale red ones before finally melting at 260°. This obviously indicates an unusual thermal rearrangement [3b]. Although we have not studied this issue further, we assume that the reaction occurs under thermodynamic control.

Scheme 2. *Proposal for the Reaction Pathway from* **1** *to* **2** *and* **3**, *and Some Tautomeric Forms* (**2A**–**C**, **3A**–**C**) *of* **2a**–**2c**, **3b**, *and* **3c** *in Solution*




To examine if the transformations of the type **1** → **2** + **3** can be extended to somewhat modified systems, several attempts to change the functional groups of **1** were made, *e.g.*, transformation of the C=O groups into the corresponding C=S moieties with the *Lawesson* reagent (=2,4-bis(4-methoxyphenyl)-1,3,2,4-dithiadiphosphetane 2,4-disulfide) [12]. *Kollenz* and co-workers reported that the reaction of compound **1a** with *Lawesson* reagent yielded the bis-furanone **6a** (Ar = Ph) instead of the expected sulfurized product [3] (*Scheme 3*). Similarly under the usual experimental procedures for thionation of carbonyl compounds with *Lawesson* reagent (60–70° in dry xylene for 3 h), the furandiones **1b** and **1c** formed dark red-blue solutions (*cf.* [3b]) from which, upon cooling, bright red crystals of **6b** and dark-violet crystals of **6c**, respectively, were

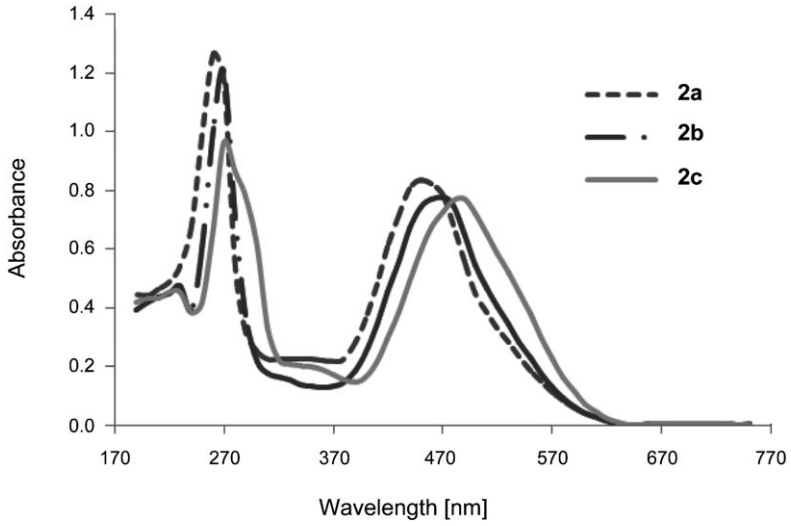


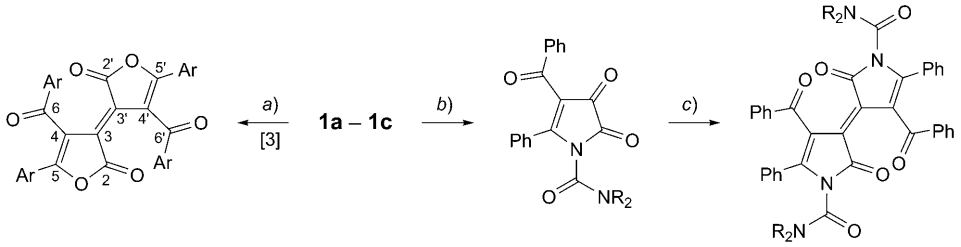

Figure. *UV/VIS Spectra of* **2a**–**2c** *in* $CHCl_3$

Table. *UV/VIS Absorption Maxima of* **2a**–**2c** *in* $CHCl_3$

| | Ar | $\lambda_{max1}$ [nm] | $\lambda_{max2}$ [nm] | Absorption shift $\Delta\lambda_{max}$ [a]) |
|---|---|---|---|---|
| **2a** | Ph | 457 | 260 | – |
| **2b** | 4-Me–$C_6H_4$ | 460 | 269 | – 3 |
| **2c** | 4-MeO–$C_6H_4$ | 485 | 270 | – 28 |

[a]) $\Delta\lambda_{max} = \lambda_{max1}(\mathbf{2a}) - \lambda_{max1}(\mathbf{2b}$ or $\mathbf{2c})$.

*Scheme 3*




*a*) *Lawesson* reagent, xylene, 60–70°, 3 h. *b*) [4f], corresponding *N,N*-dialkylurea, reflux in benzene, 3 h. *c*) *Lawesson* reagent, xylene, 60–70°, 2.5 h.

obtained in moderate yields (48 and 52%). The bis-furanones **6b** and **6c** represent oxa analogues of isoindigoid derivatives.

Extending the reaction with *Lawesson* reagent to the pyrrol-2,3-diones **7**, prepared from cyclocondensation reactions of the corresponding *N*,*N*-dialkylureas and **1a** [4f], similar results were achieved: Instead of the expected sulfurized products, again deep blue isoindigoid dyes **8** were obtained in moderate yields (32 and 36%; *Scheme 3*). A close structural similarity of **8** with the long-known *Pechmann* dyes is obvious [13]. This analogy, in particular, is also nicely documented by comparing the UV/VIS spectra of **8** and a *Pechmann* dye, selecting the $\lambda_{max}$ values ($CHCl_3$) in the VIS region only: $\lambda_{max}$ of **8a** 520 and 550 nm, $\lambda_{max}$ of **8b** 540 and 570 nm, and $\lambda_{max}$ of *Pechmann* dye 502 and 538 nm [13a].

**Conclusions.** – The efficient synthesis of some nonbenzoid oxa analogues of isoindigoids was reported here. Our current studies suggest that the strategy outlined herein is rather general and can be successfully applied to the synthesis of a variety of derivatives containing different oxindole moieties. The biological properties of these compounds are currently under investigation.

We gratefully acknowledge financial support from the *Scientific Research Projects Chairmanship of Erciyes University.*

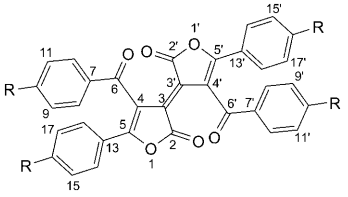
## Experimental Part

*General.* Compounds **1** were prepared according to [9]. Oxindole, *Lawesson* reagent, and other reagents or solvents were purchased from *Merck*, *Fluka*, and *Sigma*, and used without further purification. TLC: *Merck* precoated silica gel plates *60 F 254*. M.p.: *Electrothermal-9200* apparatus; uncorrected. IR Spectra: *Shimadzu-8400* FT-IR spectrometer; ATR = attenuated total reflection; in $cm^{-1}$. $^1H$- and $^{13}C$-NMR Spectra: *Bruker-Ultrashield* spectrometer; at 400.13 ($^1H$) and 100.61 MHz ($^{13}C$); in ($D_6$)DMSO and/or $CDCl_3$; $\delta$ in ppm, $J$ in Hz; when necessary to identify all C-atoms, complementary NMR experiments (HETCOR, APT, HSQC, and HMBC) were performed. Elemental analyses: *Leco-932-CHNS-O* analyzer.

*3-Substituted Oxindoles* **2** *and* **3**: *General Procedure.* Compound **1** (1 mmol) and oxindole (1 mmol) were dissolved in dry benzene (30 ml) and refluxed for 24 h (TLC monitoring). After cooling to r.t., the yellow precipitate was filtered off and recrystallized from BuOH to give **3** as yellow crystals, and the remaining soln. was triturated with petroleum ether (40–60°) to give a crude product that was filtered and recrystallized from benzene/petroleum ether 4:1 to give **2** as dark red crystals.

*(3*E*)-3-[4-Benzoyl-2-oxo-5-phenylfuran-3(*2H*)-ylidene]-1,3-dihydro-*2H*-indol-2-one* (**2a**). From **1a** (0.28 g): 0.23 g (58%) of **2a**. M.p. 225° (brightening), 260° (see *General Part*). UV/VIS: *Fig.* IR (ATR): 3171 (NH), 1773, 1691, 1659 (C=O), 1601, 1576, 1533, 1488, 1461, 1450 (C=C). $^1H$-NMR (($D_6$)DMSO)[1]): 10.64 (*s*, NH); 8.76 (*d*, $^3J(4,5) = 7.8$, H–C(4)); 7.95 (*dd*, $^4J(14,16) = {}^4J(16,18) = 1.3$, $^3J(14,15) = {}^3J(17,18) = 7.9$, H–C(14), H–C(18)); 7.62 (*dd*, $^4J(8,10) = {}^4J(10,12) = 1.4$, $^3J(8,9) = {}^3J(11,12) = 8.0$, H–C(8), H–C(12)); 7.58 (*m*, H–C(9), H–C(10), H–C(11), H–C(15), H–C(16), H–C(17)); 7.35 (*dt*, $^4J(4,6) =$

[1]) For the arbitrary atom numbering of **2**–**5** and **8**, see *Scheme 1*. The arbitrary atom numbering of **6** is given below:



1.0, $^3J(5,6) = {}^3J(6,7) = 7.7$, H–C(6)); 7.04 (*dt*, $^4J(5,7) = 1.0$, $^3J(4,5) = {}^3J(5,6) = 7.9$, H–C(5)); 6.82 (*d*, $^3J(6,7) = 7.8$, H–C(7)). $^{13}$C-NMR ((D$_6$)DMSO[1]): 188.23 (PhC=O); 167.56, 165.96 (C(2), C(2′)); 158.19 (C(5′)); 145.27 (C(7a)); 138.88 (C(6)); 134.06, 133.20 (C(3), C(3′)); 129.33 (C(4)); 132.32, 131.01, 129.12, 128.96, 128.49, 128.02, 127.86, 127.46, 118.85 (8 arom. C, C(4′)); 122.25 (C(5)); 121.57 (C(3a)); 110.71 (C(7)). Anal. calc. for $C_{25}H_{15}NO_4$ (393.39): C 76.33, H 3.84, N, 3.56; found: C 76.43, H 3.80, N 3.65.

*(3*E*)-1,3-Dihydro-3-[4-(4-methylbenzoyl)-5-(4-methylphenyl)-2-oxofuran-3(2*H*)-ylidene]-2*H*-indol-2-one* (**2b**). From **1b** (0.31 g): 0.17 g (39%) of **2b**. M.p. 282–284°. UV/VIS: *Fig.* IR (ATR): 3174 (NH), 1776, 1719, 1695 (C=O), 1606, 1574, 1529, 1501, 1462 (C=C). $^1$H-NMR ((D$_6$)DMSO[1]): 10.60 (*s*, 0.90 H, NH, **2A** form); 8.74 (*d*, $^3J(4,5) = 7.9$, H–C(4)); 8.00 (br., 0.10 H, OH, **2B** form); 7.85 (*d*, $^3J = 8.0$, H–C(14), H–C(18)); 7.49 (*d*, $^3J = 8.0$, H–C(8), H–C(12)); 7.35–7.19 (*m*, H–C(6), 4 arom. H); 7.03 (*t*, $^3J(4,6) = 7.6$, H–C(5)); 6.80 (*d*, $^3J(6,7) = 7.6$, H–C(7)); 2.30, 2.28 (2*s*, 2 *Me*C$_6$H$_4$). $^{13}$C-NMR ((D$_6$)DMSO[1]): 188.13 (ArC=O); 167.55, 166.08 (C(2), C(2′)); 158.07 (C(5′)); 145.14 (C(7a)); 144.51 (C(6)); 133.12, 132.26 (C(3), C(3′)); 129.42 (C(4)); 129.07, 128.98, 128.76, 128.43, 128.20, 127.89, 126.40, 124.68, 118.44 (8 arom. C, C(4′)); 122.16 (C(5)); 121.66 (C(3a)); 110.63 (C(7)); 21.69, 21.52 (2 *Me*C$_6$H$_4$). Anal. calc. for $C_{27}H_{19}NO_4$ (421.44): C 76.95, H 4.54, N 3.32; found: C 76.90, H 4.40, N 3.23.

*(3*E*)-1,3-Dihydro-3-[4-(4-methoxybenzoyl)-5-(4-methoxyphenyl)-2-oxofuran-3(2*H*)-ylidene]-2*H*-indol-2-one* (**2c**). From **1c** (0.34 g): 0.25 g (42%) of **2c**. M.p. 250°. UV/VIS: *Fig.* IR (ATR): 3165 (NH), 1769, 1700, 1659 (C=O), 1598, 1537, 1495, 1456 (C=C), 1256 (C–O). $^1$H-NMR ((D$_6$)DMSO[1]): 10.58 (*s*, NH); 8.73 (*d*, $^3J(4,5) = 8.0$, H–C(4)); 7.91 (*d*, $^3J = 8.6$, H–C(14), H–C(18)); 7.60 (*d*, $^3J = 8.8$, H–C(8), H–C(12)); 7.40–6.89 (*m*, 6 arom. H); 6.80 (*d*, $^3J = 8.7$, H–C(7)); 3.77, 3.76 (2*s*, 2 MeO). $^{13}$C-NMR ((D$_6$)DMSO[1]): 187.53 (ArC=O); 167.60, 166.18 (C(2), C(2′)); 157.80 (C(5′)); 163.26, 162.59 (arom. C); 144.93 (C(7a)); 133.45 (C(6)); 132.15, 131.23 (C(3), C(3′)); 129.56 (C(4)); 129.90, 128.48, 127.86, 124.79, 119.67, 115.07, 109.54 (6 arom. C, C(4′)); 122.04 (C(5)); 121.55 (C(3a)); 114.22 (C(7)); 56.00, 55.85 (2 MeO). Anal. calc. for $C_{27}H_{19}NO_6$ (453.44): C 71.52, H 4.22, N 3.09; found: C 71.60, H 4.20, N 2.97.

*(4*Z*)-4-(1,2-Dihydro-2-oxo-3*H*-indol-3-ylidene)-3-(4-methylbenzoyl)-4-(4-methylphenyl)-2-oxobutanoic Acid* (=*(*γZ*)-γ-(1,2-Dihydro-2-oxo-3*H*-indol-3-ylidene)-β-(4-methylbenzoyl)-4-methyl-α-oxobenzenebutanoic Acid*; **3b**). From **1b** (0.31 g): 0.10 g (22%) of **3b**. M.p. 213°. IR (ATR): 3423 (NH), 1767, 1726, 1709, 1659 (C=O), 1618, 1603, 1576, 1551, 1470 (C=C). $^1$H-NMR ((D$_6$)DMSO[1]): 11.57 (*s*, NH); 7.98 (*d*, $^3J = 8.1$, H–C(4)); 8.00 (*s*, OH, D$_2$O exchangeable); 7.40–6.92 (*m*, 11 arom. H); 7.30 (*s*, CH); 2.32, 2.19 (2*s*, 2 *Me*C$_6$H$_4$). $^{13}$C-NMR ((D$_6$)DMSO[1]): 192.43 (C=O); 191.72 (C=O); 172.47 (C=O); 165.12 (C=O); 146.20, 145.80, 143.70, 143.39, 133.16, 130.57, 130.23, 129.86, 129.30, 128.78, 128.47, 126.41, 126.00, 125.76, 123.29 (C(3a)); 111.13 (C(7)); 66.47 (CH); 21.74, 21.43 (2 *Me*C$_6$H$_4$). Anal. calc. for $C_{27}H_{21}NO_5$ (439.46): C 73.79, H 4.82, N 3.19; found: C 73.73, H 4.90, N 2.99.

*(4*Z*)-4-(1,2-Dihydro-2-oxo-3*H*-indol-3-ylidene)-3-(4-methoxybenzoyl)-4-(4-methoxyphenyl)-2-oxobutanoic Acid* (=*(*γZ*)-γ-(1,2-Dihydro-2-oxo-3*H*-indol-3-ylidene)-β-(4-methoxybenzoyl)-4-methoxy-α-oxobenzenebutanoic Acid*; **3c**). From **1c** (0.34 g): 0.14 g (30%) of **3c**. M.p. 210°. IR (ATR): 3418 (NH), 1772, 1719, 1707, 1670 (C=O), 1612, 1593, 1564, 1506, 1464 (C=C). $^1$H-NMR ((D$_6$)DMSO[1]): 11.52 (*s*, NH); 8.05 (*d*, $^3J = 8.6$, H–C(4)); 8.07 (*s*, OH, D$_2$O exchangeable); 7.41–6.83 (*m*, 11 arom. H); 7.33 (*s*, CH); 3.79, 3.66 (2*s*, 2 MeO). $^{13}$C-NMR ((D$_6$)DMSO[1]): 191.99 (C=O); 191.64 (C=O); 172.55 (C=O); 164.94 (C=O); 163.97, 163.30, 145.07, 143.25, 132.29, 131.13, 130.56, 128.77, 128.53, 126.36, 126.14, 123.47, 123.34, 115.51, 115.03 (arom. C); 111.24 (C(7)); 66.40 (CH); 56.20, 56.02 (2 MeO). Anal. calc. for $C_{27}H_{21}NO_7$ (471.46): C 68.78, H 4.49, N 2.97; found: C 69.02, H 4.35, N 3.00.

*(2*E*)-2-(1,2-Dihydro-2-oxo-3*H*-indol-3-ylidene)-3-(4-methylbenzoyl)-4-(4-methylphenyl)-4-oxobutanoic Acid* (=*(*αE*)-α-(1,2-Dihydro-2-oxo-3*H*-indol-3-ylidene)-β-(4-methylbenzoyl)-4-methyl-4-oxobenzenebutanoic Acid*; **4b**). A mixure of **2b** (0.42 g, 1 mmol) and 10% KOH/EtOH (1.5 ml) was stirred under reflux for 1 h thus forming an orange precipitate. After cooling to r.t., H$_2$O was added until a clear yellow soln. was obtained. Acidification with dil. HCl soln. afforded a yellow precipitate **4b** (0.17 g, 39%), which by no means could be further purified. M.p. 159° (→ red), 303°. IR (ATR): 3388 (NH), 1776, 1715, 1700, 1669 (C=O). $^1$H-NMR ((D$_6$)DMSO[1]): 13.40 (br., 0.75 H, COOH, D$_2$O exchangeable); 10.74 (*s*, NH); 8.03 (*d*, $^3J = 8.0$, H–C(4)); 7.79 (*d*, $^3J = 7.8$, 1 arom. H); 7.60–7.04 (2 *AA′BB′*, 8 arom. H); 6.79 (*dd*, $^3J(4,5) = {}^3J(5,6) = 7.7$, H–C(5)); 6.72 (*d*, $^3J(6,7) = 7.8$, H–C(7)); 5.00 (*s*, CH); 2.35, 2.23 (2*s*, 2 Me). $^{13}$C-NMR ((D$_6$) DMSO[1]): 195.40 (Ar*C*=O); 169.41 (C=O, COOH); 169.09 (C(2)); 144.26

(C(3)); 142.46, 137.78, 134.45, 131.00, 129.86, 129.77, 128.93, 128.76, 128.58, 128.12, 127.04, 124.65; 121.84 (C(3a)); 120.88 (C(5)); 110.33 (C(7)); 103.02 (C(4)); 42.95 (CH); 21.61 (*Me*$C_6H_4$). Anal. calc. for $C_{27}H_{21}NO_5$ (439.46): C 73.79, H 4.82, N 3.19; found: C 73.80, H 4.88, N 3.39.

*Oxindoles* **5***: General Procedure.* To the cold soln. of oxindole **3** in $H_2SO_4$ was added a large excess of EtOH with stirring. Then, the mixture was refluxed on a steam bath for 6 h with stirring. After cooling to 5°, the precipitate formed was filtered off and recrystallized from EtOH: ester **5**.

*Ethyl (4*Z*)-4-(1,2-Dihydro-2-oxo-3*H*-indol-3-ylidene)-3-(4-methylbenzoyl)-4-(4-methylphenyl)-2-oxobutanoate* (**5b**): From **3b** (0.50 g): 0.34 g (64%) of **5b**. Yellow crystals. M.p. 155°. IR (ATR): 3287 (NH), 1745, 1720, 1684, 1651 (C=O). $^1$H-NMR ((D$_6$)DMSO)[1]): 12.25 (*s*, 0.44 H, OH); 10.80 (*s*, 0.44 H, NH, enol form); 10.60 (*s*, 0.56 H, NH, keto form); 8.99 (*d*, 0.44 H, H–C(4)); 8.18–6.43 (*m*, 11.56 H, arom. H); 7.27 (*s*, 0.56 H, CH); 3.98–3.79 (*m*, $CH_2O$); 2.41, 2.39, 2.36, 2.31 (4*s*, 2 Me); 1.25–1.06 (*m*, Me). $^{13}$C-NMR ((D$_6$)DMSO): 193.93, 191.91, 189.09 (C=O); 174.07, 169.50, 167.19, 163.73, 161.04 (C=O); 148.57, 144.46, 143.87, 143.53, 140.78, 139.96, 139.83, 138.00, 137.45, 134.29, 133.58, 131.85, 131.17, 130.79, 130.23, 130.15, 129.87, 129.66, 129.53, 129.48, 129.33, 128.88, 128.35, 127.95, 127.87, 127.61, 126.88, 122.77, 122.45, 122.32, 122.10, 122.05, 121.61, 121.07, 11.00, 110.57, 109.78 (arom. C); 64.42 (CH); 62.57, 62.17 ($CH_2O$); 21.71, 21.60, 21.35, 21.09 (2 Me); 14.81, 13.91 (*Me*$CH_2O$). Anal. calc. for $C_{29}H_{25}NO_5$ (467.51): C 74.50, H 5.39, N 3.00; found: C 74.51, H 5.39, N 3.02.

*Ethyl (4*Z*)-4-(1,2-Dihydro-2-oxo-3*H*-indol-3-ylidene)-3-(4-methoxybenzoyl)-4-(4-methoxyphenyl)-2-oxobutanoate* (**5c**). From **3c** (0.50 g): 0.32 g (60%) of **5c**. Orange crystals. M.p. 168°. IR (ATR): 3266 (NH), 1730, 1717, 1686, 1650 (C=O). $^1$H-NMR ((D$_6$)DMSO)[1]): 12.32 (*s*, 0.48 H, OH); 10.75 (*s*, 0.48 H, NH, enol form); 10.65 (*s*, 0.52 H, NH, keto form); 9.03 (*d*, 0.48 H, H–C(4)); 8.26–6.53 (*m*, 11.52 H, arom. H); 7.30 (*s*, 0.52 H, CH); 4.00–3.82 (*m*, $CH_2O$); 3.79, 3.77, 3.75, 3.71 (4*s*, 2 MeO); 1.24–1.01 (*m*, Me). $^{13}$C-NMR ((D$_6$)DMSO): 193.07, 192.68, 189.11 (C=O); 170.76, 168.89, 164.59, 163.70 (C=O); 160.10, 159.92, 158.49, 145.57, 145.46, 139.78, 134.19, 133.67, 133.45, 132.00, 131.77, 131.60, 131.20, 130.99, 129.92, 129.46, 129.24, 129.04, 128.70, 128.51, 128.154, 127.60, 124.05, 123.47, 122.84, 122.72, 122.35, 122.07, 121.70, 121.11, 115.30, 114.34, 113.88, 113.75, 113.43, 113.23, 111.33, 110.54 (arom. C); 64.36 (CH); 63.08, 62.87 ($CH_2O$); 56.48, 56.15, 55.65, 55.57 (2 MeO); 14.18, 13.89 (*Me*$CH_2O$). Anal. calc. for $C_{29}H_{25}NO_7$ (499.51): C 69.78, H 5.04, N 2.80; found: C 69.81, H 5.06, N 2.97.

*Bis-furanones* **6** *and Bis-pyrrolones* **8***: General Procedure. Lawesson* reagent (0.5 g, 1.1 mmol) and the corresponding compound **1** or **7** (2 mmol) were kept in dry xylene (10 ml) at 60–70° for 3 h (**1**) or 2.5 h (**7**). After cooling to r.t., a dark precipitate was filtered off and recrystallized from AcOH to give **6** or **8** as colored crystals, similarly to the literature procedures [3b].

*(3*E*)-4-(4-Methylbenzoyl)-3-[4-(4-methylbenzoyl)-5-(4-methylphenyl)-2-oxofuran-3(2*H*)-ylidene]-5-(4-methylphenyl)furan-2(3*H*)-one* (**6b**): From **1b** (0.61 g): 0.31 g (48%) of **6b**. Bright red crystals. M.p. 326° (brightening), 386–390°. IR (ATR): 1768, 1666 (C=O). $^1$H-NMR ($CDCl_3$)[1]): 7.89 (*d*, $^3J$ = 8.1, H–C(14), H–C(18), H–C(14′), H–C(18′)); 7.53 (*d*, $^3J$ = 8.4, H–C(8), H–C(12), H–C(8′), H–C(12′)); 7.27 (*d*, $^3J$ = 8.0, H–C(15), H–C(17), H–C(15′), H–C(17′)); 7.10 (*d*, $^3J$ = 8.3, H–C(9), H–C(11), H–C(9′), H–C(11′)); 2.45 (*s*, 2 *Me*$C_6H_4$); 2.35 (*s*, 2 *Me*$C_6H_4$). $^{13}$C-NMR ($CDCl_3$)[1]): 189.70 (Ar*C*=O); 164.44 (C(2)); 159.12 (C(5)); 144.60, 143.49, 135.57, 129.60, 129.23, 128.54, 126.00, 123.95, 118.25 (arom. C); 21.76, 21.65 (4 *Me*$C_6H_4$). Anal. calc. for $C_{38}H_{28}O_6$ (580.63): C 78.61, H 4.86; found: C 78.79, H 4.75.

*(3*E*)-4-(4-Methoxybenzoyl)-3-[4-(4-methoxybenzoyl)-5-(4-methoxyphenyl)-2-oxofuran-3(2*H*)-ylidene]-5-(4-methoxyphenyl)furan-2(3*H*)-one* (**6c**): From **1c** (0.68 g): 0.30 g (52%) of **6c**. Dark-violet crystals. M.p. 368°. IR (ATR): 1749, 1703, 1651 (C=O), 1259 (C–O–C). $^1$H-NMR ($CDCl_3$)[1]): 7.96 (*d*, $^3J$ = 8.2, H–C(14), H–C(18), H–C(14′), H–C(18′)); 7.62 (*d*, $^3J$ = 8.9, H–C(8), H–C(12), H–C(8′), H–C(12′)); 6.94 (*d*, $^3J$ = 8.5, H–C(15), H–C(17), H–C(15′), H–C(17′)); 6.79 (*d*, $^3J$ = 9.0, H–C(9), H–C(11), H–C(9′), H–C(11′)); 3.85 (*s*, 2 MeO), 3.78 (*s*, 2 MeO). $^{13}$C-NMR ($CDCl_3$)[1]): 189.34 (ArC=O); 164.16 (C(2)); 158.44 (C(5)); 132.33, 131.69, 131.47, 130.85, 129.30, 125.62, 119.51, 117.65, 114.79 (arom. C); 55.71, 55.69 (4 MeO). Anal. calc. for $C_{38}H_{28}O_{10}$ (644.62): C 70.80, H 4.38; found: C 70.77, H 4.44.

*(3*E*)-4-Benzoyl-3-{4-benzoyl-1-[(dimethylamino)carbonyl]-1,2-dihydro-2-oxo-5-phenyl-3*H*-pyrrol-3-ylidene}-2,3-dihydro-*N,N*-dimethyl-2-oxo-5-phenyl-1-pyrrole-1-carboxamide* (**8a**): From **7a** (0.70 g): 0.23 g (36%) of **8a**. Dark-blue crystals. M.p. 307°. IR (ATR): 1690, 1665 (C=O), 1609. $^1$H-NMR ($CDCl_3$): 7.60–6.94 (*m*, 20 arom. H); 3.80 (*s*, 1 $Me_2N$); 3.62 (*s*, 1 $Me_2N$). $^{13}$C-NMR ($CDCl_3$)[1]): 189.18 (ArC=O); 175.14 (C(5)); 162.20 (C(2)); 153.01 (NCON); 142.00, 132.87, 132.76, 129.70, 129.01, 128.78,

128.29 (arom. C); 114.04, 113.89 (C(4), C(4′)); 40.71 (MeN); 38.96 (MeN). Anal. calc. for $C_{40}H_{32}N_4O_6$ (664.71): C 72.28, H 4.85, N 8.43; found: C 71.97, H 4.93, N 8.38.

*(3*E*)-4-Benzoyl-3-{4-benzoyl-1-[(diethylamino)carbonyl]-1,2-dihydro-2-oxo-5-phenyl-3*H*-pyrrol-3-ylidene}-*N,N*-diethyl-2,3-dihydro-2-oxo-5-phenyl-1*H*-pyrrole-1-carboxamide* (**8b**): From **7b** (0.75 g): 0.22 g (32%) of **8b**. Dark-blue crystals. M.p. 315°. IR (ATR): 1699, 1670 (C=O). $^1$H-NMR ($CDCl_3$): 7.80–6.95 (*m*, 20 arom. H); 3.30 (*q*, $^3J$ = 7.0, 2 H, $CH_2N$); 3.15 (*q*, $^3J$ = 7.1, 2 H, $CH_2N$); 3.05 (*q*, $^3J$ = 6.9, 4 H, $CH_2N$); 0.94 (*t*, $^3J$ = 7.1, Me); 0.88 (*t*, $^3J$ = 7.2, Me); 0.81 (*t*, $^3J$ = 7.0, 2 Me). $^{13}$C-NMR ($CDCl_3$)[1]): 189.20 (Ar*C*=O); 175.77 (C(5)); 165.90 (C(2)); 154.44 (NCON); 142.07, 131.76, 131.99, 130.31, 129.12, 128.82, 127.89, 127.45 (arom. C); 114.76, 114.09 (C(4), C(4′)); 42.82 ($CH_2N$); 42.00 ($CH_2N$); 12.98 (Me); 12.65 (Me). Anal. calc. for $C_{44}H_{40}N_4O_6$ (720.81): C 73.32, H 5.59, N 7.77; found: C 73.45, H 5.45, N 7.82.

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